USING ENHANCED KNOWLEDGE OF CLIMATE VARIABILITY FOR THE BENEFIT OF WATER RESOURCE MANAGEMENT

Report to the
Water Research Commission

by

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Executive summary

Introduction

Seasonal climate forecasts are available in South Africa, yet they are of little value to the water management sector if they are not accessible and understood. Currently, these products, that address annual climate variability, do not yet appear to meet the needs and expectations of water resource managers. This project sought to identify processes and products that might facilitate increased uptake of all types of useful weather and climate information, and especially seasonal climate forecasts, among water resource managers.

Water resources are significantly impacted by climate variability particularly through the impact on run-off. There is also evidence that climate variability impacts on groundwater reserves much more dramatically than abstraction does (WRC, 2003). In a climate change context it will become more important to understand the impact of annual variability on water resources where climate change is expected to see changes in means and extremes (Midgley et al., 2005; Hewitson, 2007). However, the water management sector has not reached a stage of integrating information about changing intra-annual climate conditions in a systematic manner. Seasonal forecasts and climate change scenarios could help to manage the impacts of climate variability on water resources so that managers do not 'miss out' on realisable benefits purely because of lack of awareness of useful products or because the products have not been tailored to suit their needs.

Aim and objectives

The aim of the project was

- To improve the understanding of how water resource managers use weather and climate information and especially seasonal forecasts, and the potential for increasing uptake of forecasts.

The objectives of the project were:

- Assessment of current uptake of weather and climate information, including seasonal forecast information, among water resource managers
- Identification of the strengths and weaknesses in current climate prediction information from the water resource management perspective
- Assessment of the potential for improvement, or improved use, of climate prediction information through incorporation of newly-gained local and international knowledge of climate variability
- Demonstration of how climate prediction information has been used for water resource management and transfer of knowledge in this regard
- Identification of longer-term research and capacity-strengthening initiatives which would enable water resource managers to derive maximum benefit from climate modelling and prediction tools.

Methodology

The project comprised three stages, each of which required different methods. The three stages include:

- Stage 1: An inventory of available climate information in South Africa including short term weather and medium term climate information.
- Stage 2: Case studies of the City of Cape Town and Overstrand Municipality that explore how information about climate variability is currently utilised by water resource managers. The case studies comprised 3 stages:
    1. Interviews with key individuals,
    2. Workshops with a big group of stakeholders and
    3. Focus groups that explored how specific water resource strategies might be better able to use seasonal forecasts.
- Stage 3: Development of an online toolkit of climate information for water resource managers

Key findings

The key findings from the project focus on the question of whether water resource managers are aware of climate prediction information such as seasonal forecasts, if they are using them and if there is potential for them to be disseminated and used more effectively.

Finding 1: Current knowledge of the spectrum of weather and climate forecasts is limited

Water resources managers in general have little understanding of seasonal forecasts. Although many are aware of them, explanation and interpretation was needed to ensure the forecast figures and terminology were correctly understood. Most stakeholders were not aware of the amount of forecast information available. However, they were all eager to hear more information about the seasonal forecasts and how to interpret them.

Stakeholders in the City of Cape Town were more aware of seasonal forecasts than those in Overstrand municipality.

Finding 2: There is little evidence of integrated use of forecasts in the water sector

Emerging from the interviews and workshops, it became apparent that seasonal forecasts are of interest to a wide range of stakeholders in the water management sector. Yet, although the forecasts are factored into some decision-making frameworks, there is little evidence of the application on seasonal forecasts in actual decisions. The available forecasts seem to be accessed by some respondents; however, there is no evidence of systematic methods of including them in decisions.

One example of where seasonal forecasts were used was in the City of Cape Town for water restriction planning. The forecast is integrated into supply planning by forming part of a rolling probability study, which informs the city and officials of the Department of Water Affairs and Forestry (DWAF) about likelihoods of dam levels and usage demands. If the forecast suggested below normal rainfall when dam levels were already low, the City was more likely to consider restrictions.

The most active current use of forecasts seems to focus on short to medium term weather information, where dam withdrawal allocation decisions, irrigation scheduling and other medium term water management actions are determined by the weather prospects.

Finding 3: Utilisation of forecasts is hindered by lack of knowledge and limited interaction with climate scientists

The most common means of access to the seasonal forecasts has been the internet, and specifically SAWS (South African Weather Service) and CSAG (Climate Systems Analysis Group at the University of Cape Town) websites. Some have had access to Envirovision (Johan vd Berg) where agricultural forecasts are provided.

Most users were not aware of the amount of information available. The nature of accessing the information via the internet means that there is limited interaction with the producers of the climate information and so users cannot further their understanding of forecast products.

Finding 4: Tailored products are needed that enable seamless integration of short, medium and longer term forecast information in water resource planning

Water resource managers requested indicators relating to the accuracy of seasonal forecasts. They also suggested that more active dissemination, interpretation and liaison between forecasters and water managers would improve the use of the information. It was clear that there were definite opportunities that were not being utilised at the moment. Methods need to be developed that enable historical data and forecast data to be used in planning. It is these tailored products that might make it easier for water resource managers to integrate seasonal forecast information in their planning.

Conclusion

In this project the uptake and usefulness of forecasts by water resource managers has been improved through intensive stakeholder involvement and lessons regarding the availability, comprehension, and current and future usefulness have been learnt. The future success of forecast uptake and usefulness depends on these lessons being converted into more skilful, better disseminated and more aptly targeted forecasts. It is also necessary that more opportunities are provided for those with climate knowledge to interact with water resource managers. This is particularly important in the context of increased long-term climate variability. A product of the project, the climate information toolkit, can assist with increasing the exposure, accessibility and usefulness of forecast information.

It is hoped that this project and specifically the toolkit resource will supplement and enhance existing products available to water resource managers in South Africa.

Table of Contents

1. Introduction

Seasonal climate forecasts are available in South Africa, yet they are of little value to the water management sector if they are not accessible and understood. Currently, the nature of these products, that addresses annual climate variability, does not yet appear to meet the needs and expectations of water resource managers. This project sought to identify processes and products that might facilitate increased uptake of seasonal climate forecasts among water resource managers.

Water resources are significantly impacted by climate variability particularly through the impact on run-off. There is also evidence that climate variability impacts on groundwater reserves much more dramatically than abstraction does (WRC, 2003). In a climate change context it will become more important to understand the impact of annual variability on water resources where climate change is expected to see changes in means and extremes (Midgley et al., 2005; Hewitson, 2007). However, the water management sector has not reached a stage of integrating information about changing intra-annual climate conditions in a systematic manner. Seasonal forecasts and climate change scenarios could help to manage the impacts of climate variability on water resources so that managers do not 'miss out' on realisable benefits purely because of lack of awareness of useful products or because the products have not been tailored to suit their needs.

Aim and objectives

The aim of the project was:

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The objectives of the project were:

- Assessment of current uptake of seasonal forecast information among water resource managers
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- Identification of longer-term research and capacity-strengthening initiatives which would enable water resource managers to derive maximum benefit from climate modelling and prediction tools.

In order to address the aims and objectives an inventory of the present nature of climate information systems and their role in water resource management was first established. Case studies in the City of Cape Town and Overstrand Municipality then assessed which information presented in the inventory was used as well as the challenges around using climate variability information, such as seasonal climate forecasts. Material from the case studies and inventory was used to develop an online toolkit to improve access to seasonal forecast information by water resource managers.

The advantage of assessing the use of seasonal forecasts is that there is real-time feedback, as the use of seasonal forecast information can be monitored during the course of the project. The effective use of forecast information can provide insight into how current climate variability as well as climate change might be managed. If stakeholders learn to use information about climate variability on the annual time-scale, they should be better equipped to adapt to a change in climate variability as experienced from a climate in transition.

It is important to identify the type of seasonal climate information that water resource managers require and could benefit from in order to match these requirements with existing and developing climate products. This could be developed further in a climate change context by identifying where seasonal forecasts can be used to adapt to annual variability versus other situations where climate change scenarios could be used in order to create long-term management strategies that can cope with an increased range in variability.

This report outlines the research process involved in addressing these objectives. Chapter 2 presents some of the key issues in the literature related to seasonal forecasts and water resource management. Chapter 3 discusses water-related issues of relevance to South Africa and in particular the Western Cape. Chapter 4 then explores how climate information is currently used in South Africa. Chapter 5 outlines the methodology used in the project (including the inventory, case studies, focus groups and the toolkit). Chapter 6 presents the results, Chapter 7 analyses the results to put forward some key findings and Chapter 8 ends with some recommendations and conclusions.

2. Climate variability, seasonal forecasts and water resource management

As research and technological capacities have increased and developed, climate information has become more detailed and accessible to the general public. Climate information can generally be divided into 3 types; short term (weather forecasts), medium term (climate forecasts) and long term (climate variability and climate change projections). Each has specific intentions and envisaged uses, as summarised in the table below.

	Climate		**Weather**	
Type of decision	**Long Term (10-50yrs)**	**Medium Term (3-9mths)**	**Medium term (7-30 days)**	**Short term (0-7days)**
	Decadal Changes	Seasonal Forecasts	Week - Monthly	Real Time → Week
Strategic				
Tactical				
Operational				

Table 1: Types of forecasts and the decision making options with each (adapted from Schulze 2005)

The use of different types of information is different within each sector depending on the types of priorities and decisions that need to be made. Examples for the water sector are given in Table 2. Within the water management sector, short term climate information can be used both for daily management of water resources as well as managing extreme events such as floods. It is most likely that seasonal forecasts will be used for tactical decisions over the medium term that consider issues about water allocation and demand management. Then on the longer-term timescale, planning issues related to demand need to consider decadal variability and climate change.

Operational	Tactical	Strategic
• Irrigation scheduling • Field operations • Flood warning	• Operating rules • Water orders • Water allocation • Demand management	• Supplying demand • Reservoir safety • Reservoir sizing • Land management

Table 2: Examples of water resource related decision types

Seasonal forecasts and their potential applications have received wide attention in the literature in a number of fields (Patt et al., 2007). The utility of forecast information for subsistence communities has received attention with a focus on whether this information might improve livelihoods (Patt and Gwata, 2002; Phillips et al., 2002; Hudson and Vogel, 2003; Orlove et al., 2004; Ziervogel et al., 2006; Patt, 2005). However there are challenges in using seasonal forecast among the poor due to reasons of accessibility and communication (Lemos and Dilling, 2007). Even after intensive communication and explanation of the forecasts the benefits are sometimes not seen (Mjelde, 1988; Lemos et al., 2002). As Everingham (2002) suggests good communication requires an understanding of each component of the chain of communication that includes an understanding of the constraints to understanding and using the information.

In order to improve communication and uptake scientists need to take responsibility alongside users in collaborating with institutional intermediaries to ensure that reliable, effective and useful forecasts are produced (Hammer et al., 2001). In addition they need to focus on ensuring good communication (Henderson-Sellers, 1998; Hartmann et al., 2002).

Seasonal forecasts can be used to plan on an annual basis and can help to respond to annual climate variability and climate change. Most research on the application of forecasts has been within agriculture (Murphy et al., 2001; Ingram et al., 2002; Stone and Meinke, 2006). In regions that lack sufficient water resources to irrigate and therefore depend on rainfall for farming, prior knowledge of the likely pattern of precipitation could lead to substantial improvements to food security as well as profits to larger-scale producers (Blench, 1999; Hammer et al., 2001). Although much research has focused on crop production, there have also been explorations to improve the utility of forecasts for livestock production (e.g. Hudson & Vogel, 2003). Seasonal forecasts have therefore been shown to be useful as an adaptive strategy to respond to climate variability, especially in determining the planting and harvesting times and responding to variability in market demand (Ziervogel et al., 2005).

Within the water sector there are limited examples of how seasonal forecasts have been effectively used (Patt et al., 2007). Water managers have traditionally relied upon historical records in order to plan for the future, inferring the probability that shortages and floods might occur given their frequency of occurrence in the past, and not necessarily according to forecasts that have not displayed a robust reliability (Ritchie et al*.,* 2004, Johnston et al., 2007). Pulwarty and Redmond (2007) have offered 8 reasons why water resource managers do not access and use the available information. Amongst these are lack of certainty, poor communication, lack of focus on users' needs, insufficient trust, lack of resources, poor timing of forecasts and the lack of training among users.

A number of studies have explored how seasonal forecasts might be used in water management contexts (Georgakakos and Yao, 2001, Landman et al., 2001, Yarnal et al., 2006). One study in south-east Australia looked at the use of seasonal streamflow forecasts using ENSO and serial correlation in reservoir inflow to optimise water restriction rules (Chiew et al., 2003). This was undertaken in an urban township where seasonal forecasts of reservoir inflow were used to help make management decisions in two irrigation systems. Marginal benefits were derived from using the forecasts.

A number of studies in the United States of America have shown that although it might be expected that seasonal climate forecasts would have utility for water resource management the evidence is limited (Callahan et al., 1999; O'Connor et al., 2005; Rayner et al., 2005). A study in South Carolina (Carbone and Dow, 2005) suggested that obstacles to using forecasts among community water system managers include a lack of awareness of their existence, distrust of their accuracy, perceived irrelevance to management decisions and competition from other technological innovations. They also explored methods on how to customise long lead forecasts into secondary products that address issues of greater relevance to water resource managers particularly under drought conditions. O'Connor et al. (2005) found that forecast skill is not the key issue, as water managers who find forecasts reliable are not more likely to use them than managers who do not find them reliable. They suggest that the most important determinant of forecast use is risk perception. This tends to be linked to past experience so that water managers who have had problems with weather events in the last 5 years, such as flood emergencies, are more likely to feel at risk and want to use weather and climate forecasts.

It is clear that although water resources are directly and indirectly impacted by climate variability, information about the seasonal climate needs to be communicated in a way that is understood, relevant and prioritised by water resource managers in order for the information to be used.

3. Water resource management in South Africa

South Africa is generally viewed as a water-stressed country with an average annual rainfall of 500mm, which is approximately 60% of the world average. The greater part of the interior and western part of the country is arid or semi-arid. 65% of the country receives less than 500mm per year and 21% of the country receives less than 200mm per year

(DWAF 1994). Since rainfall displays strong seasonality with rainfall predominantly received in summer when evaporation is highest, the natural availability of water across the country is variable, with stream flow in many South African rivers, especially in semi-arid regions, at a relatively low level for most of the year. This limits the proportion of stream flow that can be relied upon for use. Moreover, excessive extraction of water by extensive forests and sugar cane plantations in the relatively wetter areas of the country, exacerbates the situation so that only 9% of the rainfall reaches the rivers, compared to a world average of 31% (DWAF 1996).

Groundwater also has an important role to play in rural water supplies, and some major groundwater aquifers exist, but aquifer characteristics (hard, fractured rock) may limit aquifer storage and yield (quantity as well as spatial variability). Salinity is a naturally occurring problem in the more arid parts of the country that limits utilisation of groundwater on a large scale.

Already water shortages are being experienced across South Africa, particularly in the Western Cape and Northern Cape provinces. With changing climatic conditions, longer and more severe shortages and scarcity can be anticipated due to enhanced desertification from the west (Midgley et al., 2005). Changes in seasonality and intensity of rainfall will impact the runoff and groundwater recharge and the storage of water in the soil, dams and reservoirs. Increased temperatures will increase evaporation and result in an increased transpiration rate from plants. Combined with land transformation (i.e. to agriculture) and denuded land surfaces, availability and accessibility of water could be further reduced.

The impact of rainfall seasonality and climate variation on water resources, including groundwater, acts through a modification of the water balance, ranging from the micro to the macro-scale. This includes factors such as surface conditions, the soil column, aquifers and catchments (Braune 1996). This was confirmed, in a more recent review of the current hydroclimatic setting in southern Africa, where Schulze (2005) motivates that there is a highly variable and highly sensitive natural hydrological system over southern Africa. He argues that even when considering average present climatic conditions, a high risk hydroclimatic environment in southern Africa is evident, since the high inter-annual rainfall variability is amplified by the natural hydrological system. He notes that different components of the hydrological system differ markedly in their responses to rainfall variability. For example streamflow variability is high in individual external sub-catchments, but a river system becomes relatively constant in internal and main stem catchments.

The effects of any decrease in precipitation may be amplified through the hydrological system, where both run-off and groundwater recharge, especially in semi-arid and arid regions, will decrease at a much higher rate than the underlying decrease in precipitation.[1]

[1] The University of the Western Cape were subcontracted by the project team to provide detailed information about groundwater and groundwater recharge and their inputs form an integral part of this report. A separate report on groundwater recharge is included in Appendix B.

