MODELLING AMENITY LANDSCAPE PLANT WATER USE IN SOUTH AFRICA

by

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ABSTRACT

South Africa is classified as a semi-arid environment with limited natural water sources. Amenity landscapes provide broad ranging benefits for society. Amenity landscapes account for between 31% - 50% of water supplied for domestic and urban use. To reduce water use and water conservation in amenity landscapes, strategies, regulations and interventions are required. Every landscape is a unique complex system with a large number of variables that differ from each other. The variability can be summarized into management/design, irrigation, climatological, edaphic and plant related aspects. Several amenity landscape water use models have been developed around the world and two in South Africa.

This study developed a comprehensive South African hydrozone based plant database and an Amenity Landscape Water Use Model South Africa (ALWUMSA). This will improve hydrozoning of amaneity landscapes and ultimately also improve water conserbvation for these sites. It allows users/owners to determine water use requirements through an extensive data gathering, from aspects such as design, management, microclimate, environmental, edaphic, irrigation and plant related factors. Comparisons of results from ALWUMSA to three test sites, selected existing models and a range of scenarios produced results demonstrating that ALWUMSA consistently projected lower water requirements. The model also allows for site aspects to be changed thus encouraging end users to implement specific water saving intiatives with the amenity landscape to reduce water use. These savings will be translated into both water-use savings as well as financial savings for users of the amenity landscape water use model.

Key Words:
Amenity Landscape, Hydrozone, Plant database, Plant factor, Amenity landscape water use model.

DECLARATION:

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Exact wording of the title of the thesis or thesis as appearing on the copies submitted for examination:

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I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE DATE

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Abbreviations

ALWUMSA	Amenity Landscape Water Use Model South Africa
CDP	Carbon Disclosure Project
DWA/DWS	Department of Water Affairs/Department of Water and Sanitation
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency (USA)
ET	Evaporation
ETo	Evapotranspiration
FAO	United Nations Food and Agriculture Organization
IE	Irrigation Efficiency
IPCC	Intergovernmental Panel on Climate Change
ITCZ	The Inter-Tropical Convergence Zone
Kc	Landscape coefficient
KL	Landscape coefficient
Kmc	Microclimate coefficient
MAP	Mean Annual Precipitation
MAR	Mean Annual Rainfall
NWRS2	National Water Resources Strategy 2
PET	Potential evapotranspiration
PF	Plant Factor
SANS	South African National Standard
Sp	Species
Spp	Species – multiple/plural
UCCECDWR	University of California Cooperative Extension California Department of Water Resources
UNEP	United Nations Environment Programme
WCWD	Water conservation water demand management
WUCOLS	Water Use Classifications of Landscape Species

Glossary

Amenity	Pleasantness (of places, persons etc.) (McIntosh, 1964).
Crop Coefficient (Kc)	Fraction of water lost from the crop relative to reference evapotranspiration (University of California Cooperative Extension California Department of Water Resources, (UCCECDWR, 2000).
Crop Evapotranspiration (ETo)	Water loss from a crop (UCCECDWR, 2000).
Density Factor (kd)	One of three factors used to generate a landscape coefficient. Adjusts the landscape coefficient to account for the effect of vegetation density on water loss from a hydrozone. (UCCECDWR, 2000)
Effective rainfall	Effective rainfall is the proportion of rainfall that is available for use by plants after all rainfall losses have been considered (Connellan, 2002).
Evapotranspiration	Includes the transfer of water to the atmosphere in the form of vapour by either evaporation from the soil and plant surfaces, or as a result of transpiration (Rey, 1999). The amount of water transpired from the plant (usually the leaves) and water evaporated from the soil. The ET rate is influenced by temperature, relative humidity, soil, plant species, sun, shade, wind and day length (Weinstein, 1999).
ETo Reference Evapotranspiration.	The approximation of water loss from a field of 4-to-7-inch-tall cool season grass that is not water stressed. ETo is measured at CIMIS weather stations in various locations around the state (UCCECDWR, 2000).
Green Industry	The bodies constituted of and limited mainly to the South African Green Industries Council (SAGIC), but inclusive of the general gardening end users (Hoy, 2009).
Hydrozone	A portion of a landscaped area having plants with similar water needs that are served by one irrigation valve or set of valves with the same schedule (UCCECDWR, 2000).
Hydrozoning:	Selecting plants appropriate to our climate, grouping them according to water needs, and then actually irrigating according to water need (Whiting and de Jong, 2014). A distinct grouping of plants with similar water needs and

	climatic requirements (Randolph, 2005).
Indigenous (Native)	Any plant or creature which originated in the defined country (Botha and Botha, 1997). Means home-grown, local; occurring naturally without artificial assistance and in a defined place (Johnson, Johnson and Nichols, 2002).
Irrigation Efficiency	*A percentage (%) of the gross quantity of water applied by the sprinklers to the net quantity of water (mm/hr) effectively put into the plant root zone* (Landscape Irrigation Association of South Africa, 2009).
Landscaper	For the purposes of this study, Landscaper refers to any member of ILASA-Institute of Landscape Architects of South Africa, SALI-South African Landscape Institute or other suitably qualified person designing or maintaining landscapes.
Landscape Coefficient (KL)	The functional equivalent of the crop coefficient. Used for estimating water needs from landscape plantings. Landscape coefficient = species factor x microclimate factor x density factor (UCCECDWR, 2000).
Landscape irrigation	Landscape irrigation is the systematic application of water to land areas that supply the water needs of amenity landscape plants (St. Hilaire, et al., 2008).
Likert Scale	Likert scale was devised in order to measure 'attitude' in a scientifically accepted and validated manner in 1932. An attitude can be defined as preferential ways of behaving/reacting in a specific circumstance rooted in relatively enduring organization of belief and ideas (around an object, a subject or a concept) acquired through social interactions (Joshi, et al., 2015).
Mean Annual rainfall (MAR)	Precipitation runs off the land surface to accumulate in streams and lakes, and also infiltrates the soil to become groundwater. The total quantity of surface flow, which is the average annual runoff originating from a certain geographic area, is referred to as the Mean Annual Rainfall (MAR) (Statistics South Africa, 2006).
Microclimates	Climates of localized spaces that differ from the overall climate of the area, such as under a tree or at the top of a hill or in between buildings (Weinstein, 1999).
Model	A simplified description, especially a mathematical one, of a

	system or process, to assist calculations and predictions (Oxford University Press, 2015).
Mulch	Any material such as straw, sawdust, leaves, plastic film, loose soil etc., that is spread on the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting and freezing, evaporation.(Foth, 1978).
Potential evaporation	Potential evaporation does not represent actual transfer of water to the atmosphere but rather the transfer that would be possible under ideal conditions of soil moisture and vegetation, it usually cannot be measured directly and is usually only determined experimentally (Thornthwaite, 1948).
Potential evapotranspiration (PET)	This describes the maximum evapotranspiration possible under specific climatic conditions with unlimited water reserves in the soil (Rey, 1999).
Quinary	A river network quinary catchment was delineated around each 1:500 000 river reach, defined as the stretch of river from the source to another tributary, or from a tributary to another tributary (i.e. the stretch of river between nodes on the 1:500 000 river network layer) (Maherry, et al., 2013).
Raster coverage	In its simplest form, a raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps (Environmental Systems Research Institute, 2016).
Species Factor (ks)	One of three factors used to generate a landscape coefficient. Adjusts the landscape coefficient to account for water loss from a hydrozone due to the plant species composition (UCCECDWR, 2000).
TWA Total water applied.	An estimate of the total amount of water to apply to a landscape planting. Calculated by dividing ETL (estimated water needs of the planting) by IE (irrigation efficiency), (UCCECDWR, 2000).
Vegetation Density	An evaluation of vegetation surface area per unit volume taking into consideration factors such as tree canopy cover and tiers of vegetation. (UCCECDWR, 2000).
Water Conservation	“Water conservation refers to action taken to use water wisely

	and efficiently, by reducing unnecessarily high usage, losses and wastage" (United Nations. Economic and social commission for Asia and the Pacific, 2001). Water Conservation (WC) refers to the minimisation of water loss or waste, the care and protection of water resources, and the efficient and effective use of water (DWAF, 2004).
Water demand management (WDM)	WDM is defined as the practical 'development and implementation of strategies aimed at influencing demand' (Willis, et al., 2011).
Water efficiency	Doing the same (or more) with less' (example: fix leaks; hydraulically efficient toilet pan and cistern design (Wegelin and Jacobs, 2013).
Xeriscape	Is derived from merging the Greek word "*Xeros*," meaning "dry," with the word "landscape. Xeriscape-type landscaping is a package of seven common-sense steps for making a landscape more water-efficient namely; Planning and Design, Soil Analysis, Appropriate Plant Selection, Practical Turf Areas, Efficient Irrigation, Use of Mulches and Appropriate Maintenance (Wade, et al., 2007).