A concern of water managers is the potential decrease in groundwater supplies for municipal and agricultural use due to climate variability which affects shallow aquifers in the short term and deep aquifers in the long term. Decreases in quantity often result in a decrease in quality especially for coastal and unconfined aquifers and subsequently on groundwater use which could have detrimental environmental effects on other dependant sectors including changing baseflow dynamics in streams. Efforts to offset declining surface water availability due to increasing precipitation variability will also be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed areas, where vulnerability is often exacerbated by the rapid increase in population and water demand. Climate change may also lead to vegetation changes which affect groundwater recharge.

Climate variability affects groundwater in relation to the type of recharge mechanism as well as the possible interactions between groundwater and surface water systems and could have a pronounced impact on the capacity of groundwater systems to maintain water supplies, in-stream conditions, and aquatic habitat; impacts such as these may increase as a result of climate change.

While surface waters typically see rapid response to climate variability, the response of groundwater systems is often difficult to detect because the magnitude of the response is lower and delayed. Longer-term variations in climate are often well preserved in aquifers. Thus, the magnitude and timing of the impact of climate variability and change on aquifers, as reflected in water levels, are difficult to recognize and quantify. This is because of the difference in time frame that exists between climate variations and the aquifer's response to them. In addition, different types of aquifers respond differently to surface stresses. Shallow aquifers consisting of weathered or fractured bedrock or unconsolidated sediments are more responsive to stresses imposed at the ground surface compared to deeper aquifers. These tend to be more isolated from surface conditions by overlying aquitards. Similarly, shallow aquifers are affected by local climate changes, whereas water levels in deeper aquifers are affected by regional changes. Therefore, climate variability, being of relatively short term compared to climate change, will have greater impact on these shallow aquifer systems. In contrast, deep aquifers have an increased capacity to buffer the effects of climate variability, and are therefore able to preserve the longer-term trends associated with climate change. It is important to note, however, that deep aquifers can be vulnerable to climate variability. As shallow groundwater resources become limited or contaminated, deeper groundwater resources are often exploited (Environment Canada, 2004).

Studies by Chapman (2007) reveal that under a drying climate a reduction in rainfall would lead to a potentially greater reduction in run-off. He cautions that the use of simple trend-lines to arrive at these figures can be misleading, and that the absolute figures should not be used. Yet the clear trend that a percentage reduction in rainfall results in a greater percentage reduction in runoff is important. Historical data and in-situ measurement should be taken for a specific site being investigated.

Site	Annual Rainfall	Rainfall reduction	Run-off reduction	Period
Cathedral Peak	> 1500 mm	19%	45%	50 years
Jonkershoek	> 3000 mm	14%	20%	60 years

Table 3: Reductions in run-off due to reductions in rainfall (Chapman 2007)

These studies reveal that the magnitude of the run-off reduction is between 2-4 times greater than the reduction in the precipitation, for a 50-60 year historical period. Historical data is required to establish the direct relationship for a site specific analysis.

Groundwater recharge has been found to be even more sensitive than run-off (Kiker 2000; Schulze & Perks 2000). Groundwater in South Africa usually occurs in secondary aquifers and normally soil cover is shallow. Recharge of the aquifer depends on its type, since some are more responsive to rainfall and recharge is closely linked to higher and persistent rains. Others, such as deep aquifers, are slow to respond and require consistent rain over a period of time (Visser 2004). Studies by Kirchner et al. (1991) have shown that before any recharge takes place, a rainfall and soil moisture threshold must be overcome. The bulk of the recharge takes place in the years in which the average annual rainfall is exceeded and during periods of high rainfall intensity. It stands to reason then, that the areas that are dependent on groundwater will be most vulnerable to decreases in rainfall and/or variability. In addition, low storage aquifers are the most vulnerable to changes and variability in recharge. This is the situation in 90% of South Africa (Braune, 1996).

Water management in the Western Cape

It is projected that the Cape Metropolitan Area (Cape MA) and surrounding areas will, in the future, have a greater demand for fresh water than is currently supplied. This challenge has led to the development of two long-term strategies. Firstly the water demand needs to be managed through pressure management, repairing leaks and conservation techniques. Secondly new sources of water need to be found to augment the existing supply. This can be achieved through desalination, re-use of treated water or using, as yet, unutilized resources such as the Table Mountain Aquifer.

There is a five-year feasibility study going into determining the use of the Table Mountain Group Aquifer (TMG) in supplementing Cape Town's water supply. The study will include the impact that abstraction may have on the environment.

Rivers in the Cape Town area are relatively small and most of the rivers that are used as water sources to supply Cape Town actually lie outside the Cape MA. These rivers include the Berg, Breede (via transfers), Eerste, Palmiet, Sonderend, Klein-Berg and Leeu rivers. Of these, the Berg River is the largest in the area; hence the decision to build a new dam in the Berg River catchment with a storage capacity of 130 million m^3. The Berg River dam and Water Project was expected to supplement the Western Cape's water supply by 2007, and was already full, due to the above normal winter rains, in 2008. It is the first water resource development project in South Africa to be directly linked to water demand management.

Most of the major dams that supply water to the Cape Town area are also situated outside the Cape metropolitan area, with the exception of Steenbras dam. Dams that supply Cape Town include Wemmershoek, Voëlvlei and Theewaterskloof. The Theewaterskloof dam forms part of the transfer scheme that regulates the flow from the Breede River basin rivers of Sonderend, to the Eerste and Berg Rivers.

Other small dams that support the Cape Town area include dams on Table Mountain, which supply water to Cape Town and the South Peninsula, and the dams at Simonstown which provide water solely for the South Peninsula.

Water management comprises varied and diverse activities in the Western Cape. They can be broadly divided into storage and supply, reticulation and disposal.

1. Storage and supply
   The City of Cape Town is the main user of water in the Western Cape and as such owns the Steenbras and Wemmershoek dams. The City has agreements with DWAF regarding the water in the other main dams viz., Voëlvlei, Theewaterskloof and the newly built Berg River dam. The storage capacity and levels of these dams is managed jointly by DWAF and the city to optimise supply and to reduce shortages. The Steenbras dam water is used to generate peak demand electricity through a pumped storage scheme and the dam levels are maintained to optimise this. The supply of water to the reticulation systems of the city and various towns in the region is controlled by a carefully regulated system that depends on imminent rainfall, demand characteristics and individual dam levels. Various municipalities in the region rely on the major dams for their supply but some have access to their own dams, although the water is still controlled by DWAF. Alterations and enlargements to dams are restricted and some municipalities are investigating sourcing water from the ground. Problems of iron oxide content and aquifer depletion are some of the difficulties they are facing.

2. Reticulation
   The supply of bulk water is the responsibility of DWAF and the City of Cape Town. In the case where towns and rural areas fall outside the City jurisdiction, arrangements are made with DWAF for the supply of sufficient water. Each town council is responsible for delivering the water to the residents and for recovering the costs. Reticulation of water within an urban area requires a robust and well-built infrastructure which requires periodic upgrading and expansion and constant maintenance. The population of these towns, and thus the supply of water, generally, is increasing, placing higher demands on the supply and infrastructure. Maintenance and upkeep is susceptible to weather conditions, such as dry spells, heavy rain, flooding and high wind.

3. Disposal
   Disposal of waste water falls into 2 categories, storm water run-off and sewage. Storm water drains are designed to cope with average rainfalls and during times of

heavy rainfall events often overflow and cause flooding in low-lying areas. The cause is often the lack of maintenance and clearing of debris. The flooding rarely leads to health hazards unless it occurs in areas without adequate sewage facilities when it can become infected leading to the risk of disease outbreaks. Storm water is usually fed into river systems or the sea.

Sewage is a more serious problem as overextended and outdated systems and treatment works are put under pressure. In many smaller municipalities conservancy tanks are used which need to be pumped empty on a regular basis. The use of septic tanks has led to infiltration into groundwater and these have been discontinued in most of the susceptible areas. When flooding does occur, due either to the lack of storm water capacity, heavy rainfall or both, the infiltration of storm water entering the sewage system leads to more strain on the purification works. The flooding of sewage systems can cause overflowing resulting in sewage entering storm water systems and the introduction of untreated sewage into river systems and coastal waters. Many towns are faced with costly but necessary sewage disposal and treatment upgrading. Budgetary and capacity shortages have led to the problem leading to crisis proportions during heavy rains.

Conversely, the consequence of water restrictions and reduced water usage and disposal is the increased concentration of effluent arriving at the treatment works. This can result in a decrease in the quality of treated effluent released into rivers and the sea.

Specifically in the Western Cape, the response to variable rainfall has been characterised by water restrictions and increased tariffs. The impact of water restrictions can be clearly seen in the variation of the seasonal demand (influenced mainly by gardening) for Cape Town in 2001 and 2006, as illustrated by Figure 2 (Sparks 2007).

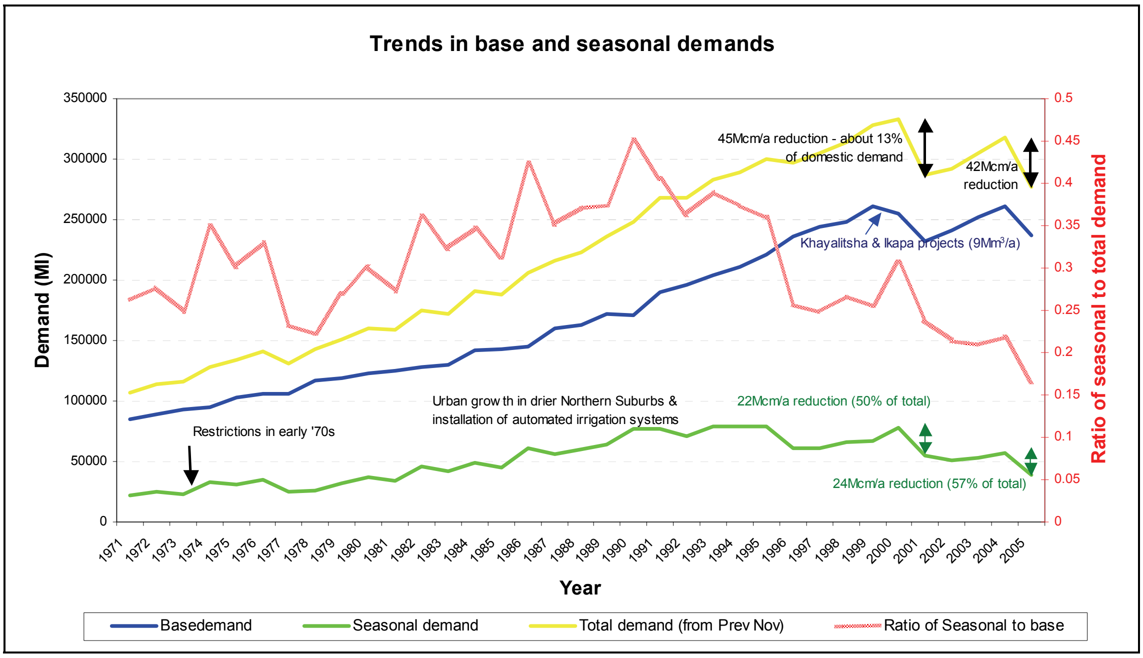

Figure 1: Seasonal demand for water in Cape Town for the period 1971 to 2006 (Sparks 2007)

One of the most effective ways being used by local authorities to encourage consumers to use water more efficiently is through tariff mechanisms. However research conducted in Cape Town by Jansen and Schultz (2006) found that consumption is insensitive to price changes among the poor, while the richer households react to price changes more. In most cases a rising block tariff has been used to curb excessive use of water. This mechanism is designed along the principle of "the more you use, the more you pay", as illustrated in Table 1 As can be seen from the example for Cape Town, the local authority increased the water tariffs substantially in an attempt to curb excessive water use. The two top tiers were increased by 87% and 191% in order to reduce high end consumption. This measure was implemented as a result of the very low water levels in the dams due the prevailing drought conditions during 2005 and 2006.

Consumption in kl	**Tariff per kl**		
	2004/5	**2005/6**	**increase**
0-6	R0.00	R0.00	R0.00
7-12	R2.32	R2.46	6%
13-20	R6.15	R6.52	6%
21-40	R10.41	R11.04	6%
41-60	R13.34	R25.00	87%
61+	R17.20	R50.00	191%

Table 4: Example of domestic consumption rising block tariff (City of Cape Town 2005)

As part of the planning and management of water resources, it has been suggested that each local authority be in a position to guarantee an assurance of water supply to its users under existing climatic conditions (Van Dyk et al., 2005). Approximately 25% of the towns in the Northern Cape for example, were using more than 80% of their available groundwater resources during the drought of 2000 because they did not have access to climate forecast information and were unable to plan for the projected drought. Responses in these cases were of a reactive nature and not pre-emptive.

4. Climate information uptake in South Africa

In South Africa different types of forecasts are produced by different institutions, including the national meteorological services and university research groups. The South African Weather Service (SAWS) is the country's national meteorological service, with a permanent representative at the World Meteorological Organisation (WMO). In terms of its WMO obligation, it is the primary weather and climate information service provider in South Africa.

The utilisation of weather and climate forecasts has mostly been limited to the 1-3 day forecasts that are easily available *i.e.*, on the news media. Over the last 5-10 years significant research has been undertaken to produce reliable and accessible seasonal forecasts for general use in sectors such as agriculture, transport and water resource management (Johnston et al., 2004). The uptake of seasonal forecast information in South Africa has, however, not been widespread (Klopper and Bartman, 2003). The national dissemination of forecasts is currently via e-mail and internet access and it has been suggested that this may be a barrier to the awareness and uptake by sectors such as water managers.

In a recent WRC study of the Northern Cape (Mukheibir & Sparks 2006), focusing on local responses to drought and future climate change impacts, two key obstacles and limitations to ensuring pre-emptive responses to drought at a local municipal level were identified viz.:

1. *Local Capacity:* A large number of the smaller municipalities lack the necessary skills capacity to adequately plan for periods of water shortages. In addition, the former Director-General of DWAF, Mr Mike Muller has stated that there is a severe shortage of qualified water managers in small to medium-sized municipalities which has resulted in 63% of municipalities not complying with the drinking-water quality standards. There is an urgent need for formal training in this sector (Venter 2005).
2. *Financial:* The skills vacuum is further exacerbated by the low financial resource base to cover the capital and running costs for adequate clean water supplies. Local governments compete with each other for nationally allocated funds for capital expenditure across all sectors. This is compounded by the fact that running costs are mostly covered from local revenues, which, for the smaller and remote local municipalities, are insufficient to ensure water security at this level.

Whilst these capacity deficiencies do not directly relate to the responses to drought impacts, they need to be overcome when developing systems to ensure the usage of forecast information, which in turn could initiate adequate responses to dry periods.

During this project it is hoped that by raising awareness of the various sources of information, water resource managers will be able to make more informed, more accurate and more regular use of forecasts. By building their capacity with regard to the availability and benefits of forecast information, planning in the water sector will be further enhanced. By being aware of their needs in this regard, water managers can leverage financial resources to ensure that forecast information is integrated into everyday planning.

5. Methodology

The project comprised three stages, each of which required different methods. The three stages include:

- Stage 1: An inventory of available climate information
- Stage 2: Case studies that explore how information about climate variability is currently utilised
- Stage 3: Development of an online toolkit

The target group and application of each of these products is presented in Table 5 and then further information is provided below on how each of them was developed.

Products			
	Inventory of climate information	**Case studies**	**Climate information training toolkit**
Target group	Climatologists and water resource managers	Water resource planners Forecast producers and disseminators Researchers	Water resource managers (to use) for training other stakeholders
Application	A national inventory of the type of climate variability information that is available and currently disseminated will help to establish gaps and opportunities in the current system. This will enable future targeting of climate information so that the information reaches those who require it.	Provide an understanding of the local context and how different users view and utilise seasonal forecast information currently.	Products that facilitate the process of improved information dissemination. These documents (that will include brochures, briefing notes, webpages and CD ROM) will help to guide water resource managers through a process of educating other stakeholders (such as farmers and local authorities) about climate variability information and its potential applications and limitations.

Table 5: Products developed within the project

Inventory

In order to create an inventory of available climate variability information a list of well-known South African weather and climate websites was first compiled from experiential knowledge. During the investigation of these websites it became clear that they were a source of information to other websites that provided similar information while targeting different stakeholder groups. Websites that are currently in use by water resource managers were identified through interviews with stakeholders.

Once a preliminary list of websites was compiled, each website was catalogued according to the information it provided. The information was categorised under daily data, seasonal data, hydrological data, specialised forecasts, archived data and educational links. The data were also divided into observed and forecast data.

A separate list of ancillary websites that do not produce forecasts specifically for South Africa was documented for reference value. Sources of information that are not electronically available were also noted.

The contents of each website were presented in an excel spreadsheet with reference to the variables available at each site. There was an additional page that contains a listing of foreign websites that may prove useful for background information or comparison studies. It also includes sources of data available telephonically.

Case studies

In order to gain specific insight into the usage of information at a grassroots level, it was necessary to focus on specific examples. To this end, a case study approach was used, linked to appropriate local authorities in the Western Cape, namely Cape Town Metropole and Overstrand local municipality (that includes the Hangklip/Kleinmond, Greater Hermanus, Stanford and Gansbaai areas). Not only is the Western Cape region already water stressed, but the climate change scenarios suggest that traditional winter rainfall patterns may be changing.

The case studies focused on the information that water resource managers and other related stakeholders presently use to make planning decisions, including, the type of data currently received and used and the interest and potential for using climate data or information, if not currently used. The case studies comprised of three components which included:

1. Interviews
2. Workshops
3. Focus groups

Interviews

To establish what the key issues were in using seasonal climate information and who the key players were in the field, a number of interviews were undertaken in each of the case study areas. These in-depth semi-structured interviews enabled detailed profiles of the users of information and their needs to be created.

For all interviewees, the following was established:

- Type of climate information accessed
- Source of access
- Dissemination method
- Data format
- Ease of access

- Passed on (to whom, how)
- Skill
- Usage and application
- Shortcomings/suggestions
- Desired climate information products.

Stakeholders interviewed included DWAF water managers, consultants involved in water resource issues, municipal water managers and a range of other stakeholders as outlined in Appendix A. The information from the interviews was used to create a map of linkages between stakeholders and different information sources. Stakeholder network analysis enables networks of information transfer to be mapped and enables quantitative and qualitative data to be integrated (Ziervogel and Downing, 2004).

Workshops and focus groups

Two workshops were held with stakeholders between May and September 2006 with 22 people attending the Cape Town workshop and 13 attending the Overstrand workshop. The workshops built on the information base from the interviews and sought wider representation in order to verify interview findings. A number of key issues emerged in the workshops and so focus groups were used to follow up these key issues for different sectors.

The workshops and focus groups sought to address four aims:

1. to determine the understanding managers have of climate variability and climate change
2. to identify the strengths and weaknesses in current forecast tools
3. to examine the type of climate variability information managers think would be relevant at an annual and longer-term scale
4. to enable water resource managers to consider how forecast and climate change information could be better used for decision making.

The workshops aimed to address the first three aims and the focus groups the fourth aim. At both the workshops and the focus groups there was an initial presentation on the type of climate information that is produced and the inherent uncertainties of the climate data and models. The workshop format facilitated a process of getting feedback from stakeholders on their understanding of the forecasts and how they might use the available information more effectively.

The focus groups broke the users into sectors so that more in-depth discussions could be had about how to improve the use of seasonal forecast information. In Cape Town, four focus group meetings were held on 22 and 29 November 2006. These were divided into the following groups:

1. Water storage
2. Urban water supply, water disposal and stormwater
3. Nature, biodiversity and agriculture

4. Disaster management

The focus group format was as follows:

1. A brief presentation of different forecasts available and how they are used
2. A presentation of the participants' previous responses (from interviews and/or the workshop) on the types of climate information accessed and how they use/can use it
3. Discussion on their responses and ways that forecasts could be used
4. A group discussion on uses of medium term forecasts (1-6 months)
5. A Forecast Risk Assessment exercise.

Toolkit framework

The workshops and inventory were used to develop a toolkit for translating climate information into decisions for water resource managers. It has basic information that appeals to a wide audience. This material could be used for planning, educational purposes or policy. This will draw on recent developments in knowledge of climate variability in South Africa, as well as techniques for interpreting data and examples of where information has and has not been useful. This material will support the existing Water Research Commission funded Global Forecasting Centre for Southern Africa (GFCSA.net). It will build on tailored forecast products and expand on ways these might be adapted in the water sector. The experience from other countries, such as Australia, will be drawn on, where they have developed useful tools for a range of users, including water resource management, rangeland and other agricultural practices (Carter et al., 2000; Chiew et al., 2000).

One of the key products to be produced by the C4W project was a 'Toolkit' of Climate and Weather information for users in the water sector. In order to achieve this, the first task of gathering all sources and types of climate and weather data available for stakeholders needed to be carried out. The product of this exercise was the Climate and Weather Data Inventory, described above, and presented in the Appendix. In addition, interviews and workshops were held with key stakeholders and information from these was incorporated into the creation of the toolkit.

Aim of the Toolkit

Currently there is a range of climate and weather information available to stakeholders from a range of sources. The access to these may be limited for some of these users as a result of lack of knowledge of their existence or the lack of the ability or knowledge to use this information.

The aim of the Toolkit in this project is to help stakeholders access this information easily and also give them information on how this data may be useful in their decision making process. Although the project is aimed at users in the water sector, this sector is made up of a wide range of different stakeholders. The anticipated audience for the website and Toolkit are therefore expected to be primarily from the following;

- Water Managers

- Dam Managers
- Agriculture
- Individual Farmers
- Municipal Civil and Technical Departments (including water)
- Bulk water
- DWAF forestry
- DWAF water
- Irrigation managers
- Conservation groups.

The Toolkit therefore needs to have basic information that appeals to a wide audience. The material can be used for planning, educational purposes or policy development. The material draws on recent developments in knowledge of climate variability in South Africa, as well as techniques for interpreting data and examples of where information has and has not been useful. The material will support the existing Water Research Commission funded Global Forecasting Centre for Southern Africa (GFCSA.net). The experience from other countries, such as Australia, is drawn on, where they have developed useful tools for a range of users, including water resource management, rangeland and other agricultural practices (Carter et al., 2000; Chiew et al., 2000).

The Climate and Weather Data Inventory highlighted the availability of a range of information on the internet. This prompted the implementation of the Toolkit also as a product available via the internet. This component was therefore termed the 'Online Toolkit'. However, a CD-Rom version of this as well as printed material was also produced by the project which included the materials contained in the 'Online toolkit' for distribution to relevant stakeholders.

At the inception of the C4W project a website (available via http://www.c4w.org.za) was created and maintained by the project team. The website contained material that would help users understand the project and its aims and objectives. It was important that the Online Toolkit be linked with this website. The contents for the Online Toolkit were then developed and the design and implementation of this task was outsourced to a web design team. The Online Toolkit was then created, based on these requirements and the integrated C4W website is hosted by a private company. The website will therefore be available after the project has been completed providing funding is available to cover the cost of hosting.

Contents for the Online Toolkit

The contents of the Online Toolkit were decided upon, based on the information that had been gained through the interviews and workshops as well as the collation of the Climate and Weather Data Inventory. There are a number of components that were highlighted as important requirements for the Online Toolkit. These are summarised below and pictured in Figure 3;

- Tutorial pages: These would provide general information for a wide audience. They can also be termed the Frequently Asked Questions.
- User information: The capturing of basic details of the users of the Toolkit is important for the project to assess the use of the Toolkit
- Registration/Log in: This is a means of capturing and monitoring the use of the Toolkit
- Station data retrieval: This section would allow users to view and download any observed historic data that the project might acquire and provide.
- Retrieval of relevant URL: This forms the bulk of the Toolkit and uses the information gathered in the Inventory.

These requirements and how the components are interlinked are represented in the schematic (Figure 3). Based on these requirements the Online Toolkit web pages were produced. A description of the various components is presented in the Results section (Section 6) below.

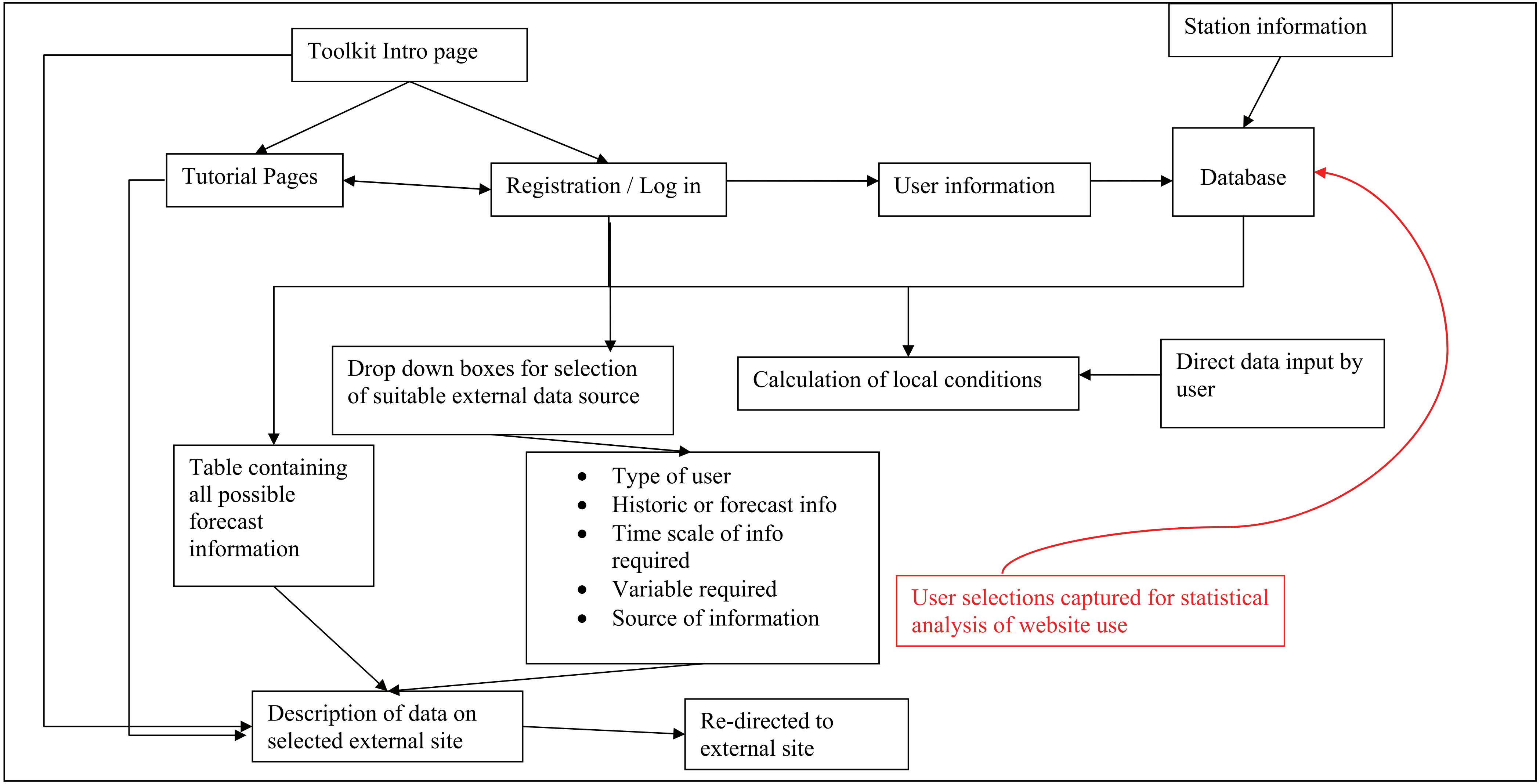

Figure 2: Online Toolkit contents map

6. Results

Inventory

The inventory table presents an initial investigation into the weather and climate information that is available on the internet and telephonically in South Africa. All of this information is freely accessible and could prove valuable to a variety of users. Included in the inventory are internet sites with observed and historical climate data, short-term weather forecasts and seasonal climate forecasts.

It was decided to include both observed and forecast data in the inventory. Websites that contain information pertaining to specialised forecasts and archived data were also included for extra interest or detailed analysis.

The purpose of compiling an inventory was to assemble a comprehensive guide to the sources of weather and climate information. This provided a reference guide from which stakeholders can access specialised information for their individual needs. It also provided a base from which the project team could start investigating the sources of climate and weather data that are currently being utilised. In addition it enabled the project team to educate stakeholders about other freely accessible information available that the stakeholders may not have been aware of or have known how to access.

Case study: City of Cape Town (CCT)

Background

The Cape Town Metropolitan area, with an urban and peri-urban population of near 3 million, depends chiefly on the dams in the mountains of the SW Cape for domestic and industrial water supply. The surrounding farmlands, considered the breadbasket of the region, the numerous industries located in the Berg River valley, the smaller towns of the region, and the extensive tourist and holiday regions both north and east of the city's urban area also require water emanating from similar sources. The region experiences a Mediterranean-type climate with rainfall confined almost entirely to the cool winter months between April and October. Dry, hot summers, fairly frequent droughts (three years in ten) together with significant population growth (over 3% pa) and increased seasonal demand from tourism place a severe strain on the city's water resources (City of Cape Town, 2006). Not only is the Western Cape region already water stressed, but climate change scenarios suggest that traditional winter rainfall patterns may be changing (Hewitson, 2007). The threat of greater climate variability has forced water resource managers to seek a better understanding of the climatic implications of management decisions.

While it is theoretically possible to forecast the weather for up to ten days in advance, techniques based on sea surface temperature anomalies make it is possible to forecast aspects of the anomalies of the expected climate conditions up to a year or more ahead. The availability of climate forecast information varies according to scale and lead times and is disseminated on local public television radio and internet sites. Many forecast products are available through the print, radio and television media, although these are usually restricted to short term weather forecast products. SAWS offers an extensive range of climate information and data on their website (www.weathersa.co.za) but this information is not sent to any users. Consequently, unless users have the knowledge, skills and access to the internet, this information may not be available to them. Many other institutions offer weather and climate forecasts and data on the web, but few offer any targeted information to water resource managers.

Interview outcomes

Interviews were held with ten water resource managers in the municipal, agricultural, environmental and Department of Water Affairs and Forestry sectors in Cape Town.

It was found that water managers in Cape Town used shorter-term weather forecasts more than longer-term forecasts. The water resource managers in Cape Town used a variety of forecasts, including:

- 1-7 day, fortnight and one month forecasts from SAWS and/or CSAG
- 3 month/ seasonal forecasts from SAWS, CSAG, GFCSA, IRI
- Raw data from the SAWS airport weather station, ARC and other sources
- Rain data from various weather stations, especially at dams

> *"I am sustained by the bulletin. It is improved by discussions… I can see trends and how close they were."*

The DWAF and some CCT water resource managers we interviewed use a bulletin emailed approximately weekly by Ninham Shand, consultants to DWAF. The bulletin includes information on cumulative rainfall figures and dam levels, dam storage forecasts under different demand scenarios, suggestions for managing water in dams supplying Cape Town as well as 7-day, one month and seasonal weather forecasts.

Figure 4 illustrates all the sources of weather data used by the interviewees. Data sources are divided into sources of raw data, forecasters/interpreters of data, and information publishers. It is clear that SAWS and CSAG forecasts are the ones most used by those interviewed, with the Ninham Shand (Anton Sparks) bulletin also giving much benefit.

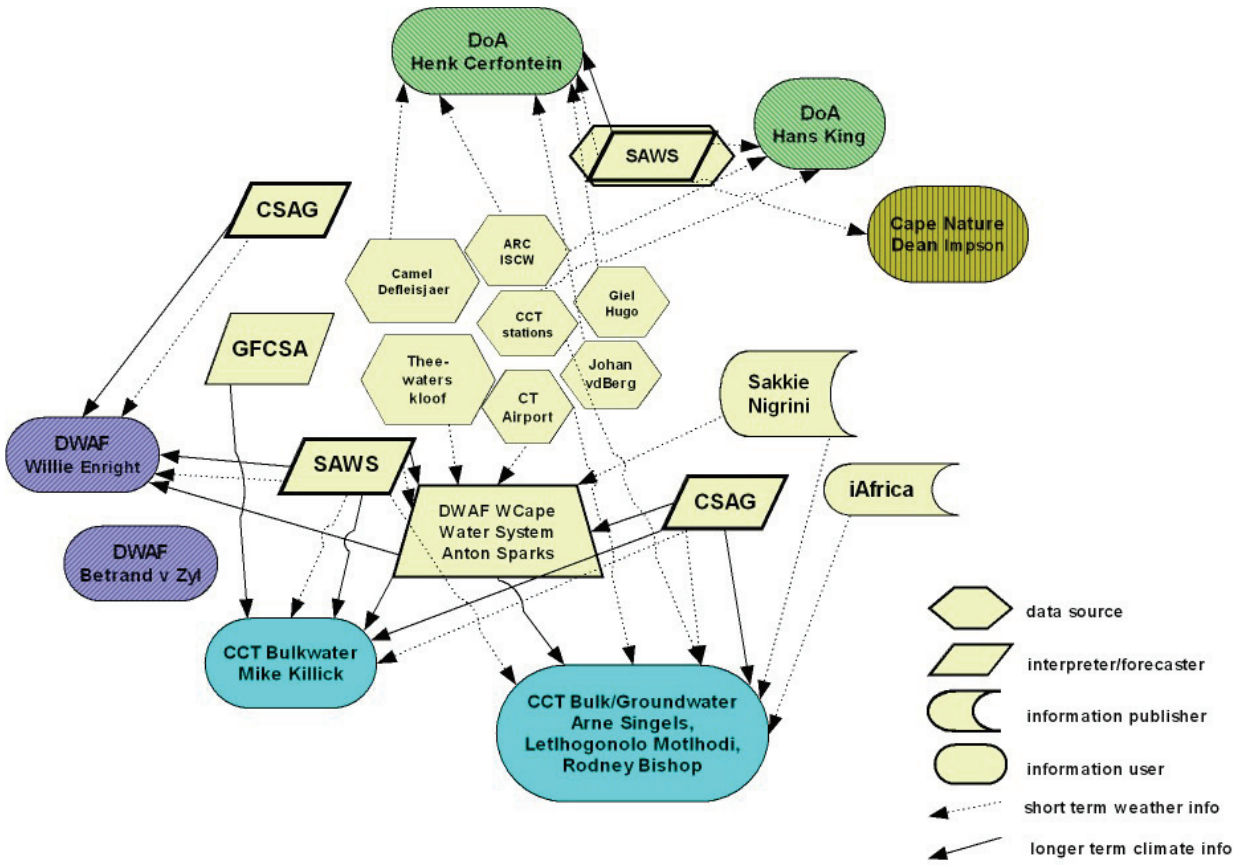

Figure 3: Stakeholder networks emerging from Cape Town interviews

CCT water managers

CCT bulk water managers used shorter term (daily to fortnightly) forecasts to manage the water in dams. Forecasts informed their decisions on which dam(s) to draw on at that time to supply Cape Town as well as on movement of water from one dam to another. Forecasts were used to inform the water managers in their planning decisions sent to operations, were discussed with others (especially DWAF), and were reported in water liaison meetings and to politicians. The most important aspect of the forecast was rainfall intensity and thus runoff.