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CHAPTER 1 – INTRODUCTION

Amenity landscapes provide us with opportunities for sanctuary, healing, aesthetics, work and enjoyment. The continual transformation of urban and amenity landscapes places pressure on water supply to meet this demand (Hof and Wolf, 2014). As the human population increases so the demand for housing, business and other associated facilities and infrastructure resulting in the shrinking of outdoor amenity and working spaces. This has resulted in the need to become more focused on sustainable utilisation (Carrow, Duncan and Waltz, 2005) and to do more with the same resources especially water. Water availability volumes per capita for South Africa place us just above scarcity status (Carbon Disclosure Project, 2010). Juxtapose to this is the continual need to create, enhance and maintain our amenity landscapes. To do this the Green Industry and amenity landscape owners need to take additional steps towards using water in a sustainable way (Randolph, 2005). Many initiatives have already been and are being implemented. However one critical area that still needs further input, is to transform the way in which water use is addressed (e.g. design and management) in amenity landscapes in South Africa.

The study aims to address water use in the amenity landscape through developing a model. It will consider a range of elements that impact on water use on the landscape ranging from the design phase through implementation and finally maintenance. The development of the model will incorporate a range of these elements both on site (micro environment factors) and in the immediate vicinity of the site (macro environment factors).

1.1. Rainfall, evaporation, weather and climate change

Given the nature of this study and that it is undertaken specifically for South Africa, an understanding of the various macro and micro-environmental factors which impact this geographic area is vital for critically assessing the problem and identifying the human and ecological drivers and the importance of determining water-use variables.

The climate of a given location in South Africa is affected by its latitude, terrain, altitude, solar radiation, evaporation, as well as nearby water bodies and their currents (King, Mitchell and Pienaar, 2011). It also changes over time both in the short and long term (King, Mitchell and Pienaar, 2011). For any location, the weather changes on a daily basis, whilst the climate is a statistical distribution of weather patterns over a period of time (Department of Environment Affairs, n.d.). Climates are classified according to average and typical ranges of among other variables, temperature and precipitation (Conradie, 2012). It is necessary to understand and consider these aspects since they impact on amenity landscapes.

1.1.1. Rainfall

Rainfall received in South Africa is unreliable and unpredictable, fluctuating in most areas of the country. Below-average annual rainfall is more common than above-average annual rainfall. Drastic and prolonged droughts also periodically afflict South Africa. (Earle, Goldin and Kgomotso, 2005; Winter, 2010; King, Mitchell and Pienaar, 2011).

The Southern Africa sub-region is mostly semi-arid, experiencing variation in rainfall, over time and between countries. Sixty five percent of South Africa receives less than 500 mm annual rainfall (King, Mitchell and Pienaar, 2011; South African Government, 2014) and there is also a steady decline in average rainfall from east to west across the country (Department of Science and Technology, n.d.; King, Mitchell and Pienaar, 2011). Southern Africa rainfall patterns are strongly influenced by different complex climatic systems including, the Inter-Tropical Convergence Zone (ITCZ), the "Botswana High", and the El Niño Southern Oscillation (ENSO) (UNEP, 2002).

Predictions are that climate change will cause extensive disruptions to the current cyclical rainfall patterns as the sub-region may experience further variability in rainfall, reduced precipitation and increased evaporation (Winter, 2010). It is predicted that rainfall intensity will increase, without an increase in total rainfall (CSIR, 2010).

1.1.2. Evaporation and runoff ratio

Of all the rain that falls to earth, about two thirds evaporates back into the atmosphere, and of the remaining water, about one half flows back into the sea, unused (Serageldin, 1995). In most parts of South Africa, potential evapotranspiration (ETo) rates exceed rainfall exhausting almost all available surface water resources (CSIR, 2010; King, Mitchell and Pienaar, 2011).

The mean annual precipitation (MAP) to mean annual runoff (MAR) ratio is 8.6% (Carbon Disclosure Project, 2010). This means that only 8.6% of rainfall is available as surface water. The rest evaporates or infiltrates into the ground. Compare this to Canada with a ratio of 65.7% and Australia a ratio of 9.8%. The annual average rainfall of Canada being 537 mm and Australia 534 mm (Jacobson, 1997).

Due to climate change anticipated decreases in rainfall of between 10% - 30% and higher rates of evapotranspiration will result in less rainfall available as surface runoff (Van

Jaarsveld and Chown, 2001; CSIR, 2010; Winter, 2010). This adds to the pressure on water systems, water storage facilities (Winter, 2010) and amenity landscapes.

Since evapotranspiration is a crucial factor in plant growth and wellbeing, the model developed in this research required that Evapotranspiration (Potential evaporation) data be used as part of the calculation for water use in landscapes.

1.2. Water is limited and critical for future growth

At current water use rates, anticipated growth in use and other climatic factors South Africa will have insufficient water to meet the needs if we do not take additional action (National Water Resources Strategy 2 (NWRS2), 2013). We are over utilising the resource and will run out of available water in the near future. This is evident from the research that follows. About 25% of renewable water in South Africa is used annually (just 10% leads to water stress) (UNEP, 2002; Carbon Disclosure Project, 2010). By 2005, 95% of our freshwater resources had already been utilised for human-associated purposes (National Business Initiative, 2012). In 2013 it was stated that South Africa is fast approaching full utilisation of available surface water yields (NWRS2, 2013). The demand for municipal water services will continue to increase, placing strain on the ability of natural water systems to sustainably provide sufficient quantity and quality of water. This pressure on the system is exacerbated by continued increases in industrialisation, urbanisation and population growth (Earle, Goldin and Kgomotso, 2005). The failure to maintain sanitation works results in inefficient systems and operation thereof resulting in increased costs of downstream water purification (CSIR, 2010). Boccaletti, Stuchtey, and Van Olst, (2010) indicated that an extreme water shortage of between -20% and -80% will be experienced by six of the nineteen water management areas in South Africa (Figure 1.1). It is expected that by 2030 there will be a shortfall of approximately 25% between available water supplied and demand (Boccaletti, Stuchtey, and Van Olst, 2010; National Business Initiative, 2011).

This all points towards a need for mechanisms to be put into place now, allowing water users to voluntarily reduce their water use, rather than being “forced” to do so in a few years’ time or as has occurred in Cape Town during the drought of 2016/18. The Amenity Landscape Plant Water Use Model for South Africa (ALWUMSA) will be a contributor to sustainable water solutions.

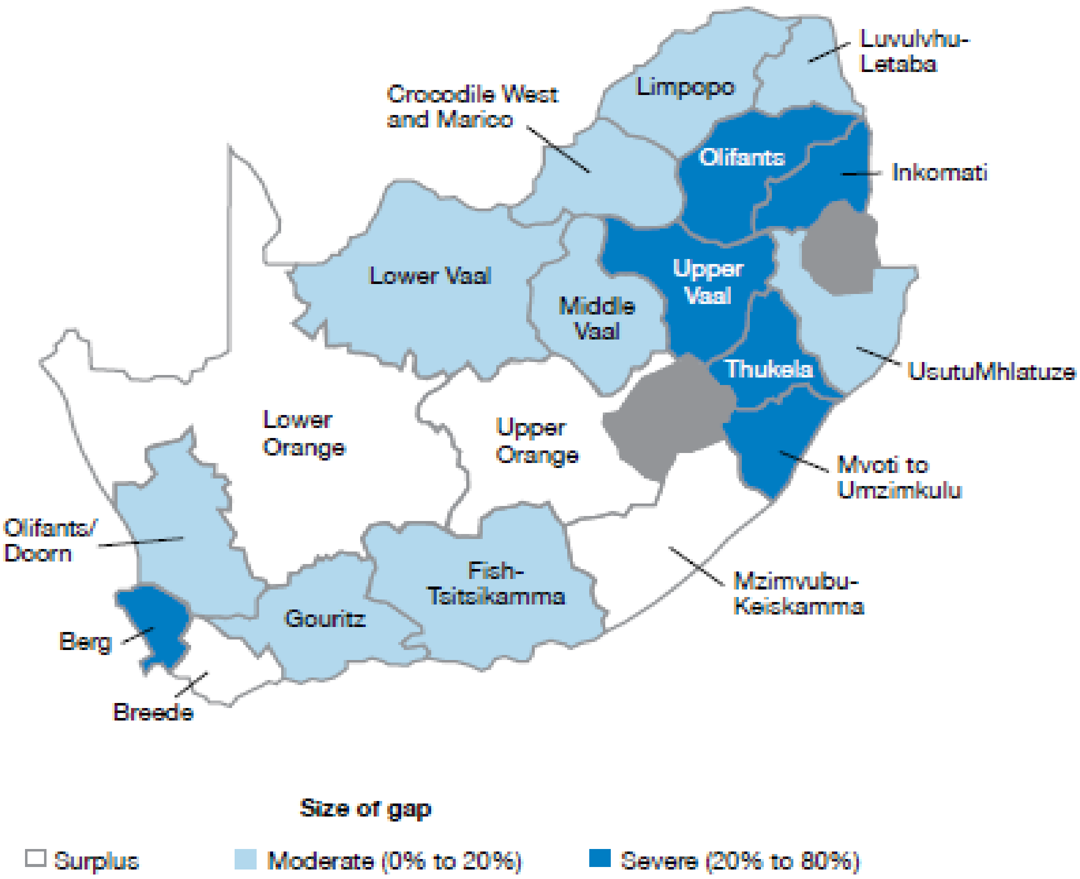

Figure 1.1: Gap between Existing Supply and Projected Demand in 2030 National Business Initiative (2011)

Sustainable water supply strategies should be aimed at achieving a balanced water supply by reducing potable water demand through implementing a range of Water Conservation (WC) and Water Demand Management (WDM) measures such as best practice, and related initiatives (Armitage, et al., 2014). Many different interventions are being proposed and implemented to address the inevitable water shortages, such as campaigns that address water loss (e.g. infrastructure leaks), water wise interventions, various Green Industry interventions, business and building green star ratings, planning and building of additional water storage systems, reuse of grey water, government and municipal policing interventions, policies, government “Green drop” and “No drop” rating systems, the “War on Leaks” program, water restrictions and even specific targeted water conservation interventions (such as the Water Wise campaign by Government and Rand Water and the water conservation program by City of Cape Town). Amenity landscapes are known to use a large percentage of urban water. The need for mechanisms to assist with more efficient use of water and reduced water use within amenity landscapes is ever increasing and urgent.

1.3. Amenity landscapes linkage to water use

It is often incorrectly thought that magnificent gardens and well-kept lawns are only possible through extensive watering and other horticultural practices (U.S. Environmental Protection Agency, 2013). However as much as a 15% to 30% reduction in outdoor water use can be achieved by implementing appropriate design strategies, suitable soil and plants and appropriate irrigation and maintenance practices (City of Kelowna, 2010). Improving the efficiency of irrigation devices and designs, the designing of low water use landscapes, as well as promoting practices that influence water use by plants are alternative methods of achieving reductions in potable water use (Devi, 2009). Connellan (2002) indicates that organisations need to develop site water management plans to allow for improved decision making. These aspects are the tip of the iceberg with regards to possible water conservation initiatives that can and should be implemented in every amenity landscape.

It is important that water-conserving landscape plants and appropriate designs be promoted for each ecogeographical region (i.e. soil and climate) as foundational mechanisms of water conservation (Cabrera, et al., 2013). To aid this, correct design followed by suitable maintenance will allow chosen plants to provide aesthetically pleasing and environment-friendly landscapes with minimal requirements for additional irrigation (Cabrera, et al., 2013).

Incorporation of landscape crop coefficients to ET-based irrigation is effective and allows for additional water savings while maintaining the aesthetic quality and function of amenity landscapes (Cabrera, et al., 2013). However, it is challenging to develop these coefficients for mixed landscape plantings particularly when combining traditional (exotic) and native species (Pannkuk, et al., 2010). This study has used a plant factor as has been adopted by other sources such as UCCECDWR, 2000; Pittenger and Shaw, 2007, and Costello and Jones, 2014. Added to this it is imperative to design amenity landscapes considering specific plants linked to a range of hydrozones with each hydrozone watered independently (Salt Lake City, 2011).

To determine both water demand and water use predictions of an amenity landscape site models (water budgets), can be used (UCCECDWR, 2000; Salt Lake City, 2011; Costello and Jones 2014; Du Plessis, 2014). Models also allow for estimating possible water conservation volumes, should water restrictions be implemented (Du Plessis, 2014). Water use models can also assist with water estimates/requirements for each amenity site and each hydrozone. Also models can allow for site water demand improvement, as the design, site conditions and maintenance are altered/manipulated.

1.4. Justification for the research

As water demand increases and water availability decreases so does the need to implement measures that will assist with improved water use management and water conservation. Each amenity landscape site is unique and adjustments to reduce water use must be site-specific (Carrow, Duncan and Waltz, 2005). The focus of this study is to develop a database of plants most commonly sold in South Africa linked to hydrozones and plant factors as well as an amenity landscape water use model for South Africa together with the necessary supporting data (e.g. rainfall and potential evapotranspiration). The aim is to allow for each site's water use to be evaluated based on the site's unique climate, environmental conditions, design, maintenance and management parameters. This will allow for improved water use and allocation of the amenity landscape site. Du Plessis and Jacobs (2015) indicate that developers need to specify a range of plants with crop coefficients or plant factors that can be used by property owners of new developments in their amenity landscapes. This would improve the ability to estimate outdoor water usage.

It is anticipated that the model will also be used as a planning tool to allow landscape designers to present various options to the "client" that will incorporate changes to the water use of the site over time as the site matures (including long-term financial benefits). This could influence changes in design, management and operational aspects, as well as plant choice in the manner that will encourage reduced water use in amenity landscapes.

1.5. Rationale for this research

1.5.1. Problem statement

The key problem to be addressed is that there is currently no comprehensive water use model (that considers a range of design, management, site, climatic and environmental factors) linked to an extensive plant database associated with hydrozones that can be applied across a broad range of amenity landscapes in South Africa.

1.5.2. Aim and objectives

<u>Aim</u>

To develop a comprehensive South African database of Water Use Classification of Landscape Plant Species as well as a Green Industry centered, Amenity Landscape Water Use model for South Africa that can be applied in the various amenity landscapes to ensure sustainable water use.

The objectives of this study are to;

- Develop a comprehensive list of the most commonly commercially available ornamental horticultural plants for South Africa that are linked to a specific identified hydrozone and plant factor.
- Obtain expected average rainfall and potential evapotranspiration data linked to selected towns in South Africa.
- Investigate and determine suitable design, site, management, microclimate and environmental factors that could be used in determining an appropriate amenity landscape water use model for sites.
- Research design, develop and test (for an actual site and various scenarios) a suitable model for landscape water use in South Africa that will allow for the determination of estimated quantities of water that should be applied to amenity landscapes for proper health, appearance and growth of an ornamental/amenity landscape.

1.5.3. Research questions:

- Will it be possible to develop a list of amenity landscape plants for South Africa each linked to a hydrozone as well as a plant coefficient?
- What are the key elements that need to be included into an amenity landscape water use model for South Africa?
- Can an amenity landscape water use model for South Africa be used to determine the most efficient water use options on a site and for each hydrozone of a site?
- Will the amenity water use landscape model be suitable for an in-field assessment which can then be modelled against?
- How does the developed model compare, in terms of recommended water use for an amenity landscape, to other existing models?

1.5.4. Hypothesis

Hypothesis 1:

H0: Site landscape aspects that are anticipated to demonstrate water savings will not exhibit water savings when input into the newly developed amenity landscape water use model.

H1: Site landscape aspects that are anticipated to demonstrate water savings will positively exhibit water savings when input into the newly developed amenity landscape water use model.