Seasonal forecasts were mainly used in drought management. Longer-term forecasts were seen as less skilful than short-term forecasts. Long-term predictions such as climate change scenarios informed their thinking of future resources along the line of diversification.

> *"If I take note of climate change it doesn't necessarily tell me what to do with water management."*

DWAF water managers

DWAF water managers use 1-7 day, monthly and 3-monthly forecasts from CSAG and SAWS as part of their decision-making, but use Ninham Shand's bulletin especially.

There are four water management areas in the Western Cape: Berg, Doring, Breede and Gouritz. Cape Town's water comes from dams in some of these catchments. The dams used are Steenbras Upper & Lower, Wemmershoek (owned by CCT), Theewaterskloof, Voëlvlei, Palmiet (owned by DWAF).

DWAF make overall decisions about level of restrictions and from which dam Cape Town must take its water. They also advise farmers and other groups. DWAF and CCT bulk water managers confer regularly about water plans. DWAF makes decisions on water use planning and disaster management preparation e.g. when floods are expected. They monitor seasonal forecasts; if a dry season is predicted, a meeting of the planning committee is called to discuss water restrictions and possible emergency measures. The committee includes water managers in CCT, Stellenbosch, Paarl, West Coast municipalities, DWAF, consultants and the irrigation board.

Interviewees were asked what shortcomings they had found in forecasts and to give suggestions or their "wish list" for forecast tools. These included:

Shorter-term forecasts

- Better information on rain intensity.
- A 3 to 4 day rainfall and temperature forecast for sluices.
- Indication of rainfall over 8.5 mm expected
- Studies on rainfall spatial and temporal distribution as well as intensity.

Longer-term forecasts

- Improved long-term forecasts
- Information on the website about the principal drivers behind long-term forecast to increase confidence
- For CSAG 1- and 3-month forecasts, links to normals, an indication of expectations, and shown skill levels would be desirable
- Research on changes to vegetation as a result of climate change.

Workshop outcomes

The workshop for Cape Town water managers was attended by 22 delegates, including representatives of CCT, DWAF, Cape Nature, DoA, Ninham Shand and the Berg River reference group.

1. The first aim of the workshop was to determine delegates' understanding of climate variability and climate change. Delegates filled in a brief questionnaire designed to reveal their knowledge and use of climate information. Their responses are summarised below:

- 20 of the delegates used weather and climate information in their work
- 16 delegates had accessed 1-7 day forecasts, 7 accessed 2-week forecasts, 8 accessed monthly forecasts and 16 accessed seasonal forecasts
- The forecast timeframes which interested them most were 1-7 day (14), 6+ months (13), followed by 3-6 months (10), 1-3 months (6) and 7-30 days (4)
- The climatic variables in which they were most interested were rainfall (21) maximum temperature (8), minimum temperature (5), average temperature (3), with 1 person each indicating windspeed/direction, relative humidity and rain data.
- Other variables which they would like to see in forecasts were surface temperature, wind direction and speed, relative humidity, rainfall intensity, longterm variation and flood warnings
- Most people accessed forecasts through the internet (17), followed by radio/television (10), email (10), newspaper (4) and cellphone (3).
- 19 indicated that they passed the information on to other people.
- 21 of the delegates indicated that they would be interested in receiving updated climate/weather forecast information
- All delegates believed that weather/climate information could be useful in decision making at work. These decisions included planning and management of water resources, whether to apply water restrictions, emergency preparedness, early warning, crop estimates, fire management, vegetation monitoring, planning outdoor work, dam and river bank inspections, environmental impact evaluations and whether to make an environmental flood release

2. The second aim of the workshop was to identify the strengths and weaknesses in current forecast tools. A brief presentation was given of four different forecasts available (SAWS 7-day, CSAG 6-day, SAWS seasonal, CSAG seasonal). Delegates then evaluated posters of the four different forecasts, giving positive or negative comments on each forecast. A summary of the comments is shown below:

CSAG 6-day forecast:	
Positive Aspects	**Negative Aspects**
• many delegates mentioned inclusion of rainfall intensity (depth), • locality of rain shown, • gives a trend over time – useful to see the movement of the weather pattern as this allows one to anticipate rainfall events, • most useful model, • graphically well laid out	• Good level of detail but too specialist for interpretation, • would be useful if there was a link to a interpretation, • the period over which rainfall intensity is shown may be misinterpreted as mm/day, • 'grid undefined' appears quite often
SAWS 7-day forecast:	
• reliable, • simple and user-friendly, • gives quick answers, • shows variation through the day, • information is point-specific, information is stated with a high level of certainty – no probability estimate required.	• too general to be used alone, • too vague for water management or flood forecasting, • no indication of intensity, • no relative humidity, • terminology confusing

CSAG Seasonal:	
• easy to visualise the climatic variations & probability, • colour coding is clear and gives good indication of precipitation probability, • includes information about uncertainty	• not clear, • difficult to understand, • interpretation too specialised – not user friendly, • description of the shading should be on key and not hidden in text, • term "anomaly" may confuse many, • resolution difficult to interpret for small areas, • probability brackets
SAWS Seasonal:	
• gives a good general idea of the spatial weather pattern probability, • normal indicated clearly by separate colours, • good overall indication	• lack of resolution, • more categories needed, • not easily understandable for lay person, • specialist knowledge needed to interpret the written information, • no indication of skill, • not specific for Western Cape – based on summer rainfall region

3. The third aim of the workshop was to examine the type of climate variability information managers think would be relevant at an annual and longer-term scale. A discussion was facilitated around specified questions –

Climate information that delegates would make use of and examples of where they would use the information:

- Historical rainfall intensity data – used for flood prediction and design of stormwater infrastructure.
- Rainfall intensity data – for water transfer planning, planning irrigation schedules, disaster planning and flood prediction.
- Change in temperature (weeks to month) – for algal bloom management, fire management, planning irrigation schedules
- Wind conditions – for fire management, planning irrigation schedules
- Radar – for intensity prediction, storm management, dam release, rescue
- Seasonal forecast – for agricultural crop management, deciding whether to plant cash crops, stock water provision, management of artificial groundwater recharge

Ideal climate information that would be helpful and how management decisions could be improved by such information:

- Return period of a particular storm – used for risk mapping
- Rainfall intensity at a smaller time scale – for water transfer planning, disaster planning and flood prediction
- Temperature change at a fine spatial resolution – for algal bloom management, fire management
- Chill unit predictions – for produce such as apples and grapes

- Better accuracy for seasonal forecasts – for dam construction and level management, corresponding runoff so decisions for water use can be made
- Integration of all the data in one place.

Feedback forms from the workshop confirmed that delegates were very happy to be involved and drew great benefit from the day. They were particularly interested in finding out more about weather forecasting – our information sessions at the workshop drew many questions. Comments included "Better understanding of accuracy and predictability"; "Learned a lot about weather forecasts"; "Should make it a full day to allow for more detailed discussion" and "I gained a lot of useful information and learned 'don't judge a forecast by its colour!'".

Focus group outcomes

In Cape Town, four focus group were held covering the themes of water storage; urban water supply, water disposal and stormwater; nature, biodiversity and agriculture and disaster management.

1. Water storage focus group

This was attended by 3 people from the City of Cape Town's bulkwater and groundwater departments and a consultant from Ninham Shand.

Issues emerging:

- The need for an annually issued forecast for the following 12 months. Decision making on water restrictions is made only once a year therefore shorter forecast is not quite suitable.

- Medium term forecasts can be used for predicting runoff from the upper Steenbras Dam to the lower Steenbras Dam and decisions about whether to have conjunctive use of dam and aquifer water.

- Rainfall and temperature greatly influences water demand in the city during summer months. This influences long-term planning. This was modelled by Ninham Shand during restrictions. One hot dry month isn't really a problem, but several in a row are more of an issue. An early warning system of progressive dry conditions would be useful.

- If climate change brings about a temperature increase in the long term, it would be logical to try to minimise future and existing dam surface areas, however there is little leeway as most of these controls take place during the design stage.

- If a change in rainfall patterns is to be expected then constructing new pipelines that could carry larger volume may need to be considered. However this would be an expensive investment, which would require strong confidence in the prediction, which predictions currently do not enjoy.

2. *Urban water supply, water disposal and stormwater focus group*

This was attended by 3 people from City of Cape Town's bulkwater and catchment management departments, and a representative of Wildlife and Environment Society of South Africa (WESSA).

Issues emerging:

- Significant increase in rainfall increases infiltration, which increases the volume of influx through the treatment plant and may disrupt treatment functioning. Infiltration may also lead to overflow of sewage into the natural systems. Forecasts of seasonal rainfall intensity could help in developing responses.

- Effluent going through the treatment plants should not be too diluted as the plant was designed to accommodate a certain range of biological matter content in the water. Therefore over diluted effluent may disrupt functioning of the treatment plant. Conversely water with overly high content of bio matter would also disrupt treatment plant functioning. Drier conditions, which lead to water restrictions, could induce more concentrated sewage which may disrupt the effective functioning of the treatment plant.

- Increases in temperature may enhance the functioning of the treatment as it may increase biological decomposing activities but this may also create stronger odours.

- Climate, rather than population, mainly influences seasonal pattern of disposed water volume.

- If there is a flood warning received from the weather service, little can be done in terms of mitigation, but rather disaster management preparation can be mobilised (e.g. have people on stand-by to unblock drains and to aid people in flooded informal settlements.).

- Seasonal forecasts can be useful in terms of planning for a winter preparedness programme that would allocate human resource to sites that are susceptible to flooding. Drier conditions would have little effect on their design philosophy.

- Long term prediction of rainfall intensity would be beneficial to help managers prepare for dam overflows, especially towards the end of winter.

3. *Nature, biodiversity and agriculture*

This focus group was attended by 5 people, representing the Department of Agriculture, UCT freshwater research group, Cape Nature (Fisheries), Wildlife and Environment Society of South Africa (WESSA) and a farmer who is also a member of the Berg River Irrigation Board.

Issues emerging:

- Users traditionally lacked trust in weather/climate information (due to a perceived poor track record) therefore they tended to not make major decisions based on such information. Users also often lack the necessary knowledge to utilise the information appropriately.

- A recommendation was that a database be created, comprising of local weather information contributed by various farmers from different towns (e.g. Wellington) connected via a network (e.g. Cape-Agri) where the collected information could be sent to weather information sources (e.g. CSAG). The collected local observed weather information could be utilised by CSAG to derive a more detailed, large scale forecast or historical data and ultimately to improve details and understanding of the large scale weather information.

- In terms of water management, long-term forecasts and climate change projections could be useful in the following ways:
  - Water resources are affected by the river/stream's biome, which is also affected by long-term climate change rather than short-term changes to which most organisms could adapt
  - They assist in determining the appropriate amount of water to use
  - They are essential in determining rules for dam operation (e.g. amount of water to release)
  - Seasonal forecasts can assist the management of lagoons and wetland areas.

- The Berg River project is a high profile project that has an environment monitoring committee, which is likely to integrate climate information into their study.

- In general, plants and animals are quite adaptive to change in the short term (unless very large and very sudden) and long-term changes seems to have a greater impact; therefore climate change projections are very important in terms of determining future distribution of various biomes.
  - Forecasts can help to predict temperature levels conducive to algal growth – helps with prediction & timing of interventions.

- Climate is an important variable in estuarine activities. One concern is estuaries that are closed in dry conditions, which require mechanical methods to re-open. It is important to know when to re-open the estuary mouth mechanically and what the consequences might be. As most small estuaries that close in dry conditions are situated in the east coast; and climate change projection indicates an increase in summer rainfall over the east coast in the next 50 years, those estuaries may, therefore, not be closed in winter in the future. This may have a serious impact on the natural environment of the estuary.

4. Disaster Management

This focus group was attended by two delegates from the City of Cape Town (CCT)'s Disaster Risk Management and Flood Risk Management departments respectively, and a representative of Cape Nature (river management).

Issues emerging:

- CCT is interested in seasonal weather forecasts – if the season is going to be wet, informal settlements could be at risk. In winter they are particularly interested in high rainfall intensity because of the likelihood of flooding.

- They are also interested in short term forecasts to know what to expect; they would not necessarily mobilise resources as it is often logistically inefficient. It is virtually impossible to predict blockages (i.e. floods) as blockages depend on various factors and not merely rainfall. However short term forecasts would help to predict how long the conditions would persist. Therefore real time monitoring may be more useful to mitigate/prevent floods.

- Long-term forecasts can influence the design of new storm water infrastructures.

- The CCT Disaster Risk Management department is involved in an annual flood risk plan (winter preparation) that uses seasonal forecasts to infer the number of shacks that are susceptible to the potential flood. With this information they can plan preventative measures and inform the finance departments. This type of annual planning seems to have attained better results over the last few years.

    - Short term forecasts are potentially useful in a variety of ways, especially the following Consecutive days of heavy rain causing flooding
    - Spring time onshore wind that can raise the tide table (e.g. Kommetjie is vulnerable)
    - Unstable slopes – weather forecasts can be used in the design and construction of mitigation/preventative measures
    - Koeberg's radioactive plumes transmission to public – wind direction can be used to determine plume's travelling route and extent

- Major fires – wind, humidity and temperature forecasts can be used to determine information:

    - the spread of fire and its potential persistence.

- Climate change projections are very important in terms of the City's planning for floods in the future. If such reliable climate change evidence is documented, then they could start advising politicians with regard to the impacts of changes in development, especially controlling development along the coastline.

Case Study: Overstrand Municipality

Background

The Overstrand local municipality stretches along 200km of coastline and covers Hangklip/Kleinmond, Greater Hermanus, Stanford and Gansbaai together with various smaller villages. The population of the entire Overstrand is about 70 000 including 50% of the population under the age of 35, 10% of the population retired and only 67% of the population economically active. Holiday towns such as Hermanus, Gansbaai and Kleinmond have a particularly high percentage of retired individuals.

Water management in the Overstrand is conducted by the municipality, which was given the authority to perform as a water services authority in 2003. Currently the greater Hermanus area obtains it water from the De Bos dam situated on the Onrus River. Hermanus's water demand is increasing at a rate that requires additional resources to be exploited. Present water resources will be enough to support the greater Hermanus area until 2008.

Interview outcomes

Interviews were held with eight people including operations managers for services for each of the three regions in the Overstrand, the technician in charge of water and sewage in Overstrand, the ex-water engineer for the Overstrand, a DWAF consultant, a manager at Overberg water and a farmer.

> *"In summer if you see Cape Point it will rain 2 days later. In winter when the whales are here and start jumping to the north 'noordkapper' it will rain."*

Most of the people interviewed made little, if any, use of weather and climate forecasts in their work. The main reason cited was lack of time; however, it was evident to the interviewers that lack of awareness of forecasts available and their possible uses was also an issue.