Hypothesis 2:

H0: Site landscape aspects that are anticipated to demonstrate excessive water use will not exhibit a saving of water when input into the amenity landscape water use model.

H1: Site landscape aspects that are anticipated to demonstrate excessive water use will exhibit water savings when input into the amenity landscape water use model.

1.6. Research design

The research was undertaken in several stages to address different aspects of what was required to produce the model.

Firstly a literature review considered the most common plants sold for use in amenity landscapes in South Africa. This was followed by sourcing hydrozone data from a range of sources varying from written literature to internet sites and sales/availability lists from South African wholesale nurseries. This was used to produce a plant database for South Africa each linked to a hydrozone with a plant factor/coefficient.

Next, workshops were held across South Africa with the South African Green Industry members (SAGIC) to obtain an agreement on the recommended site, design, management, microclimate and environmental related aspects and factors that needed to be considered and included in the proposed model, as well as limited parameters for each. Workshop participants were members of SAGIC and were identified by means of a stratified sampling process. Workshops used the Delphi technique to achieve the end results. The model was produced considering recommendations from the workshops and formulae from existing models (South Africa's Green Star rating system, the South African Outdoor Water Model, Landscape Coefficient Method (LCM) – California USA and Green Star Potable Water Calculator – Australia). Finally it was tested against existing models from SA, USA and Australia using three amenity landscape site designs and a range of scenarios.

1.7. Thesis structure

The thesis covers seven main chapters as outlined below.

Chapter 2 provides a context to the study by reviewing the water situation as well as the need to conserve water in the amenity landscape. A range of topics that are specifically relevant to the plant database, the climatic data used in the model and the various aspects that influence amenity landscape water use are discussed.

Chapter 3 explains the methodology used in the project and discusses the approach used to focus on the selected target audience. It also addresses the process used to obtain potential evapotranspiration and rainfall data as well as the mapping process that followed. The procedure used to determine and produce the plant data base and to allocate a plant factor is also explained. Finally the methodology used in the workshops to elicit what type of data should be used in the model, the refinement of the model itself as well as the testing of the model to aspects on-site, as well as a range of scenarios is also explained.

Chapter 4 addresses the actual results of the evapotranspiration and rainfall data obtained with the resultant maps and data. Included is some discussion on the extremes of data for different locations in South Africa (this places a context of some of the climatic influences that could impact water use on amenity landscapes in these different locations).

Chapter 5 focuses on the plant data base, some of the features of the data base and some of the plants in the database. All plants in the database are specifically linked to a hydrozone and each hydrozone has a range of plant factors that can be allocated to it.

Chapter 6 provides a breakdown of the model elements that are to be used to assess site hydrozones. It then provides details of the formula used to determine the model (ALWUMSA). The model was tested on three sites. The results are addressed. The data from the three sites was also tested on several existing overseas and South African models for comparison. The model was also tested on a range of scenarios based on the three sites. All data is discussed with results demonstrating suitability of the ALWUMSA.

Chapter 7 offers some discussion on the final views of the evapotranspiration and rainfall data and maps, the plant data base as well as ALWUMSA. Proposed implementation within the Green Industry is discussed as well as elements that require further study and improvement for the future.

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CHAPTER 2 – LITERATURE REVIEW

2.1. Introduction

Part of the reality of being a South African citizen, is that large portions of the country are dry and providing as well as obtaining sufficient water resources will always be a challenge in the country. If water misuse (uncontrolled leaks and excessive application, both indoors and in the amenity landscape) continues at the current rate in South Africa, it is predicted that many parts of the country will face excessive water shortages within the next few years. The Western Cape has experienced water shortages during 2015-2018 (Masante, McCormick and Vogt, 2018). Many different interventions are being proposed and implemented to address this potential water crisis such as legislation (Water Services Act, 1997), guidelines (NWRS2, 2013) and voluntary associations encouraging water reduction (Green Building Council of SA, 2014). Despite the variety of interventions which impact a wide range of different communities and has the ability to influence everyone in some way, water is still in short supply, with water restrictions in place across different parts of the country on an ongoing basis.

Currently, the amount of water applied to amenity landscapes is consistently more than baseline plant water requirements. This may be as a result of non-uniformity in application of irrigation systems (Kjelgren, Rupp and Kilgren, 2000) or indiscriminate water application. To address the excessive and wasteful use of water in amenity landscapes it is important that mechanisms to reduce water use should be studied.

An understanding of the value of water depends on several components, namely "*the volume of water supplied, where the water is supplied, when it is supplied, whether the supply is reliable, and whether the quality of the water meets the requirements of the intended use*" (US EPA, 2013). All these aspects are relevant when considering requirements of a watered amenity landscape.

Water availability and use within the urban environment, as has been traditionally managed in the past, can no longer continue. Increasing demand from residents, industry, business and other water users is placing strain on water resources in terms of availability, storage, transportation, supply and management. Added to this is climate change and associated variables that impact on water availability.

Climate change will impose challenges on our fresh water sources. Most of South Africa is likely to become drier and hotter over time. The storage infrastructure on our river systems is almost maximised and storing additional water is becoming a major challenge (National

Business Initiative, 2011). This is exacerbated by the fact that South Africans use more water than our catchments are able to replenish. Lack of sufficient water could impact business processes and function (more particularly wet industries), and this could have a significant impact on South Africa's industrial and economic competitiveness (National Business Initiative, 2011). As a result, South Africa has resorted to balancing supply and demand by transferring water across catchments on a scale not common elsewhere in the world. According to the National Water Act (Act No. 36 of 1998), government is the custodian of all water sources in the country. Water catchment areas serve multiple users. It is therefore critical that the South African government effectively negotiates, regulates and distributes water among equally deserving users (National Business Initiative, 2011). Added to this, demand for water in the large and rapidly growing areas of Johannesburg-Pretoria (Gauteng), Cape Town (Western Province) and Durban (Kwazulu-Natal), is compounding the requirement for additional water supply (Binns, et al., 2001). All these aspects will impact on available water for amenity landscapes.

Amenity plant water use, plant species linked to specific hydrozones, as well as environmental climatic and management factors linked to amenity landscapes in South Africa, have not been extensively discussed or researched. Moreover, there is little scientific data available for such studies within the South African context. As a result, many references available are either policy or recommendations that are mostly scientifically unconfirmed (e.g. data quoted by the Rand Water, Water Wise brand).

2.1.1. Strategies to reduce water use

Many strategies to reduce water use involve dissemination of information and tools to end users through various media/forms (Rand Water, 2017). Water demand management that focusses on aspects such as leak detection, retrofitting, pressure reduction techniques etc. has also been implemented. All Water Service authorities are required to educate end users on water conservation (Water Services Act, 1997) and as a result many authorities and municipalities in South Africa have started to address this matter at various levels. The government's 'Blue drop status' that commenced in 2009, is awarded to Water Service Authorities and also to municipalities (Department Water and Sanitation, 2015). It addresses a wide range of water related activities and considers amongst others the extent that they have engaged with and educated end users on water conservation (Department Water and Sanitation, 2015). The Department of Water and Sanitation has also proposed that a "No drop" reporting and awarding system focusing more specifically on water conservation and water demand management, be implemented, however this has yet to fully materialize and be reported upon (Tancott, 2013). The National Water Resource Strategy 2 (NWRS2) notes the need to implement numerous practical, educational and awareness initiatives that will contribute towards water conservation and water demand management (NWRS2, 2013). Devi (2009) indicates three broad methods that are used to promote outdoor demand management programs. These methods being, communication and education, economic incentives as well as best practice, and benchmarking. This research study addresses the latter methods.

Since 1997 Rand Water has made huge contributions in South Africa and especially in the Gauteng Province with its Water Wise campaign researching, educating, and demonstrating of practical methods of how water conservation can be applied. Predominantly this was focused on the horticultural, landscaping and gardening industry but has since spread its attention to include other areas. This position was reinforced in 2017, with their campaign receiving the International Water Association award for PIA 2016 Marketing and Communications Award as well as the PIA Grand Award 2016 (Rand Water, 2017). Added to this, several organisations (e.g. Green Building Council of SA, 2014) and non-governmental organisations (e.g. World Wildlife Fund, 2018) are in their own capacity attempting to influence a radical water use ethic and culture across South Africa as part of their operations. Despite these attempts by many role players, there is still a need for greater input to conserve water in order to reduce wastage and demand.

2.1.2. Water conservation measures in times of drought

In 2009, Hoy made several recommendations with regard to proactive and reactive water restrictions for amenity landscapes. It included estimated water savings for each level of restriction (Hoy, 2009). These were never implemented. However the reality is that droughts are still periodically experienced. When droughts impact the water storage below pre-set levels for each storage facility, many political and/or water regulatory structures announce various forms of restrictions, often seemingly at the last minute. They are seldom phased in over a long period of time, as stated by Hoy (2009) and echoed by Carrow (2006). This same scenario was again repeated in numerous regions of South Africa in the drought of 2016 - 2018. Water restrictions in most instances involve dictating times and frequencies of using any form of outdoor watering device/method and are usually imposed for a specific period of time based on water availability (Devi, 2009). None of the current methods (restrictions) specifically indicate how much water can be saved through these initiatives either in buildings or in the amenity landscape. For the Green Industry, this is contrary to what was proposed by Hoy (2009) where specific restrictions were proposed together with the anticipated water savings, based on international benchmarking and South African Green Industry input.

Generally, water restrictions in themselves do not change long-term water use habits, as the restrictions are mainly implemented only during times of crisis. This is primarily because the restrictions themselves do not address the underlying issues, but merely the use factor of water itself (Devi, 2009; Hoy, 2009). This points to a potential gap in the manner in which amenity landscape water is used and managed.

2.2. Impact of water use on amenity landscapes

Amenity landscapes and the Green Industry in general are dependent on water. Plants require water to grow in a landscape even if they are xerophytic type plants. The saying used so often "*Water is life*" applies equally to amenity landscapes as it does to human survival. Amenity landscapes very often require supplementary water application over and above normal rainfall (Stabler and Martin, 2004). Within the South African context where the average annual rainfall is only approximately 450 mm, compared to the global average of 860 mm (Winter, 2010). This becomes a pertinent issue, as the average South African amenity landscape would almost always require supplementary water application. To draw the linkage of the water situation to amenity landscapes, it is necessary to understand the extent of drought(s) and how the lack of water impacts amenity landscapes and ultimately the value of these landscapes to society.

There is a need within society to continually quantify goods, services or benefits. When considering the world of flora, amenity landscapes (mixture of turfgrass/lawns, annuals, perennials, shrubs and woody plant species) are measured against an unquantifiable yield, whereas agriculture is measured with a specific yield in mind. As a result, the concept of optimum growth and yield of agricultural crops is irrelevant for amenity landscapes (Allen, et al., 1998; Kjelgren, Rupp and Kilgren, 2000). Hence the conundrum of water use/requirements for amenity landscapes.

2.2.1. Droughts impact water availability

South Africa is periodically afflicted by severe and prolonged droughts, which are often terminated by severe floods (Earle, Goldin and Kgomotso, 2005). Examples of previous severe droughts occurred from 1925 to 1933, from 1944 to 1946, from 1950 to 1952, from 1962 to 1971 (The Department of Water Affairs, 1986), 1982 to 1995 (Backeberg and Viljoen, 2003), 2016 (Agri SA, 2016) and more recently 2017 (Masante, McCormick and Vogt, 2018).

Droughts imapct on available water as is indicated in recommendations from the OXFAM report on the current severe drought indicating that more focus be placed on water conservation and water demand management, that tighter restrictions be placed on water users, and that charges be imposed on higher use households (e.g. leisure uses, car washing, garden watering, etc.) (Hornby, et al., 2016). These pressures will place more and more constraints on water use for amenity landscapes, as users try to redistribute their available water for consumption between applications.

2.2.2. Sustainability of water systems

The continual and almost cyclical droughts point society to an ever increased need to use water more sustainably. Achieving the objectives of water efficiency, equity and sustainability are possibly the biggest problems for society (Armitage, et al., 2014). The transforming of cities to include sustainable urban water management concepts requires not only a paradigm shift for planners but also with end users alike. This amongst other factors involves creating landscapes that have an inherent ecological function linked to the inter-relationships within the environment (Armitage, et al., 2014). In Australia, in recent years actions aimed at sustainable water use, have been implemented to encourage water management plans across the country (Australian Government National Water Commission, 2011), namely:

- short-term restrictions focussed mainly on outdoor garden watering,
- medium-term water efficiency programs, influencing both indoor and outdoor structures and behavioural demand,
- long-term regulations, compelling new and existing households to meet significant demand-reduction targets.

Pares-Franzi, Sauri-Pujol and Domene (2006) state that the environmental performance of urban spaces could be improved significantly if practices of using high water demand species where changed to rather focus on utilising plants that require less water. This type of intervention should be applied to the South African context to assist with improving sustainable water use in urban areas, by business, industry, and particularly in amenity landscapes.

2.2.3. Traditional and technical water conservation practices improved over time

Many traditional and technical practices/interventions (e.g. mulching, water harvesting, water recycling and head to head spacing of sprinklers) are implemented within amenity landscapes to reduce supplementary water requirements. Some examples of these interventions being (Bartlett, 2006);

- In recent years the use of polymers and wetting agents has enabled water to remain longer within the root zone.

- The improved understanding of the chemistry of water and soils has allowed for the altering of pH levels with natural elements, which has improved water and nutrient uptake.
- Moreover, the ability to create a network of multiple amenity landscape sites using specific computer generated data, allows for accurate irrigation schedules by means of accurate programming.
- Irrigation technology (sprinkler check valves, droplet size control and flow sensors) has improved by allowing for greater control over water application rates, times and volumes.
- On-site weather stations linked to irrigation systems provide for real-time information on wind, humidity, heat and solar radiation, which can be used to influence water application periods and frequency to specific parts of the landscape based on need.

Improved cultural practices assists in providing a mechanism which allows for improved water use in amenity landscapes.

2.2.4. The value of amenity landscapes and plants

The benefits of well-maintained amenity landscapes are not widely understood, resulting in these landscapes being high on the priority list when imposing water conservation measures (International Turf Producers Federation (ITPF), n.d.). Without an agreed or perceived market value of an amenity landscape, the value of the water application on the amenity landscape cannot be measured. Unfortunately, most of the benefits (direct as well as indirect, physical and psychological) of the Green Industry are difficult to quantify financially, which results in them being seen as non-essential. Unseen benefits of the Green Industry/amenity landscapes include amongst others (Dwyer, Schroeder and Gobster, 1991; Moffat, and Schiller,1994; Holtzhausen, 2005; Fjeld, 2000; Aldous and Binkley, 2001; Ashwell and Hoffman, 2001; Frumkin, 2001; Akbari, 2002; Fang and Ling, 2003; Omasa, et al., 2003; Grobbelaar, 2005; Gies, 2006; Dixon and Wolf, 2007; Kollmuss, Polycarp and Zink, 2008):

- Improved aesthetics,
- Psychological well-being,
- Reduced sickness and improved health,
- Physical fitness, body health and stress relief,
- Carbon sinking/sequestration,
- Air conditioning and temperature control,
- Noise reduction barrier,
- Flood attenuation,
- Increased shading and associated cooling,

- Urban greening,
- Reducing and slowing down soil erosion,
- Reduction in loss of soil water content,
- Reduction of heat island effect, and
- Wastewater treatment.

Direct and indirect benefits of amenity landscapes are increased or decreased depending on the condition, management of and standard of these landscapes. This in turn is influenced by aspects such as, design, plant selection and placement, maintenance and water application.

2.2.5. Amenity landscape water use

Water use in an amenity landscape involves a wide range of environmental and site related matters (such as microclimate, solar radiation, wind, slope, soil factors shade, etc.). Each amenity landscape is unique, in its plant selection, design and location resulting in specific water requirements and should be treated as such.