Currently water management is just a small part of the job portfolio of the "Operations Managers for Services" interviewed in Hermanus, Gansbaai and Kleinmond. Their roles include water, sewerage, roads, parks, beaches, cemeteries, refuse and services to informal settlements. Time is clearly a limiting factor for the officials in the Overstrand municipality. This could well be common in many small municipalities in South Africa, where a wide range of services need to be managed by one person.

> *More than 80% of staff fall under the 3 Operations Managers for Services, so we spend a lot of time on staff and union issues or in meetings.*

It was apparent that none of the Overstrand municipal officials were aware of all the forecasts that were available or the usefulness of forecasts in their work. Many of those interviewed were not clear on the meaning of forecast terms such as probability. A regular newsletter (similar to that of Anton Sparks) giving weather / climate forecasts and pertinent water information could be useful to water resource managers in the Overstrand. Three of those interviewed said that if an interpreted forecast were sent to them it would certainly be used.

In their 'wish list for forecast tools', several people asked for forecasts which were already available such as a 7-day forecast, temperature conditions, warning of severe events. Other requests included

- Rainfall patterns
- Localised information of daily rainfall statistics,

- Warning of sea storm surges
- With longer-term forecasts: forecasts giving predicted amount of rain rather than a percentage of the normal rainfall.
- Interpreted weather/climate information.

Workshop outcomes

The workshop in the Overstrand was attended by 13 people representing the municipalities, nature conservation, DWAF, agriculture and rate payers associations.

1. The first aim of the workshop was to determine delegates' understanding of climate variability and climate change. Delegates filled in brief questionnaire covering their knowledge and use of climate information. Their responses are summarised below:

    - Nine delegates currently used weather/climate information in their work
    - Ten delegates had ever accessed weather/climate forecasts
    - Of these, seven had accessed 2-day forecasts, five had accessed 2-week forecasts, four had accessed seasonal forecasts and one had accessed 7-day forecasts
    - The variables in which they were most interested were rainfall (11), temperature (8) and windspeed/direction (1)
    - They accessed the information through the internet (9), radio/television (4), newspapers (2), by phoning the airport (2), by email (1) and by cellphone (1)
    - Nine found the forecasts understandable and easy to use, while one said that the newspaper forecast was more difficult
    - Things that were lacking that they would have liked to have seen in the forecast included crop information, area specific information, translation to English (Overbergagri forecast), greater accuracy, rainfall intensity, more detailed discussion in media, monthly forecasts, forecasts for longer periods and historical averages
    - Seven delegates found the timing of the release of the forecast suitable to help in decision making or planning, while one responded that it was timely but was often wrong which caused delays
    - Seven delegates said that they passed the information on to others
    - Eleven delegates said that climate information could help in decision making related to their work. Areas that were applicable included disaster management, water conservation, demand management, fire anticipation, development planning, daily work operations, groundwater recharge and abstraction rates, water pricing, drought / flood planning and implementation, water allocation and licences
    - Of those who had not used weather/climate forecasts, three said that they would like to receive forecasts
    - The information that they would like to receive included seasonal rainfall and information to encourage water conservation and assist the Kogelberg Reserve
    - Rainfall was the only variable listed that they would like to have on a forecast
    - The forecast timeframes that interested them most were 1-3 months (1), 3-6 months (2), 6+ months (2).

2. The second aim of the workshop was to identify the strengths and weaknesses in current forecast tools. A brief presentation was given of four different forecasts available (SAWS 7-day, CSAG 6-day, SAWS seasonal, CSAG seasonal). Delegates then evaluated posters of the four different forecasts, giving positive or negative comments on each forecast. A summary of the comments is shown below:

Positive aspects:	Negative aspects:
SAWS 7-day	
• clear and easy to understand • quick and easy to read • simple • accessible.	• no information about sea conditions • does not quantify rainfall • no spatial information • no fire index • does not allow for uncertainty • compare Overberg Agri format • "Strong" wind is vague – rather give speed range.
CSAG 6-day	
• spatially explicit • well presented • gives very clear forecast.	• not that easy to read and understand– no keys to interpretation • explain 'geopotential height' • unclear as mm on bottom scale not showing • need more accuracy at local level.
SAWS Seasonal	
• shows that these forecasts are very statistically based • well understood.	• need more accuracy • make it more local / regional • areas too broad, e.g. coastal vs. inland given same colour code • transition line about 100km across • too busy, difficult to comprehend all the detail.
CSAG Seasonal	
• easy to interpret • well presented • colour coding great • good spatial detail • more user friendly than SAWS.	• very busy • would like more local detail • regions too widely defined • takes too long to read • need some knowledge • needs more explanation as to what the key means • what is: 700hpa geopotential height; vorticity?

3. The third aim of the workshop was to examine the type of climate variability information managers think would be relevant at an annual and longer-term scale. Delegates were asked to think and make notes about the kind of climate information that they would find useful in their work. They were asked to consider the timing, resolutions, variables and format of the information that they would like to receive. A discussion was facilitated around these questions –

Type of forecast and timing

- Weekly rain & wind ← previous Friday
- 7-day forecast updated 3-hourly (Nature Conservation)
- 2-3 weeks (to predict water demand)
- 3-months (operational planning) ← rolling

- Agriculture: whole range of info. April to October ← before people plant
- Medium term (18 months) ← autumn
- Long term (3 years) ← updated annually
- 5 years (more climate change) ←at beginning of year
- Ten year scenarios re water.

Resolution
- Coverage over larger area
- Specific to Western Cape (long term)
- Southern Cape – mountains & concentrate on 'vlaktes'
- More specific re topography and rain shadow
- Berg / Breede WMAs
  - Velddrift to Cape Town
  - Every different catchment
  - Recharge area-specific.

Other Variables
- Short term: precipitation, wind, temperature (short term operations)
- High rainfall / severe events / flood warning (breaching estuaries)
- Wave heights
- UV
- More interpretation and reasoning e.g. when fire risks, when to burn
- Informing water demand and management strategic long term
- Seasonal: include temperature (for restrictions)
- Water restriction and related warnings
- Long term historic data sets for comparison ↔ baseline
- Agriculture: risk & variability mapping (coupled to seasonal forecasts)
- Impacts on local rivers, development control
- Long-term effects on groundwater
- Increased data stations: re-commissioning plus adding others.

Format & communication:
- Internet is best
- Ability to ask questions online
- Simple and not too much small print
- Newsletter emailed every Friday with short term and seasonal forecasts as well as interpretation.
- Seasonal newsletter and long term
- Periodic report / summary with some interpretation and explanation (simple)
- Warnings sent by sms or email if you register for them
- Phone in number
- Explanation of terms

- More community awareness workshops
- Target recreational sports.

Focus group outcomes

One combined focus group meeting was held with municipal water managers in the Overstrand. This focused on water disposal, stormwater and disaster management which were the main areas of interest of water managers who had been present at the workshop earlier in the year, and due to the low number of people involved, it was decided to hold just the one focus group. It was also not relevant to focus on water storage as the Overstrand municipality relies on DWAF for access to water – they have no direct decision-making power in how water is stored. The Overstrand focus group included Operations Managers for Services for the towns of Gansbaai, Kleinmond and Hermanus, as well as the Water Manager for the Overstrand.

Discussion:

- Weather information is currently mainly used to schedule regular work, such as road maintenance, clearing drains etc.

- Participants expressed the need for warnings of extreme weather. A sms warning was sent to them once by someone from DWAF, but the predicted weather did not happen. They said that they would be more hesitant to react to a similar warning in future.

- Long-term forecasts could be useful for planning tender publication.

- Long range forecasts of rainfall for the wide area surrounding Hermanus, and information on how this could impact on groundwater recharge and levels could be used to decide how groundwater should be managed – and to predict where additional boreholes could be sited

- Monthly forecasts would be useful in summer, especially in December until early January over the peak season. Forecasts of rain, or even overcast weather could help in planning water purification. In hot, dry weather restrictions would be necessary as the water purification plant would not be able to cope with demand.

Participants said that they did not value maps as much as a brief summary of the forecast, together with probabilities. Alternatively, a website with a map and an interpretation would be useful. Participants said that seasonal forecasts were difficult to read/interpret – even with the training they had received in our sessions, they struggled to interpret the maps. Thus giving the un-interpreted maps to councillors to back up a request for imposition of restrictions would not be useful.

Description of the Online C4W Toolkit

The Online Toolkit has two separate components; the User Interface (UI) and the Admin User Interface (AUI). Both of these components are accessed via the Internet.

The User Interface

The user interface section of the Toolkit is what is visible to the general public on the website. It can be viewed when the user chooses the 'Toolkit' option on the C4W website. The toolkit web pages have been constructed to link with the Admin User Interface to make maintenance and upkeep of the site easier for the C4W team. A description of the functionality of the Toolkit is provided below, followed by a description of the AUI.

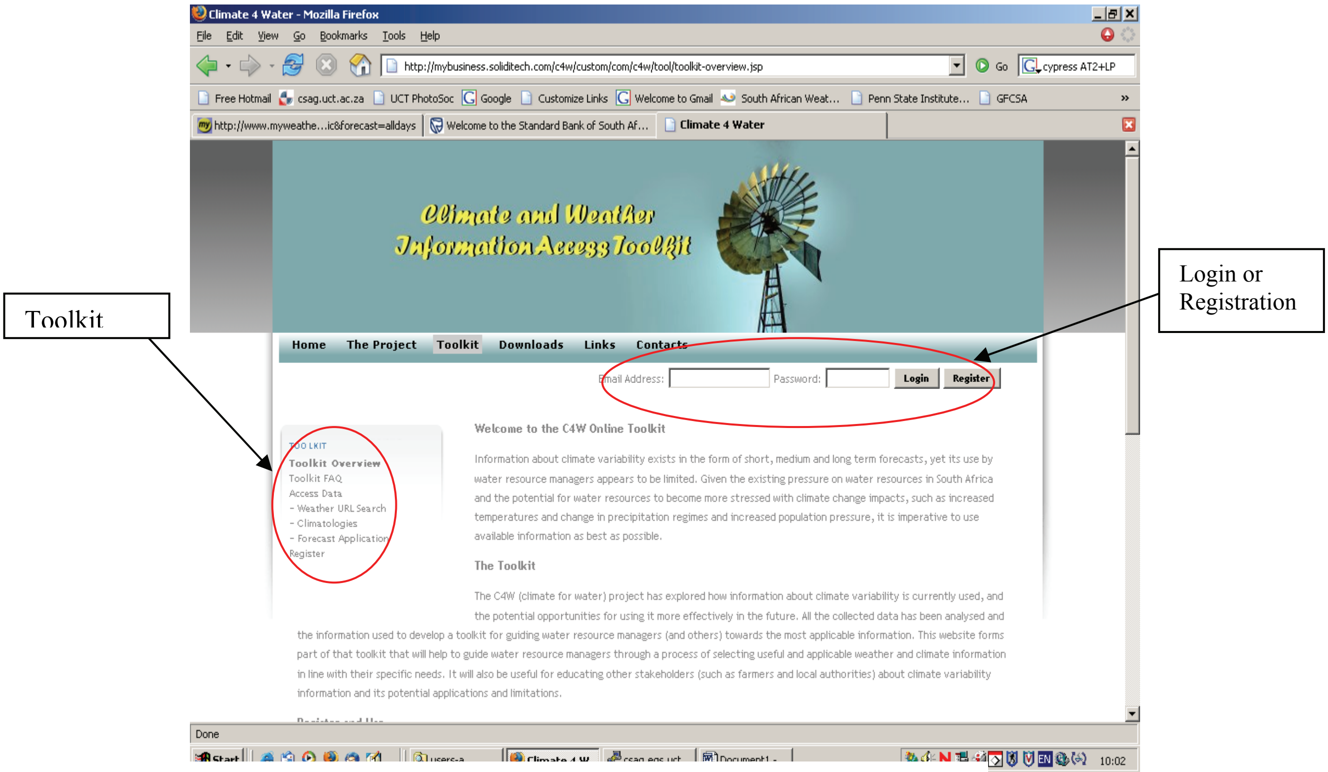

Figure 4: Toolkit main page

The Main Toolkit page:

This page gives a brief overview of the Toolkit and also allows users to login or register if they have not done so already. The menu with all the Toolkit functions is displayed on the left hand side (see Figure 5 above). The user is then able to choose one of the following functions:

- Toolkit FAQ
- Access Data
    - Climate & Weather URL Search
    - Climatologies
    - Forecast Application

- Register.

Toolkit FAQ:
This section is accessible to all users (no login required). It is a section of questions that has been put together by the C4W team. The information contained here covers what was noticeably the most frequently requested information during the interviews and workshops held for the project. Although we are unable to provide all information requested by the users we hope to grow this section as is necessary. This is therefore a start and this section will be expanded in the future.

Access Data:
This section is only accessible to registered users who have logged in to the website. This is done not to restrict the site to certain users but to monitor the use of the product and thereby be able to improve on the content.

This section contains the main part of the Toolkit – access to climate and weather information URLs. In addition we have also created a function where users can apply the forecast to their area of interest. This is available under 'Forecast Application' which uses station mean data that is also made available through the 'Climatologies' section of this page.

Climate and Weather URL Search

During the initial stage of this project, one of the team's tasks was to identify and collect all available sources of climate and weather data on the Internet (relevant to Western Cape only). This was completed and an inventory of the findings was produced and provided as a deliverable. It was then important to make this accessible to the users of our web page. This was achieved through the use of a database which stores all the relevant URLs and tags them appropriately to allow for a logical search.

The web page for users was constructed to allow the user a number of choices (Figure 6). He/she must decide firstly what type of data is required. The options here are; 'Forecast', 'Historical' or 'Near Real-Time'. The options for time range and variable will depend on this first selection. The page processes each selection stage to extract all appropriate choices relevant at that stage. To do this the data are stored on a database and the java code processes the requests. The result is that the user is given a manageable list of URLs that correspond to his/her request. These URLs are for external sites that provide the kind of data required. A description of the source of this URL and information about this link is also available to the user (Figure 7). This information is displayed on a new pop-up window and the selected URL link will be opened in a new browser window.