Plants require sufficient water of adequate quality and at the right time and frequency within the root growth zone for them to grow (FAO, 2017; Whiting and Wilson, 2018). In an ideal situation, amenity landscapes should only be irrigated when rain is insufficient to support expected plant growth. Depending on site location, this irrigation can be permanent in more arid type areas or temporary in areas with high rainfall in the rainy season (Kjelgren, Rupp and Kilgren, 2000). However, in many situations watering systems are set to water at specific times and as a result water irrespectively of whether water is required by the landscape or not. There are specific periods and reasons why some landscapes legitimately require additional watering, examples being:

- Plants planted from bags need short term irrigation after planting until they have established new roots in the surrounding soil. Similarly, plant pots and planters require periodic irrigation/watering regardless of the climate (Kjelgren, Rupp and Kilgren, 2000).
- Plants planted in incorrect climate or hydrozones with insufficient rainfall/irrigation to sustain their growth (Randolph, 2005).
- The in-situ growth and establishment of annuals and grasses from seed, in an amenity landscape.
- Newly planted landscapes should be well watered for between 12 and 24 months to allow for settling in of plants (SAGIC, 2018).

Traditionally outdoor water use was calculated by taking the average winter consumption and subtracting that from the total water consumption for summer (Kjelgren, Rupp and Kilgren, 2000). This excluded actual rainfall. This approach assumed that no outdoor watering occurred in winter. It has more recently been considered to be incorrect, as outdoor watering does in fact occur in many amenity landscapes in winter (American Water Works Association Research Foundation (AWWARF), 1999; Australian Government National Water Commission (ANWC), 2011. Devi (2009) indicates that the use of water for amenity landscapes, swimming pools and car washing, varies depending on the location of the landscape and the climate of the location (Devi, 2009). This is evident in Table 2.1 where water use in America and Australia for a large variety of locations, varies between 7% of total domestic water use to 75%, whilst for South Africa figures are quoted at between 30% and 73%. More detailed examples are available in Annexure 1.

Table 2.1: Example of external water use by various communities in different locations.

Location	**Percentage of total domestic water used outdoors**	**Note/Location**	**Source**
Australia	8%	Gold Coast (Residents with moderate concern for environment)	(Willis, et al., 2011)
	65%	Alice Springs	(Devi, 2009)
	14%	Gold Coast (Residents with high concern for environment)	(Willis, et al., 2011).
New Zealand	8%	Auckland	(Willis, et al., 2011)
America	7%	Cambridge (Ontario)	(Devi, 2009)
	72%	Las Virgenes (California)	(Devi, 2009)
	58%	America (as an average)	(AWWARF, 1999)
	75%	USA (Hot dry climates)	(Barta, et al., 2004)
South Africa	30%-50%	South Africa	(Landscape Irrigation Association of SA, 2009; Wegelin and Jacobs, 2013)
	73%	South Africa (perceived use)	(Jacobs, 2008)

Turfgrass and amenity landscapes tend to be overwatered (Barta, et al., 2004), in an attempt to preserve aesthetic appearance, to maintain the landscape ecosystem, to maintain continual "green lawns" or beds of seemingly lush well watered plants. This is often due to lack of education and incorrect practices (St. Hilaire, et al., 2008). The Association of California Water Agencies (ACWA) estimates that California (USA) residents overwater amenity landscapes by as much as 60% (SABI, 2016). Plants and amenity landscapes that are overwatered can, become waterlogged with soggy soils, experience increased diseases, plant dieback and defoliation, root dieback whilst for others excessive growth which can lead to weaker plants (Weinstein, 1999; Stabler and Martin, 2004; Carrow, Duncan and Waltz, 2005). Plants can be stressed from either overwatering or underwatering; however, overwatering causes more harm (Hartin, et al., 2015).

According to SABI (2016) it is possible for residential gardens to reduce water consumption by up to 25% and still have gardens that add value to our lives. Measures to reduce water use in amenity landscapes should include improved plant selection, water efficient landscaping, installation of water meters, mulching of garden beds, installation of drip irrigation systems, improvement in irrigation efficiency, installation of electronic controllers and moisture sensors, the use of irrigation systems that rely on rain or grey water (St. Hilaire, et al., 2008; Gössling et al., 2012) and the use of indigenous plants and appropriate garden designs (Gössling, et al., 2012). Due to the complexity and diversity of plant species within a landscape, it is difficult to provide clear water conservation management recommendations for all situations. However, implementing water conservation within amenity landscapes is easier because the species diversity available to meet individual and highly variable expectations allows for a wide range of landscape water configuration options (Kjelgren, Rupp and Kilgren, 2000)**.**

It is therefore important when considering a water use model for the amenity landscape that the various water conserving principles used by others be considered for inclusion. Within amenity horticulture several approaches have been taken to introduce and create an ethic of water conservation amongst the gardening public, landscapers and horticultural industry. In America some terms associated with water conservation actions are; "Xeriscaping™" (Duble, et al*.,* n.d.), "Water Wise Gardening" (Santa Clara Valley Water District, n.d.), "WaterSmart", "Low Water" and "Natural gardening" (Environmental Protection Agency Water Resources Agency, 2002). In South Africa the term "Water Wise Gardening/Water Wise Landscaping" or "Water Wise" is most commonly used (Hoy, et al., 2017).

According to Pittenger and Shaw (2005), reducing or limiting water applied to urban landscapes should be the main focus of urban water conservation. Analysis of data from various studies suggest an average of 16% to 60% water savings can be achieved by using various waterwise/xeriscaping principles (Texas Water Development Board City of Austin, 1994).

2.2.6. Constraints to water conservation on site

Despite the many obvious benefits of implementing water conservation measures and programs in amenity landscapes, there are pitfalls and constraints that need to be managed or overcome. Best Management Practices in Golf courses (USA) indicate that there are several possible constraints to an on-site water conservation program, which are also equally applicable to amenity landscapes that must be addressed. Examples being;

- Agronomic. The current grasses on site may not be very efficient in water uptake and their use or a clay soil may possibly cause high runoff of precipitation.
- Educational. Lack of data may hinder understanding of actual water use. Options available to implement water conservation may not be understood by golf course board members.
- Financial. In some cases the high costs of implementing water conservation measures can act as a disincentive in itself.
- Infrastructure. Inadequately designed irrigation systems hinder water conservation measures.
- Management. To successfully achieve water conservation it must continually be prioritised (Carrow, Duncan and Waltz, 2005).

Correct plant choices as well as the correct placement of these plants in the appropriate hydrozone of an amenity landscape, if not implemented correctly also act as a constraint to achieving water conservation.

2.3. Plant database, hydrozones and other plant water aspects associated to amenity landscape water use models

A hydrozone in amenity landscapes can be defined as that portion of the landscape that has plants with similar water needs that are served by the same irrigation valve and thus given the same amount of water at each watering (University of California Cooperative Extension California Department of Water Resources, 2000). An appropriate hydrozone design allows for suitable plant selection to achieve the goals of water conservation (Randolph, 2005). A crop/species/plant factor is determined for each hydrozone plant group. To achieve this, a plant database is required where hydrozone related information is matched for the various plants available to landscapers. Such a database must also highlight local indigenous plant options which should be the preferred (but could also include appropriate exotic plants) for amenity landscapes due to their adaptation/suitability to local conditions. Plant choice for hydrozoning is important and potentially complex. Hence a South African based method of assessment and implementation is recommended.

2.3.1. Plants and hydrozones

Hydrozoning involves placing plants of similar water needs in the same area of the amenity landscape, in high, medium, low and very low water requirement categories (Los Alamos National Laboratory, 2002; Randolph, 2005; Byrne and Associates, 2013; Hartin, et al., 2015). Although commonalities do exist, there is no definitive definition, no identical use of language or categorisation for different hydrozones. Additionally opinions differ as to how they should be watered, how often they should be watered and how much water should be applied. Some examples are listed in Annexure 2. The terminology applied to hydrozones vary considerably; such as oasis zone, drought tolerant zone and natural zone (Brandies, 1994) to, moist, moderate, and low/dry (Denver Water, 1998), and high, medium, low and very low water hydrozones (University of California Cooperative Extension California Department of Water Resources, 2000). Some references even revert to using pictorial descriptions showing droplets or watering cans that are either full, three quarters full, half full or empty, whilst others use one, two or three droplets to demonstrate the basics of high, medium and low water use zones (Annexure 2). As such the Water Wise description of hydrozones which is the Water Wise Standard Operating Procedures (SOP) (Hoy, et al., 2017), has been adopted as a basis for this research project. The sentiment of these zones is supported by University of California Cooperative Extension California Department of Water Resources (2000) and Malakar, Acharyya and Bhargava, (2015).