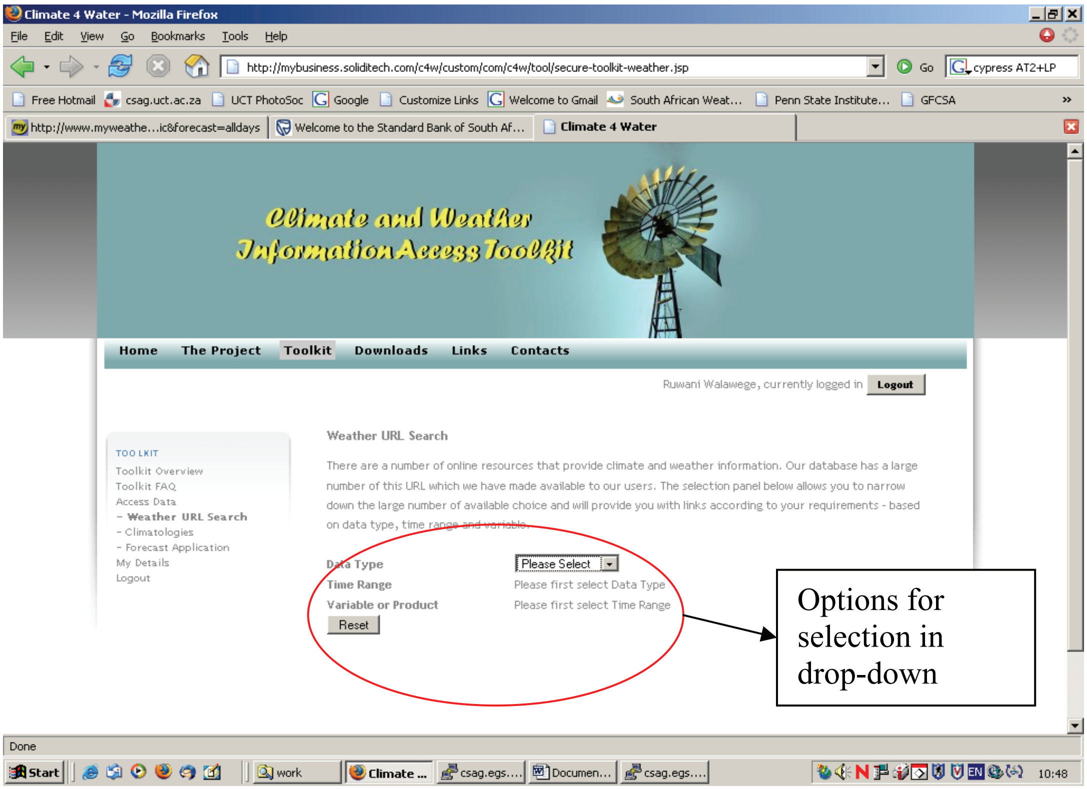

Figure 5: Climate and weather URL selection process

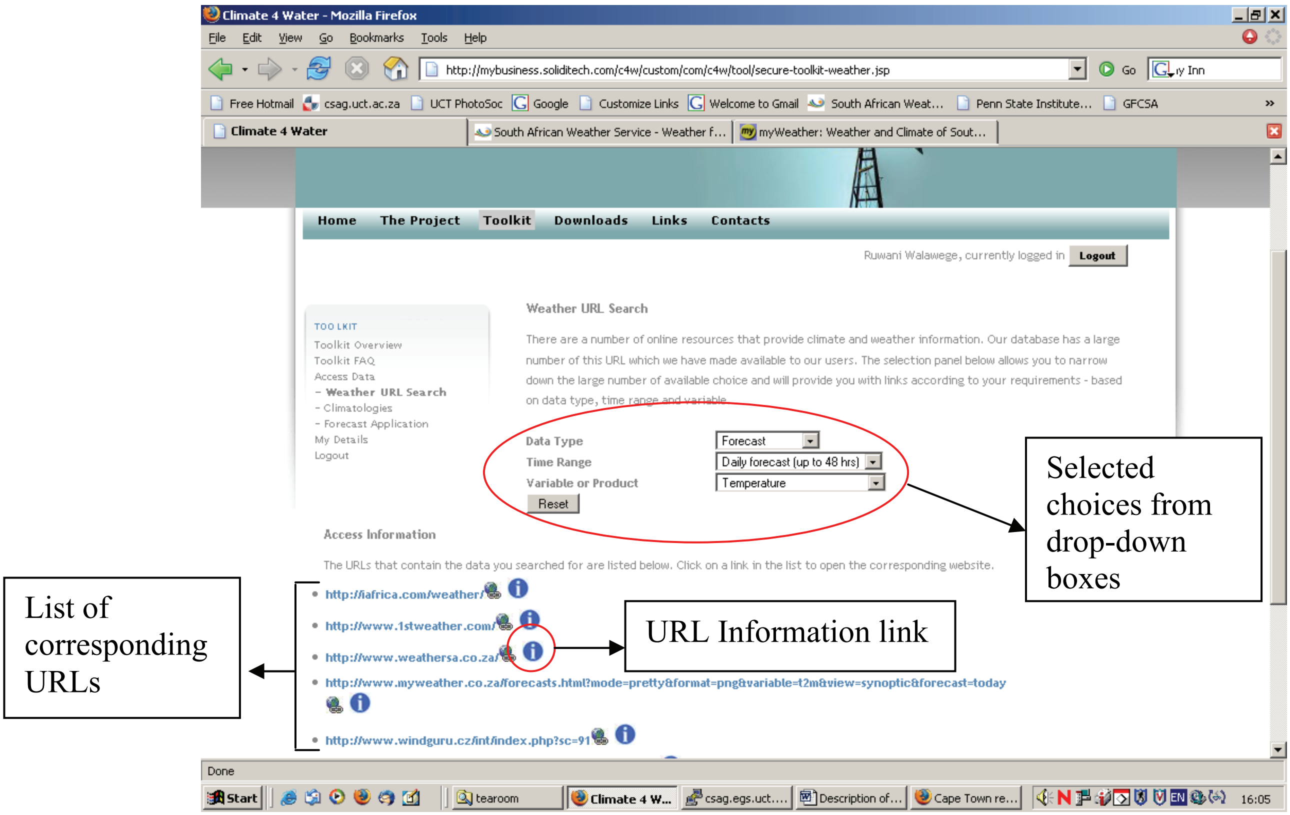

Figure 6: Final URL selected list displaying information icon.

Climatologies

This section of the Toolkit stores a subset of station climatological means. The data have been collected by the C4W team and are made available to the users. The site user may select a variable from the list. The corresponding data will be displayed in a table. As more station data becomes available these will be added to the database.

Forecast Application

This section of the Toolkit was created to assist users to apply the seasonal forecast to their particular region or city/town. The tool allows users who have viewed the seasonal forecast from one of the external sources, to use this information together with the monthly climatological mean values that have been stored in the database. Currently the algorithm only allows users to calculate the forecasted value for precipitation. In addition the function has also been adapted such that if a specific city/town does not appear on the list of climatological data that are available, but the user has reliable records of his own, he/she may use these values in conjunction with the seasonal forecast and get the forecasted value for the required city/town or farm.

This function is also to be used in conjunction with the forecast verification table that has been produced through observation of the model performance through a longer time period (i.e. for the CSAG forecast only). Explanation of this is also available on the FAQ section of the Toolkit.

Register:

In order to access certain sections of the Toolkit, the user needs to have a unique username and password. This can be obtained by the user by registering on the C4W website. The registration process is simple and does not require a lot of information from the user. This was done explicitly not to discourage any website users from registering on the website. The information obtained through this process is merely to assist with the later analysis of the website (and toolkit) use.

The website has also been designed so that once the user uses his username and password once to log in, the information can be captured by the user's computer avoiding the need to remember the information in any future visits to the Toolkit page.

Admin User interface

This section of the Toolkit is a more complicated part of the whole product that has been written on a JAVA platform. The admin interface can be accessed from the C4W website through the login button at the foot of the website. Only selected team members have access to this interface, but any number of people may be added onto the system.

The primary purpose of the Admin Interface is to allow the C4W team easy access to the Toolkit pages and allow for simple changes and maintenance on these pages. This effectively means that the website host/designers need not be involved with this process unless there are large/difficult changes to be made. A brief description of the different admin tools are given below.

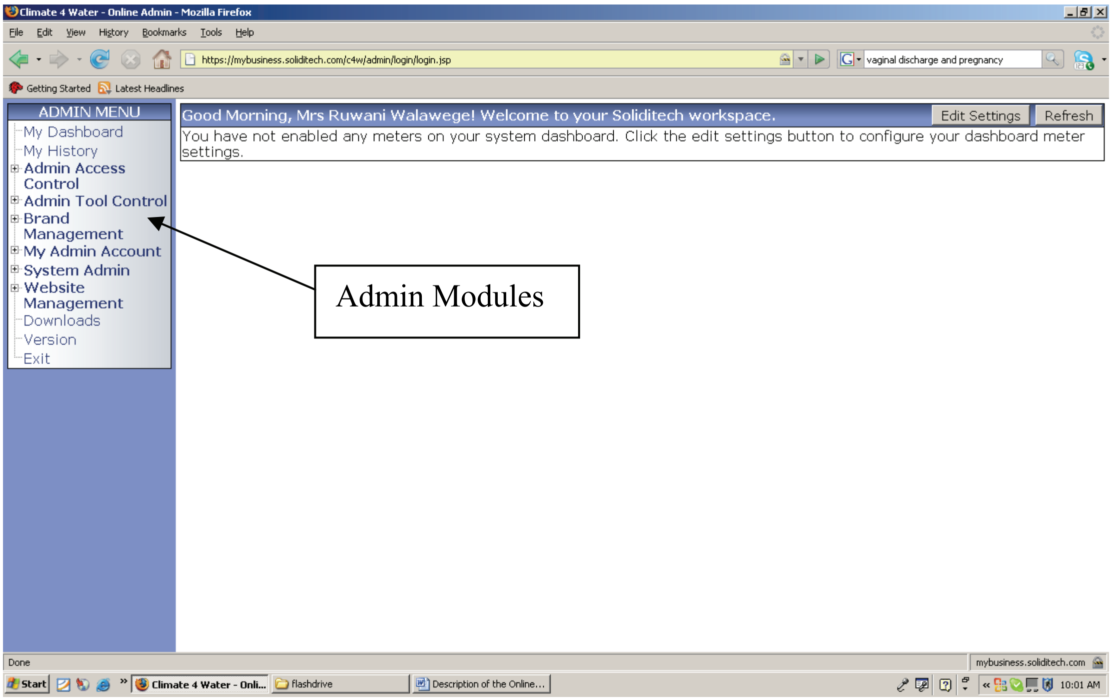

Figure 7: Front page of Admin Interface page

The Admin Interface page is simple and shows the modules available on the left hand side menu. Modules on the system allow the user to add other users and to also control what access these users have to the various modules. Some of the most important functions of the admin interface are listed below.

Email templates

The admin interface allows the admin user to edit/change or add an email template onto the systems. Such templates are used for example to welcome users when they register on the C4W website or when they change their password.

Station data admin

This module allows the user to easily upload station data that can be viewed on the C4W website. Changes if necessary to the station data can also be done via this module.

Toolkit FAQ management

The Toolkit page has a *frequently asked question* section which can be managed through a module on the Admin interface. This module allows the admin user to edit existing questions using a simple text editor built into the system. It also allows the user to add any new questions as well as change the order of the questions that appear on the Toolkit webpage.

Website comments

This module allows the admin user to view any comments left by the website user. If the website user was registered the details of the user may also be obtained from this.

Website News
This module allows the admin user to add any new news or announcement to be displayed on the front page of the C4W website. Existing articles may also be viewed and either deleted or moved to an archive.

Website users
This module contains all the information gathered from the registered users. This information can be exported to be used in other programs.

Website Stats
The usage of the Toolkit pages is monitored constantly by the software as the results of these can be viewed through this module. The statistics for each month are grouped and one can browse and see the number of 'hits' to a single page or view the individual account for a registered user. This will give the C4W team necessary information on how the Toolkit is being used.

Website URLs
The bulk of the Toolkit page is based on the ability of individual users being able to select URLs that contain the climate and weather information that they require. This section of the Toolkit is built on the data being stored in a database. The data is indexed in an appropriate way such that this search is made simple. This module in the Admin interface allows the admin users to add or delete any of the URLs in the database. Any new URL can be added to the database using the module and indexing the new entry is straightforward. Each entry has an attached description which will appear on the Toolkit page when necessary.

Outcomes

The Online Toolkit was launched mid-2007 to a selected group of stakeholders identified through the workshops and interviews held previously. Modification of the initial Online Toolkit was necessary since the initial product produced by the web design company was unsatisfactory. The modifications and the final Toolkit as described above were then completed by a second company, who are now hosting the current website.

Initial registration rate on the site was found to be very low. This may have been due to the small number of people been made aware of the availability of the product. The number of registrations was found to have increased once the booklet version of the Toolkit was distributed to a wider audience.

Summary Website Statistics
A summary of the C4W website statistics, as of Feb 2007, is shown in Table 6 below.

Total Registered Users	29
Website Usage Stats	**Hits**
Jul 2007	178
Aug 2007	28
Oct 2007	37
Nov 2007	3
Jan 2008	517
Feb 2008	3
Mar 2008	2
Toolkit Usage Stats	**Hits**
Jul 2007	7
Oct 2007	5
Jan 2008	45

Table 6: Toolkit and website usage statistics

The "hits" referred to in the above table are the number of times users access the general website or the Toolkit page. As can be seen the frequency of 'hits' tends to vary a lot. The nature of the information on the website itself is also such that users will not necessarily access the site on a daily basis. It is better to rather expect the user to register and access the information he/she requires and subsequently go directly to the source of the required information rather than returning to the C4W website.

However, for a number of stakeholders who may not have much knowledge about climate and weather information, this site and the Toolkit would be a valuable resource that they can visit more often.

More publicity to the initiatives of the project amongst a wider audience will also help promote the Toolkit as well and improve on the usage of the product. The project has therefore made a pamphlet describing the Online Toolkit and has distributed these amongst the Western Cape Municipalities and the DWAF offices in the province.

The launch and dissemination of the toolkit

The toolkit was presented at a stakeholder function early in 2008 at a Cape Town venue. Hard copy documents and promotional stickers were distributed to stakeholders, after a visual presentation on the ways the toolkit could be used.

Subsequently, in August 2008, a presentation was made to a range of invited water managers from Gauteng and surrounding municipalities. The outputs of this workshop are summarised in Table 7. Users in the northern regions had very similar experiences of available climate and weather information to those in the Western Cape case study areas, but the value of seasonal forecasts was significantly more noticeable.

Comments on forecasts used	
SAWS seasonal forecast	It is not helpful in the sense that the dividing line is difficult to interpret
CSAG seasonal forecast	Looks useful, but concern that it gives specific value without probability – would like range of skill
General	Currently no sites give information in needed format for immediate use
	Need geo-referenced grid
	In order to use forecast one needs to have knowledge of baseline. Many people don't have this knowledge so don't know what their variability of climate is.
	Both seasonal and 10 day forecasts could help to keep as much water in dams and ensure reliability of supply.
Current use	Short term forecasts are used in water resource management in real time systems for the Orange and Crocodile river
	Longer term forecasts used to produce predictions of run-off into future
	Use forecast to give min, med, 25%, 75% and 100th percentile to program scheduled releases
	Use forecast for predicted flows from historical/ stochastic then take envelope according to seasonal forecast. Provide entire envelope but highlight where forecast falls.

Comments regarding the toolkit were gladly received and will be incorporated into the continued revision of the website. In this regard it was recommended that project partners and specifically users that found value in the toolkit could be approached for maintenance funding.

7. Key findings

The key findings from the project focus on the question of whether water resource managers are aware of seasonal forecasts, if they are using them and if there is potential for them to be disseminated and used more effectively?

Finding 1: Current knowledge of seasonal forecasts is limited
Water resources managers in general have little understanding of seasonal forecasts. Although many are aware of them, explanation and interpretation was needed to ensure the forecast figures and terminology were correctly understood.

A number of key points emerged from the workshops around seasonal forecast knowledge:

- A number of stakeholders are aware of seasonal forecasts and access them
- All stakeholders were eager to hear more information about the seasonal forecasts and how to interpret them
- Most stakeholders did not understand the forecast terminology and how to interpret the information
- All stakeholders were not aware of the amount of forecast information available
- Stakeholders in the City of Cape Town were more aware of seasonal forecasts than those in Overstrand municipality.

Finding 2: There is little evidence of use of seasonal forecasts in the water sector
Emerging from the interviews and workshops it became apparent that seasonal forecasts (SF) are of interest to a wide range of stakeholders in the water management sector. Yet, although the available forecasts seem to be accessed by some respondents and are factored in to some decision-making frameworks, there is little evidence of the systematic application of seasonal forecasts being included in actual decisions.

Current examples of SF usage include:

- One example of where seasonal forecasts were used was in the City of Cape Town for water restriction planning. If the forecast suggested below normal rainfall when dam levels were already low, the City was more likely to consider restrictions.
- In the Overstrand the seasonal forecast was not being used but interest in using it for scheduling outdoor work was expressed.
- Those who think it would be beneficial to have advance notification of probable climate conditions have made an effort to acquaint themselves with the forecasts.
- In most instances the SF output is used internally to make decisions or as additional information, but in some cases it is passed on to the agricultural sector and used in crop estimation and by farmers. In the case of water restriction decisions, it forms part of a rolling probability study, which informs the city and DWAF officials about likelihoods of dam levels and usage demands.
- The most active current use of forecasts seems to be in the short to medium term, where dam withdrawal allocation decisions, irrigation scheduling and other medium term water management actions are determined by the weather prospects.

Finding 3: Utilisation of seasonal forecasts is hindered by lack of knowledge about forecasts and limited interaction with climate scientists
The most common means of access has been the internet and specifically SAWS and CSAG (either direct or via GFCSA) websites. Some have had access to Johan vd Berg at Envirovision where agricultural forecasts are provided. One of the implications of receiving forecast information via the internet is that there is limited interaction with the producers and so users do not build up their understanding of forecast products.

Some of the challenges that emerged were:

- Users were not aware of the amount of information available
- Even when working in small groups it was hard to identify how the seasonal forecast information could be directly integrated into planning
- More opportunities are needed for those with climate knowledge to interact with water resource managers.

Finding 4: Tailored products are needed that enable seamless integration of seasonal forecast information in water resource planning
Among the requests and improvements suggested are indicators relating to the accuracy of SFs, more active dissemination and interpretation and liaison between forecasters and

water managers. When interviewees were drawn on the potential of using SFs it was clear that there were definite opportunities that were not being utilised at the moment.

- Tailored information is not available for water resource managers
- Methods need to be developed that enable historical data and forecast data to be used in planning.

8. Conclusions and Recommendations

Through the interviews, workshops and focus group meetings information about forecast use emerged. It is apparent that the current forecast information is not sufficiently meeting the expressed needs of water resource managers. This is partly as a result of access because few of the water managers (especially in the Overstrand) access climate information regularly, and partly one of accessibility, with users expressing difficulty in interpreting or understanding seasonal forecasts. It is possible that a different format for seasonal forecasts needs to be explored to make them more accessible to users. Water managers expressed the need for other information to assist with their decision making, such as rainfall intensity predictions (frequently mentioned), more specific locations for forecasts (especially in the Overstrand), and also longer forecasts (9-12 months) for drought and restrictions planning.