- High water usage (3 Drop plant zone) – plants in this zone require regular watering (and originate from areas of 750 mm rainfall/water and more per year) should be as small as possible (10% - 20% of the landscape). The zone includes lawns, wetlands, 3 drop plants, vegetables, annuals and spring flowering bulbs. It should be designed as focal points or positioned in visible areas.
- Medium water usage (2 Drop plant zone) – plants that need more water than rainfall can provide (and originate from areas of 500 mm – 750 mm rainfall/water per year). Area should be 20% - 40% of the landscape.
- Low water usage (1 Drop plant zone) – this hydrozone must be as large as possible (30% - 80%) in any landscape. In summer rainfall areas plants in this hydrozone thrive mainly on

rainfall, with minimal supplementary watering, especially in winter (and originate from areas of 300 mm – 500 mm rainfall/water per year).

- No water usage zone – this includes areas (10% - 30% of the landscape) that require no supplementary watering except for rainfall (and originate from areas of 300 mm and less rainfall/water per year). It includes areas with various types of paving (Permeable and non-permeable). Plants in this zone are usually established and/or endemic (Rand Water, n.d.; Hoy, et al., 2017).

The watering amounts linked to each "Water Wise" defined hydrozone have been adopted for use in the Amenity Landscape Water Use Model (ALWUMSA) in this study (which is addressed in later chapters).

Any plant can be considered to be a water wise plant as long as it is grouped and planted in the correct hydrozone according to its water needs (Hoy, et al., 2017). Thoughtful hydrozoning placement of plants saves water (Schuch and Burger, 1997; Randolph, 2005; Byrne and Associates, 2013). This allows irrigation systems to target and water individual plant zones, based on specific water requirements, thus reducing water wastage (Kopp, Cerny and Hefelbower, 2002; Hartin, et al., 2015). Most established amenity landscapes consist of mixed plantings that contain ground cover, shrubs and trees, creating structural variations in terms of canopy cover and shading (Pittenger and Shaw, 2004). The use of a "*Hydrozone Plant Selection Guide*" (such as used in California) for landscaping of sites assists with suitable plant selection, contributes to water conservation (Randolph, 2005) and assists with hydrozoning requirements of amenity landscape water use models. To reduce overwatering, irrigation should be designed to water each hydrozone separately (Randolph, 2005; Hoy, et al., 2017; Team Watersmart - Regional District of Nanaimo, 2018).

Factors that need to be considered when hydrozoning, are amongst others, the plant species, slope, exposure to the sun and shade, soil type, and soil variations (Cabrera, et al., 2013), as these factors ultimately drive the individual plants water usage. In America many local authorities have produced lists of plants to guide residents and landscapers with a selection of plants, providing advice on which plants are best suited to either local climate or specific hydrozones (Southern Nevada Water Authority (SNWA), n.d.; Utah State University Cooperative Extension 2003; City of Kelowna, 2010). Some of these lists are extensive. Such an extensive list has not been produced and used in South Africa.

2.3.2. Water use by plants

The water requirements to sustain healthy plant growth in amenity landscapes is defined as the percentage of evapotranspiration required by the landscape plants to maintain appearance and their intended function (Pittenger and Shaw, 2015). Different plants growing under identical weather and site conditions will have different ETo rates and as a result will have different water requirements due to their physiology make-up/structure and resulting dissimilar responses to weather (Ash, 1998; Pittenger, 2014). The amount of water that is used and required by different plant species for growth and development varies temporally and spatially according to a range of factors such as the plants stage of development, health, the physical and chemical properties of the soil it is growing in, and meteorological conditions (wind, humidity and temperature) (Pittenger and Shaw 2005).

Many plants from the Mediterranean region and the Western USA perform acceptably in landscapes that apply low amounts of water (Pittenger and Shaw, 2005) due to the fact that these plants naturally occur within environments where there is minimal rainfall. Additionally, different areas albeit on different continents, experience similar climate and rainfall, and therefore naturally occurring plants from the one could be transferred to the other and exhibit similarly satisfactory growth and performance without the need for supplemental watering. Likewise, many species of plants will, as they mature and establish themselves require less water (University of California Cooperative Extension California Department of Water Resources, 2000), due to improved root growth and establishment.

Many drought tolerant woody plant species maintain their aesthetic appearance under soil water deficits, while some plants are opportunistic water extractors in situations of frequent shallow watering (Sun, Kopp and Kjelgren, 2012). Many plant species have developed mechanisms to reduce water use in order to improve water use efficiency.

2.3.2.1. Plant characteristics that reduce water use

To achieve this reduced water use, many plants regulate the demand for water by adaptations such as varying leaf size and orientation, stomatal opening/closing, and total leaf area (Kjelgren, Rupp and Kilgren, 2000; Hoy, et al., 2017), hairy leaves, waxy cuticles, bulbs and tubers, dormancy, fleshy leaves and leaf colouration amongst others (Hoy, et al., 2017). Additional adaptations include deep root systems combined with high root hair length and density, rolled leaf blades, thick cuticle layer on leaves, reduced leaf surface area, slow leaf extension rates and leaf density (Harivandi, et al., 2009; Hoy, et al., 2017).

2.3.2.2. Water use by lawns/turfgrass

For most amenity landscapes, lawned areas make up the majority of plant cover (Kjelgren, Rupp and Kilgren, 2000). A study of residential estates in South Africa revealed that 76% of amenity landscape areas consist of turfgrass. There is thus a 3.14 times higher probability of planting lawn instead of trees and shrubs (Du Plessis, 2014). According to Bramwell (2008), modern lawn requires significant amounts of water to thrive and in urban areas, with turfgrass irrigation ranging from 30% of total water consumption (East Coast - USA) to 60% (West Coast - USA). In general, turfgrass requires 25 mm/week during the driest part of the year (City of Kelowna, 2010). However, when water use is decreased below a definite threshold, performance of the lawn declines (Carrow, 2006). Irrigating at 60% of crop factor (crop factor = 0.69 - 0.78) for warm season grasses will not result in considerable loss in quality of the turfgrass. Similarly, cool season grasses should not be irrigated at less than 80% of crop factor (crop factor = 0.74) (Jansen Van Vuuren, 1997). It is acceptable practice that turfgrass and landscape irrigation systems be managed with 50% depletion (Connellan, 2002; Harivandi, et al., 2009). It is also possible to water turfgrass at different percentages of ETo, which allows for different end results (Table 2.2). This implies that if the selected grasses are watered at the deficit level, this will save about 25% of the water required for optimum level watering (Harivandi, et al., 2009).

Table 2.2: Turfgrass water requirements (as a percentage of ETo) at optimum, deficit, and survival levels of irrigation (Harivandi, et al., 2009).

Grass Type	% of ETo for optimum growth	% of ETo for deficit growth	% of ETo for survival growth
Warm season grass e.g. Common or hybrid Bermuda grass, St. Augustin grass, Seashore paspalum, Zoysia grass, Buffalo grass and Kikuyu grass.	60	40	20
Cool season grass e.g. Tall fescue, perennial ryegrass, Kentucky bluegrass, fine leaf fescues, creeping bentgrass and rough bluegrass.	80	60	40

2.3.3. Water use of plants linked to hydrozones

Although common trends can be observed, there is unfortunately no identical standard for water use in hydrozones. Weinstein (1999) suggests that high irrigation zones require 37.5 mm per week, moderate irrigation zones 18.75 mm per week and low irrigation zones 25 mm every few weeks. The Water Wise brand of Rand Water (based on historical practical experience and field observations) recommends a lower irrigation rate that is scheduled to change according to the seasonal weather conditions. As an example, the medium hydrozone receives 15 mm per week in summer and 12 mm per week in spring and autumn, whilst in winter it only receives 7 mm per week (Table 2.3). The Water Wise brand caters for four different hydrozones in the amenity landscape (Rand Water, n.d.; Hoy, et al., 2017).

Table 2.3: Water Wise application rates (Rand Water, n.d.; Hoy, et al., 2017).