Forecasts of different types were used for many operational, tactical and strategic decisions. Shorter term climate and weather information was used by many water managers to plan and manage water storage and supply. Some also used this information to schedule short term operational activities such as road maintenance. Short term forecasts are also used to help with managing the levels in each dam, decisions on which dam to draw water from, and whether to move water between dams.

Seasonal forecasts are used mostly when considering the adoption of water restrictions, the level of restrictions and the implementation timing.

All users expressed interest in receiving warnings of extreme weather, preferably by cellphone, sms or brief email, so that they could prepare for it.

The value of forecast information was in most cases undiscovered and thus unappreciated by users. We found that access and use was haphazard and random in many cases. Some users knew exactly what they wanted, were used to and trusted a certain source and subsequently used it for their purposes without being aware of alternatives. The creation of the toolkit is potentially the most valuable product of this project to promote and encourage forecast use. While the presentations made by team members were appreciated, the lasting nature of a toolkit would be more effective as a long term outreach to water managers.

Results of the Cape Town and the Overstrand case studies showed that the activities of water resource managers would be enhanced by access to and uptake of forecasts and that their requirements could mostly be met by existing weather and climate information available from various sources. It was apparent that current forecast information was used to a limited degree and that once the stakeholders had been exposed to the various types of information that were available they would be more inclined to use them in future (O'Connor et al., 2005). However it became clear that there were elements of the weather and climate that, for various reasons, were not predicted or predictable, and that would be useful for various types of user. Some of these were runoff, fire danger, river temperatures, intensity of rainfall within short time frames and extreme conditions.

Despite the potential usefulness of forecast information, it was clear from the stakeholder interviews and larger group meetings that managers do not always use weather and climate forecasts very efficiently. The barriers to managers' use of climate forecasts were similar to those revealed in other studies (Callahan et al., 1999; Rayner et al., 2005). To realise the potential of climate forecasts for water resource managers, technical improvements to the forecast products and specific verification and skill evaluations are required as well as active communication of the information.

As the toolkit was being developed we experienced limited engagement among users to test it. Although we had tried to publicise the toolkit as widely as possible within the South Western Cape, it was not accessed as many times as we had hoped. This may have been a season-related situation since the rainfall in 2007 was normal to above normal and usage during a drier season may increase, or it may have been a lack of awareness as to why and how they should use the website. In January 2008 when the website underwent some major updating and a notice was sent out to all registered stakeholders, usage suddenly surged.

It must be said that the provision of apt and timely information was always the aim of the toolkit, but that the information would only be used if it proved valuable to users. In this respect this project did not make any attempt to adapt or analyse the information that was referenced in order to make it more useful for users. It did however create pathways for access to ordered information for anyone looking for particular data.

The economic benefit of the information provided was also not assessed. In terms of water managers making operational decisions, the benefits would be economically intangible unless assessed in terms of savings in manpower, resources and avoided damages. The biggest economic benefits would probably be measured in the strategic and tactical decisions that could save water in the short term and prevent shortages and costly adaptation options in the longer term. The way water resources are strategically managed has been shown to have benefited and will benefit even more from the availability of timely, accurate and informative forecast products.

Other research (Rayner et al., 2005; Johnston, 2008) has shown that users in other sectors have been keen to welcome seasonal forecasts into their decision making, but that it requires significant training, explanation and supplementary analysis. Forecasts in their current form do not focus on specific users' needs, but rather cater for general use. Although much useful information is available for immediate and practical use, if water resource managers are to gain the most possible benefit from forecasts they will need expert assistance in interpretation for their specific uses. It has been shown in the case of Cape Town that this formula works, but requires the services of a private consulting company. Whether this is within the capabilities of other metropolitan and urban areas is questionable, but on the other hand can policy and decision makers manage without it? In the case of smaller urban areas, the costs of such a service will have to be weighed up against the benefits that may accrue.

Joint efforts between forecast producers and water resource managers are clearly necessary to develop and demonstrate climate forecast applications through two-way education and interaction (Rayner et al., 2005). This was shown to be highly effective in Western Australia in 2003 (Power et al., 2005). Effective communication of forecast information depends not only on the user education and awareness creation, but equally as much on the forecast producers and research funders who will have to always be aware of the changing and developing needs of users in the latter's quest to maximise their advantage by minimising their weather-related risks.

In this project the uptake and usefulness of forecasts by water resource managers has been improved through intensive stakeholder involvement and lessons regarding the availability, comprehension, and current and future usefulness have been learnt. The future success of forecast uptake and usefulness depends on these lessons being converted into more skilful, better disseminated and more aptly targeted forecasts The results of this research will be fed back to policy makers to enable the policy environment to be adapted in the interests of sustainability in light of increased long-term climate variability.

It has been clear that all users and reviewers found that the toolkit was a good way of presenting information in a usable form and that it should be maintained and publicised more widely to increase usage. Efforts to promote its visibility on linked and related websites will continue and maintenance funding will be sought from partners and users.

Insofar as international engagement within this project was concerned, a paper was presented at the Applied Geography Conference in Indianapolis in 2007 (Johnston et al., 2007). The project and the toolkit were discussed in a special water management session there.

It is hoped that this project and specifically the toolkit resource will supplement and enhance existing products available to water resource managers in South Africa.

References

Blench R (1999) Seasonal climatic forecasting: Who can use it and how should it be disseminated? Natural Resource Perspectives 47, Overseas Development Institute, London. www.oneworld.org/odi/nip/47.html

Braune, E 1996. Chapter 6.5 Groundwater resources. L Y Shackleton, S J Lennon and G R Tosen (Eds). Global Climate Change and South Africa. Johannesburg, Environmental Scientific Association: 152pp.

Callahan, B.M., E.L. Miles, and D.L. Fluharty. 1999. Policy Implications of Climate Forecasts for Water Resources Management in the Pacific Northwest. Policy Sciences 32(3):269-293.

Carbone, G. J. and K. Dow, 2005. Water Resource Management and Drought Forecasts in South Carolina. Journal of the American Water Resources Association. 41 (1): 145-155.

Chapman, A (Council for Scientific and Industrial Research) 2007. Personal communication. July 2007.

Chiew, F.H.S., Zhou, S.L. and McMahon, T.A. 2003. Use of seasonal streamflow forecasts in water resources management. Journal of Hydrology. 270 (1-2).

City of Cape Town 2005. Development and Infrastructure (Tariff funded) – Water Services – 20% restriction tariff. http://www.capetown.gov.za/tariffs/.

City of Cape Town. 2006. Draft water services development plan for City of Cape Town 2006/07.

DWAF (Department of Water Affairs and Forestry) 1994. Water supply and sanitation policy – White Paper. Water – an indivisible national asset. Cape Town. November 1994,

DWAF (Department of Water Affairs and Forestry) 1996. The Working for Water Programme annual report 1995/96. Pretoria, DWAF.

Environment Canada. (2004) Threats to water availability in Canada. National Water Research Institute, Burlington, Ontario. *NWRI Scientific Assessment Report Series No. 3* and ACSD Science Assessment Series No. 1. 128p.

Everingham YL, Muchow RC, Stone RC, Inman-Bamber NG, Singels A, Bezuidenhout CN (2002) Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. Agric Syst 74:459–477

Georgakakos, A. P. and Yao, H. 2001. Value of climate forecasts for the management of Lake Lanier. Georgia Water Resources Institute.

Hammer GL, Hansen JW, Phillips JG, Mjelde JW, Hill H, Love A, Potgieter A (2001) Advances in application of climate prediction in agriculture. Agric Syst 70:515–553

Hartmann HC, Bales R, Sorooshian S (2002) Weather, Climate and Hydrologic Forecasting for the US Southwest: A Survey. Clim Res 21(3):239-258

Henderson-Sellers A (1998) Climate whispers: media communication about climate change. Climatic Change 40: 421-456

Hewitson, B. 2007. Regional Climate Change Scenarios for the Western Cape Province. Presentation to the Western Cape Government Climate Change Conference.

Hudson J, Vogel C (2003) The use of seasonal forecasts by livestock farmers in South Africa, in: O'Brien K, Vogel C (eds) Coping with climate variability: the use of seasonal forecasts in Southern Africa. Ashgate, Aldershot, 75–96

Huq, S, Kovats, S, Reid, H & Satterthwaite, D 2007. Editorial: Reducing risk to cities from disasters and climate change. Environment & Urbanisation. 19 (1), 3-16.

Ingram KT, Roncoli MC, Kirshen PH (2002) Opportunities and constraints for farmers of west Africa to use seasonal forecasts with Burkina Faso as a case study. Agric Syst 74:331-349

Jansen, A & Schulz, C-E 2006. Water demand and the urban poor: A study of the factors influencing water consumption among households in Cape Town, South Africa. Working paper Series in Economics and Management. No 02/06. Tromso, University of Tromso. January 2006.

Johnston, P. 2008. The Uptake and Utility of Seasonal Forecasting Products for Commercial Maize Farmers in South Africa. Ph D thesis. University of Cape Town.

Johnston, P., E. Archer, C. Vogel, C. Bezuidenhout, W. Tennant, and R. Kuschke. 2004. Review of Seasonal Forecasting in South Africa: Producer to End-User. Climate Research 28(1):67-82.

Johnston PA, Ziervogel G, Matthew M (2007) The uptake and usefulness of weather and climate information among water resource managers. Papers Appl Geog Conf 30:380-389.

Kiker, G A 2000. Synthesis report for the vulnerability and adaptation assessment section: South African Country Study on Climate Change. Pretoria, Department of Environmental Affairs and Tourism. www.sanbi.org/countrystudy/main.htm (Accessed in Dec 2004).

Kirchner, J, Van Tonder, G J & Lukas, E 1991. Exploitation potential of Karoo aquifers. Pretoria, Water Research Commission. WRC Report No 170/1/191

Klopper, E., and A. Bartman. 2003. Forecasts and Commercial Agriculture: A Survey of User Needs in South Africa. In: Coping with Climate Variability: The Use of Seasonal Climate Forecasts in Southern Africa, eds K. O'Brien and C. Vogel, C., 170–182. Hampshire, England: Ashgate.

Landman, W.A., Mason, S.J. Tyson, P.D. & Tennant, W.J. 2001: Statistical downscaling of GCM simulations to streamflow. Journal of Hydrology, 252, 221-236.

Lemos M, Dilling L (2007) Equity in forecasting climate: can science save the world's poor? Science and Public Policy 34(2):109-116

Lemos M, Finan T, Fox R, Nelson D, Tucker J (2002) The use of seasonal climate forecasting in policymaking: lessons from NE Brazil, Climate Change 55: 479-507

Mjelde JW, Hill HSJ, Griffiths JF (1998) A review of current evidence on climate forecasts and their economic effects in agriculture. Amer J of Agro Econ 80(5):1089-95

Midgley, G., R. Chapman, B. Hewitson, P. Johnston, M. De Wit, G. Ziervogel, P. Mukheibir, L. Van Niekerk, M. Tadross, B. Van Wilgen, B. Kgope, P. Morant, A. Theron, R. Scholes, and G. Forsyth. 2005 Western Cape Report: A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic

Effects of Climate.
http://www.erc.uct.ac.za/publications/wcape_climate_change_impacts_11.pdf.

Mukheibir, P. 2007. Qualitative assessment of municipal water resource management strategies under climate impacts: the case of the Northern Cape, South Africa. Water SA. 33 (4), 575-581. July 2007.

Mukheibir, P & Sparks, D 2006. Climate variability, climate change and water resource strategies for small municipalities. Pretoria, South Africa, Water Research Commission. January 2006, WRC Report No. 1500/1/06

Murphy SJ, Washington R, Downing TE, Martin RV, Ziervogel G, Preston A, Todd M, Butterfield R, Briden J (2001) Seasonal Forecasting for climate hazards: prospects and responses. Natural hazards 23:171-196

NDA 2002. Abstract of agricultural statistics. Pretoria. http://www.nda.agric.za/ see publications – statistics.

O'Connor, R.E., B. Yarnal, C. Dow, C.L. Jocoy, and G.J. Carbone. 2005. Feeling at Risk Matters: Water Managers and the Decision to Use Forecasts. Risk Analysis 25(5):1265-1275.

Orlove BS, Broad K, Petty AM (2004) Factors that influence the use of climate forecasts. Bull Am Meteorol Soc 85:11 1735-43

Patt, A. G., Ogallo, L. and Hellmuth, M. (2007) Learning from ten years of Climate Outlook Forums in Africa. Science 318, 49-50.

Patt AG, Gwata C (2002) Effective seasonal climate forecast applications – examining constraints for subsistence farmers in Zimbabwe. Global Env Change 12:185-195

Patt AG, Suarez P, Gwata C (2005) Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. Proceedings of the National Academy of Sciences 102(35):12623-12628

Phillips JG, Deane D, Unganai L, Chimeli A (2002) Implications of farm level response to seasonal climate response for aggregate grain production in Zimbabwe. Agric Syst 74:331-369

Power, S., B. Sadler, and N. Nicholls. 2005. The Influence of Climate Science on Water Management in Western Australia. Bulletin of the American Meteorological Society 86(6):839-844.

Pulwarty, R.S., and K. Redmond. 1997. Climate and Salmon Restoration in the Columbia River Basin: The Role and Usability of Seasonal Forecasts. Bulletin of the American Meteorological Society 78(3):381-397.

Rayner, S., D. Lach, and H. Ingram. 2005. Weather Forecasts are for Wimps: Why Water Resource Managers Do Not Use Climate Forecasts. Climatic Change 69(2-3):197-227.

Ritchie, J.W., C. Zammit, and D. Beal. 2004. Can Seasonal Climate Forecasting Assist in Catchment Water Management Decision-Making? A Case Study of the Border

Rivers Catchment in Australia. Agriculture Ecosystems & Environment 104(3):553-565.

Schulze, R & Perks, L 2000. Assessment of the Impact of Climate Change on Hydrology and Water Resources in South Africa. Pietermaritzburg, School of Bioresources Engineering and Environmental Hydrology, University of Natal. January 2000, ACRUcons Report 33

Schulze, R E 2005. Setting the Scene: The Current Hydroclimatic "Landscape" in Southern Africa. R E Schulze (Ed). Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Pretoria, Water Research Commission. WRC Report 1430/1/05: Chapter 6, pp 83-94.

Sparks, A (Ninham Shand – Cape Town) 2007. Personal communication. Cape Town water restrictions. 30/07/07.

Stern, P. C., and W. E. Easterling, eds. 1999. Making Climate Forecasts Matter. Washington D.C.: National Academy Press.

Stone RC, Meinke H (2006) Weather, climate, and farmers: an overview. Meteorol Appl 13: 7-20

van Dyk, G, Peters, R & Fourie, S 2005. Water provision from Groundwater in the Northern Cape: Balancing demand and supply. Biennial Groundwater Conference, March 2005. 381 -391.

Venter, I. 2005. Back to basics. Engineering News October 21-27 2005.

Visser, D. (SRK Consulting) 2004. Personal communication. May 2004.

Yarnal, B., A.L. Heasley, R. E. O'Connor, K. Dow, and C. L. Jocoy, 2006. The Potential Use of Climate Forecasts by Community Water System Managers, Land Use and Water Resources Research. 6. Available online at http://www.luwrr.com/contents.html.

Ziervogel, G, Bharwani, S & Downing, T 2005. Adapting to climate variability: Pumpkins, people and policy. Natural Resources Forum. 30 (4). November 2006.

Appendix A: List of Interviewees

Interviews in Cape Town

- Willie Enright (DWAF Western Cape)
- Bertrand van Zyl (DWAF Western Cape)
- Anton Sparks (Ninham Shand: consultant to DWAF)
- Mike Killick (Planning manager: bulk water and infrastructure, CCT)
- Letlhogonolo Motlhodi (Head: CCT bulk water), Arne Singels (ex Head of CCT bulk water), Rodney Bishop (CCT water engineer, special interest in groundwater)
- Henk Cerfontein (DoA Western Cape)
- Hans King (DoA Western Cape)
- Dean Impson (Cape Nature)

Interviews in the Overstrand

- James van der Linde (ex Water Engineer, Overstrand Head Office)
- Dennis Hendriks (Overstrand Head Office Senior technician: water & sewerage), Dion van Vuuren (Hermanus Operations Manager for Services)
- Dirk Crafford (Gansbaai Operations Manager for services)
- Mike Bartman (Kleinmond Operations Manager for services)
- Bea Whittaker (DWAF consultant. Communications officer on Greater Hermanus Water Conservation Campaign in 2000)
- Rory Pringle (farmer above de Bos Dam)
- Dries Potgieter (Overberg Water)

Appendix B: Relationship between Rainfall and Water level fluctuation: from Cumulative Recharge Departure (CRD) to Rainfall Infiltration Breakthrough (RIB)

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Recharge is defined as "an addition of water to a groundwater reservoir". This implies that the addition of any water to an aquifer is seen as recharge regardless of its origin. The concept of recharge has been widely discussed. Numerous research articles tackle aspects concerning recharge estimation and the relationships between its various counterparts; with specific reference to rainfall, climate change and types of aquifers.

The importance of recharge quantification has been advocated for many years with the values of recharge being used as critical indicators for sustainable utilization of water resources. According to Custodio (2002), overexploitation of an aquifer occurs when "the average aquifer abstraction rate is greater than, or close to the average recharge rate." The expansion of human activities and the resultant increase in abstraction amounts has an observable negative effect in the reservoir quantity. A good method to evaluate the recharge rate and to determine the extent of recharge is therefore required in preventing overexploitation of an aquifer. In fact, there are different techniques that have been used to quantify groundwater recharge**.** The various types of techniques are classified by Scanlon et al. (2002) into surface water, unsaturated-zone and saturated zone studies. Amongst others these techniques include: the channel water budget, seepage meters, isotopic tracers, heat tracers, Darcy's Law, numerical modeling, environmental tracers and the water-table fluctuation model. These techniques, when used in conjunction with one another, are seen as multiple techniques. They are widely used as they can reduce any uncertainties in recharge estimates as well as increase the understanding of recharge. Under most circumstances an applicable conceptual model is produced from the data collected.

In this document an emphasis is placed on Rainfall Infiltration Breakthrough (RIB), one of the simple approaches arising from the "water-table fluctuation" model. The Recharge Estimation Model (REME), an Excel program used to calculate the recharge with the use of the CRD method, is available of request.

The simulation of water-table fluctuation against rainfall events is widely used to figure out recharge rates in South Africa. Leading on from this we see that this concept is manifested in CRD (the Cumulative Rainfall Departure Method) (Bredenkamp *et al.,* 1995; Xu and Van Tonder, 2001). The cumulative rainfall departure is defined as $\sum (R_i - R_{av})$, which is thought of as the cause of water level fluctuation in many shallow aquifers. In this way, the Bredenkamp Formula below was originated.

$$_{av}^{1}CRD_i = \sum_{n=1}^{i} R_n - \kappa \sum_{n=1}^{i} R_{av} \quad (i = 0, 1, 2, 3, \ldots N)$$

The above equation represents the rainfall amounts (*R*), the specific month ($_i$) and calculated rainfall average ($_{av}$) over the time period. The *k* value indicates abstraction amounts. This means that if *k=1* no pumping is indicated, whilst *k>1* indicates pumping or natural flow. Due to the deterministic properties of the rainfall series the *k* value was found to be inefficient in reflecting the trend which develops over a short rainfall series.
The original CRD method has presently been revised by Xu and Van Tonder (2001) in which an advancement of the abstraction term (*k)* has been posited. The revised CRD formula is as follows:

$$_{t}^{1}CRD_i = \sum_{n=1}^{i} R_n - \left(2 - \frac{1}{R_{av} i} \sum_{n=1}^{i} R_n \right) \sum_{n=1}^{i} R_t$$
$$(i = 1, 2, 3, \ldots N)$$

The *R* value represents the aquifer boundary conditions and it falls within the range 0 (closed system) to the R_{av} (open system). The *k* value in the Bredenkamp Formula has been replaced with the following equation which attempts to show the trend of a short rainfall series.

$$\left(2 - \frac{1}{R_{av} i} \sum_{n=1}^{i} R_n \right)$$

The revised CRD method incorporates two assumptions. Firstly that the monthly water level change is primarily due to the CRD. Secondly that the other known stresses remain constant.
Through the case studies in a Dolomitic aquifer (Grootfontein) and the Karoo Aquifer (Dewetsdorp) by Xu and Van Tonder (2001), the revised CRD method proves:

i. that the recharge amount is nearly half of the expected recharge and;
ii. a better fit in the resultant simulated groundwater fluctuation graphs compared to the original CRD method.

One of the limitations the CRD method is seen in fractured aquifers, which comprises approximately 90% of South African aquifers. The CRD method shows inconsistency in these types of aquifers due to its low storativity properties.
Another limitation can be found in relation to the depth of the groundwater table in each aquifer. In fractured aquifers, due to the secondary porosity, the water table can reach depths ranging from 10–125m (Xu and Van Tonder, 2001). Water tables at depths beyond the 50m mark are considered deep aquifers which may produce a delay in the unsaturated zone for rainfall. These limitations are verified by Baalousha (2005) during research on recharge of the Gaza Strip using the CRD method.

Time lags are suggested by Xu and Van Tonder (2001) to combat the subsequent delay. Xu and Beekman (2003) addressed this issue using three RIB scenarios which distinguishes the various time scales as follows:

a. the use of the cumulative result of all rainfall events (Sum of 1~ n);
b. results from the of rainfall events immediately prior to the current rainfall event (sum of i ~ n); and
c. results from the rainfall series between m and n (sum of m ~ n-j).

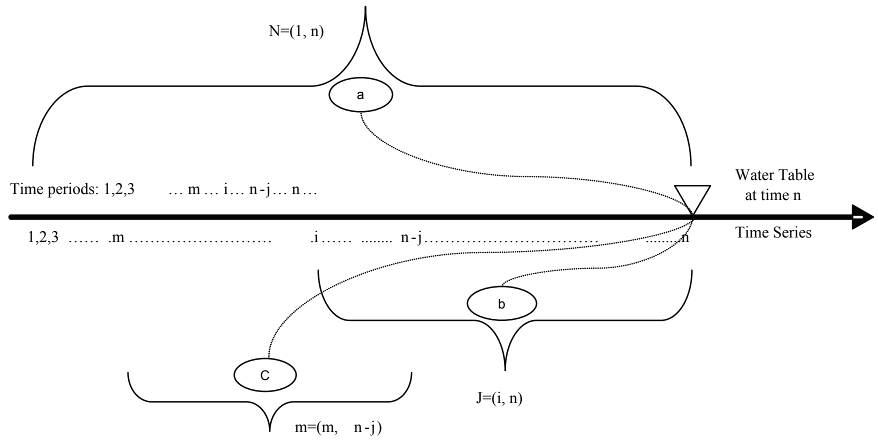

Fig 1: Adopted from Xu and Beekman (2003).

Therefore, the type of porosity in an aquifer and the depth of the resultant water table ensure that the water level fluctuations are a result of more than the recent rainfall events. Recent rainfall events in the area, as well as rainfall events that have taken place in the past, has an affect on the water fluctuations. This is dependent on the flow path which results in the delayed effect on the water level. As seen in Fig.1 below the rainfall can enter the system as diffuse or point recharge dependent on the geology of the area. As well as a mixture of the autogenic and allogenic systems can also arise.

The groundwater flow paths can be identified by using the groundwater chemistry of the borehole water at various abstraction points. In this way the amount of recharge that has accumulated from recent rainfall events as well as those that has a considerable time lag can be identified. The rationale for this research arises from the need to adequately understand the interactions that occur between recharge and its environment, as well as identify the time allocated for a specific rainfall event to impact the aquifer. Tweed et al. (2005) have attempted to identify groundwater flow paths in a fractured rock aquifer with the use of the groundwater chemistry. Major ion chemistry and physical hydrogeology were used in this study. The geology of the aquifer, in this instance basalt and sedimentary rocks, allows the identification of mixing water amounts to be identified. Residence times were identified using geological tracers and the extent of inter-aquifer mixing.

Other papers addressing the use of the geochemical properties of groundwater and water balance method for groundwater estimation include Ting et al. (1998) and Khazaei et al. (2003), respectively. The identification of groundwater using its geochemical data can improve the use of the CRD method as well as understand the complex relationships between rainfall and recharge.

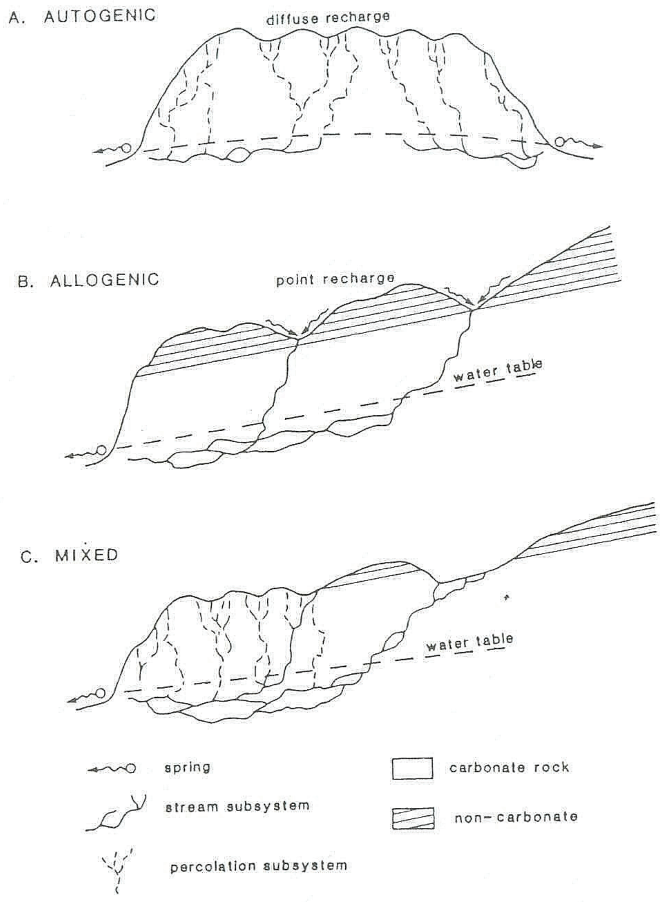

Figure 4.1 Three karst denudation systems: A autogenic and B allogenic are end members with C the mixed autogenic–allogenic intermediate case being the most common.

RIB	$Rain_{av}$(mm)	Q_{other}(m^3/m)	$Q_{pumpage}$(m^3/m)	WL_{av}(m)	Kcrd	Rref	R_e%	S_y	A(km^2)	Q_{out}(m^3/d)	Lagmonths	Sum_Min
34	58.66	#DIV/0!	4426.76	0.00	0.96	45.39	1.60	1.90E-03	2.10E+01	5.90E+02	10.00	31.88
$Month_i$	Rain (mm)	Q_other	Q_pumpage	dh_obs	dh(crd)	dh(rib)	16.00	19.00		59.00	23.00	graph
1	103.10		3900	-1.75	-1.75	-1.75	0.00	0.00				
2	75.50		3780	-1.36	-1.36	-1.36	0.00	0.00				
3	120.70		4380	-0.84	-0.84	-0.84	0.00	0.00				
4	66.50		3690	-0.76	-0.76	-0.76	0.00	0.00				
5	24.30		3870	-0.42	-0.42	-0.42	0.00	0.00				
6	84.50		4080	-0.61	-0.61	-0.61	0.00	0.00				
7	17.50		4920	-0.83	-0.83	-0.83	0.00	0.00				
8	0.00		4530	-1.03	-0.1	[illegible]	[illegible]	[illegible]				
9	10.20		4920	-1.00	-0.0	[illegible]	[illegible]	[illegible]				
10	2.70		3630	-1.23	-0.4	[illegible]	[illegible]	[illegible]				
11	35.10		4680	-1.26	-0.2	[illegible]	[illegible]	[illegible]				
12	25.80		5250	-1.28	-0.8	[illegible]	[illegible]	[illegible]				
13	89.20		3810	-1.28	-0.7	[illegible]	[illegible]	[illegible]				
14	86.00		3450	-1.29	-1.0	[illegible]	[illegible]	[illegible]				
15	26.20		4710	-1.22	-1.3	[illegible]	[illegible]	[illegible]				
16	15.30		3300	-1.31	-1.4	[illegible]	[illegible]	[illegible]				
17	108.40		4710	-1.46	-1.2	[illegible]	[illegible]	[illegible]				
18	61.80		6060	-1.34	-0.8	[illegible]	[illegible]	[illegible]				
19	41.30		4050	-1.23	-0.5	[illegible]	[illegible]	[illegible]				
20	0.00		5160	-1.23	-0.6	[illegible]	[illegible]	[illegible]				
21	4.40		4560	-1.26	-0.5	[illegible]	[illegible]	[illegible]				
22	14.70		5100	-1.15	-0.76	-1.43	0.15	0.08				
23	39.40		4560	-1.16	-0.65	-1.22	0.27	0.00				
24	126.00		4080	-1.14	-0.34	-0.68	0.64	0.21				
25	21.10		2970.00	-0.96	-0.89	-1.58	0.00	0.39				
26	133.00		5340.00	-0.51	0.01	-0.11	0.28	0.16				
27	36.40		3900.00	-0.41	0.19	0.23	0.37	0.41				
28	31.40		4410.00	0.38	-0.46	-0.89	0.70	1.62				
29	405.50		5550.00	0.51	2.44	4.01	3.73	12.29				
30	118.70		2970.00	4.78	3.09	5.19	2.87	0.16				
31	50.00		4050.00	5.83	3.51	5.88	5.36	0.00				
32	5.00		4800.00	6.18	3.52	5.87	7.07	0.10				
33	14.80		5640.00	5.93	3.52	5.85	5.82	0.01				
34	0.00		5700.00	5.74	3.18	5.28	6.50	0.21				

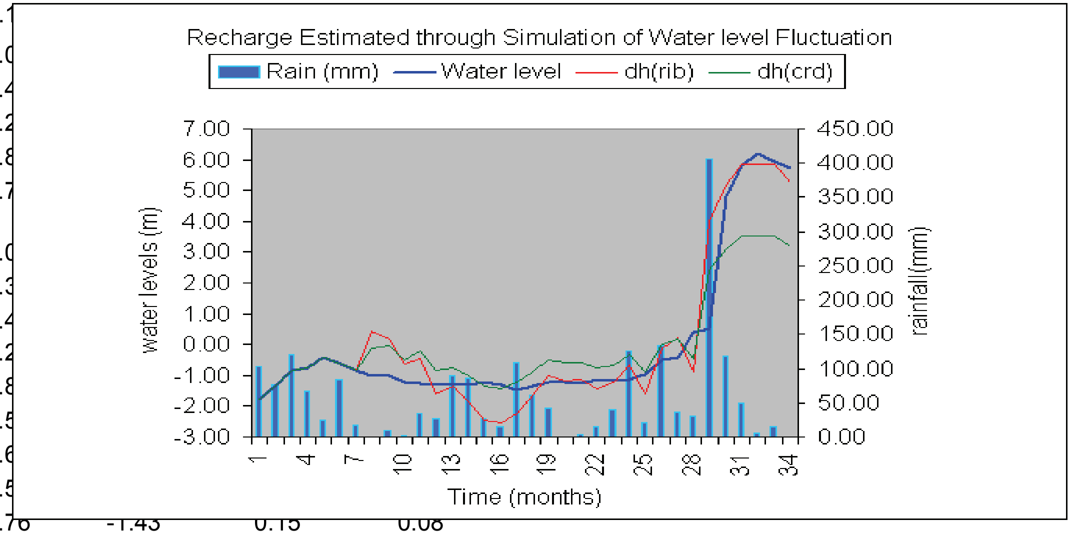

Fig 2 An exemplar from the software

References:

Baalousha, H. (2005). Using CRD method for quantification of groundwater recharge in the Gaza Strip, Palestine. *Environmental Geology*. 48: 889-900

Custodio, E. (2002). Aquifer overexploitation: what does it mean? *Hydrogeology Journal*. 10: 254-277.

Khazaei, E.; Spink, A. E. F. & Warner, J. W. (2003). A catchment water balance model for estimating groundwater recharge in arid and semiarid regions of south-east Iran. *Hydrogeology Journal*. 11: 333-342.

Scanlon, B. R.; Healey, R. W. & Cook, P. G. (2002). Choosing appropriate techniques for quantifying techniques for quantifying groundwater recharge. *Hydrogeology Journal*. 10: 18-39.

Ting, C.; Kerh, T. & Liao, C. (1998). Estimation of groundwater recharge using the chloride mass-balance method, Pingtung Plain, Taiwan. *Hydrogeology Journal*. 6: 282-292.

Tweed, S. O.; Weaver, T. R. & Cartwright, I. (2005). Distinguishing groundwater flow paths in different fractured-rock aquifers using groundwater chemistry: Dandenong Ranges, south east Australia. *Hydrogeology Journal*. 13: 771-786.

Xu, Y. and Beekman, H. E. (Eds). (2003). Groundwater recharge estimation in Southern Africa. United Nations Educational, Scientific and Cultural Organization (UNESCO). Printed Mills Litho.