	High zone	**Medium zone**	**Low zone**	**No Water use zone**
Summer	25 mm/week	15 mm/week	12 mm/week	Rely on natural rainfall.
Spring	15 mm/week	12 mm/week	7 mm/week	Rely on natural rainfall.
Winter	12 mm/week	7 mm/week	12 mm every second week (excluding lawns, however if dormant no water)	Rely on natural rainfall.
Autumn	15 mm/week	12 mm/week	7 mm/week	Rely on natural rainfall.
Annual water use	750 mm – 1000 mm/annum	500 mm – 750 mm/annum	300 mm – 500 mm/annum	< 300 mm/annum

2.3.3.1. Plant water use database and associated information

There are large numbers of plant water use databases (see Chapter 5) indicating how much water to apply to each species (for example categories of high, medium, low, no water). There is no single method of determining water use categories for plants. Water use for plants can be determined by producing a crop coefficient (University of California Cooperative Extension California Department of Water Resources, 2000). Many gardening books (for example, Maclay, 1984; Poynton, 1984; Van Jaarsveld, 2000; Joffe, 2003; and Lord, 2010) indicate some level of water use by plants. Several institutions (University of California Cooperative Extension California Department of Water Resources, 2000; Utah State University Cooperative Extension, 2003; Green Building Council of South Africa, 2014) have developed plant water use data bases (discussed in Chapter 5).

The most commonly quoted data base from the USA is the “Water Use Classification of Landscape Species” (WUCOLS), (University of California Cooperative Extension California Department of Water Resources, 2000). The WUCOLS guide consists of 1900 species used in California amenity landscapes.

WUCOLs defines plants in four categories (hydrozones) expressed as a percentage of reference evapotranspiration (ETo), namely;

- High (H) = 70 - 90% ETo
- Moderate (M) = 40 - 60% ETo
- Low (L) = 10 - 30% ETo
- Very Low (VL) = <10% ETo

All plant species in the WUCOLS list were evaluated based on the concept that the plants would be positioned and watered according to each plant’s physiological requirements (University of California Cooperative Extension California Department of Water Resources, 2000).

2.3.3.2. Crop factor/coefficient, species factor and plant factor (coefficient)

The terms crop factor/coefficient (used more commonly for agricultural type crops or turfgrass, where high performance, optimal growth and maximum yield are required) as well as species factor and plant factor (used often for amenity landscape plants where the focus is on acceptable appearance and function) (University of California Division of Agriculture and Natural Sciences, 2018) are frequently used interchangeably by various authors. The crop factor/coefficient, species factor and/or plant factor is determined by taking into account the ETo of a particular site. The specific crop coefficient for limited plant species has been developed, however it is lengthy, time consuming and an expensive process using complex instruments/methods such as using lysimeters or gravimetrical methods (Jansen Van Vuuren, 1997; Niu, et al., 2006). Due to the complexity of determining the specific crop coefficient, the determination of crop factor or plant factors is often used. Determining plant factors often involves using various plant related data for that hydrozone inclusive of the ETo for the site. For this study the term plant/species factor has been adopted for use when considering the hydrozone in which the plant should be positioned in the amenity landscape.

The water use rate of many woody species does not show a direct linear function to ETo (Kjelgren, Rupp and Kilgren, 2000). It is therefore, important that the ETo adjustment factors for amenity landscape plants should preferably determine the minimum amount of water that is required for them to sustain a satisfactory appearance and the designed function such as screening, shading and desired foliage. This type of adjustment factor should rather be termed a plant factor (PF) than a crop coefficient (Kc) as the focus is on appearance (functionality as well as minimum acceptable aesthetics) as opposed to optimum growth and yield (Shaw and Pittenger, 2004; Sun, Kopp and Kjelgren, 2012; Nouri, et al., 2013; Pittenger and Shaw, 2015). This can be illustrated in that Kc's have been developed for optimal and minimum performance of both cool and warm season grasses (Table 2.4) (Pittenger and Shaw, 2015). It is not possible to provide a single PF value for all amenity turf grass species due to variations in cultivars, climates, intended usage and maintenance regimes, however where turfgrass of optimum growth is required, such as sports field the ETo factor will need to be higher (Pittenger, 2014). Due to the extremely large variety of ornamental species used in amenity landscapes, it is impossible to determine their minimum water use requirements (PF value) (Pittenger and Shaw, 2004; Pittenger, 2014). To assist amenity landscapers, lists of plants have been produced with an associated Kc/PF value. This Kc/PF value is indicated as an annual, monthly or daily value. Examples of sources of these data bases are Jansen Van Vuuren, 1997; Ash, 1998; University of California Cooperative Extension California Department of Water Resources, 2000; Connellan, 2002; Pittenger and Shaw, 2004; McCabe, 2005; Harivandi, et al., 2009; and Pittenger, 2014.

Table 2.4: Illustration of Kc based on required turfgrass performance (Pittenger, 2014*; Pittenger and Shaw, 2015).

Grass type.	**Kc for minimum performance as a percentage of ETo**	**Kc for optimum performance as a percentage of ETo**	**Plant factor assigned for growing season ***
Cool season grass	64%	80%	0.8*
Warm season grass	36%	60%	0.6*

According to Pittenger (2014), plants respond differently to varying amounts of applied water as a percentage of ETo. Trees, shrubs and ground cover plants growing in arid climates that experience a relatively dry growing season require approximately 50% water application of ETo. Conversely, plants growing in humid climates or associated with wet habitats require approximately 70% water application of ETo (Pittenger, 2014). Where water requirements are unknown, a 50% water application of ETo should be used for non-turf plantings (Pittenger and Shaw, 2004). The percentage water application being over and above available rainfall. Despite this rational there are still many other site, environmental, management and climatic factors that will influence the actual water to be applied on a hydrozone.

2.3.3.3. Native/indigenous plants use less water

Although amenity landscapes are usually created using a mixture of both exotic and indigenous/native plants, some amenity landscapes are developed using exclusively indigenous or exotic plants. However, in order to be more successful in creating beautiful landscapes it is best to use plants suited to local habitat (endemic) and that will survive on natural rainfall (Johnson, Johnson, and Nichols, 2002; Hoy, et al., 2017), as they are accustomed to the local climate and can encourage low water demand landscape design (Los Alamos National Laboratory, 2002; City of Kelowna, 2010; Team Watersmart - Regional District of Nanaimo, 2018). Having said this, water will also still need to be applied during the first two years of establishing these plants and during dryer periods (Bartlett, 2006). For South African amenity landscapes, South African plants are lower maintenance and require less watering and feeding than exotic plants (Stodels Nurseries, 2016; Water Wise, 2016), provided they are planted in a similar climatic situation/landscape (Pienaar, 1985; Van Jaarsveld, 2000; Johnson, Johnson, and Nichols, 2002), and that are regionally appropriate/indigenous to the area (Byrne and Associates, 2013; Cabrera, et al., 2013; Moloney, 2014).

2.4. Climate

The climate of a given location is affected by its latitude, terrain and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables; most commonly temperature and precipitation (Conradie, 2012). Records of rainfall for the period from the early 1900s to mid-1980s show that Africa's average annual rainfall has decreased since 1968 (UNEP, 2002). South Africa is defined as mostly semi-arid, and experiences variation in rainfall over space and time (Earle, Goldin and Kgomotso, 2005). It is also expected to experience further variability in rainfall, reduced precipitation and increased evaporation, as a result of climate change. With a rapidly growing population, and demands from the domestic, agricultural and industrial sectors for water, freshwater availability is a priority concern for the sub-region (UNEP, 2002). This is influenced by the average annual rainfall for South Africa which is approximately 450 mm; however this is deceptive as 65% of the country receives less than 500 mm (South African Government, 2014). There is also a steady decline in average rainfall from East to West across South Africa (Department of Science and Technology, n.d.; King, Mitchell and Pienaar, 2011). Studies undertaken from 1910 onwards point to cyclical rainfall patterns for summer rainfall regions. These patterns vary by as much as 140% above normal and 70% below the average

(Winter, 2010). Climate change will however cause significant disruptions to the current cyclical rainfall patterns (Winter, 2010).

The natural variability in the rainfall coupled with the high rates of potential evapotranspiration has placed the importance of gathering, storage and reticulation of water high on the planning agenda for many years. Climate change will no doubt place pressure on municipal water services, which will be intensified by continued increase in industrialisation, urbanisation and population growth.

2.4.1. Climatic aspects (Macro)

It is important to understand the climate (macro and micro) of an area in which amenity landscapes occur or will be established, so that effective design and appropriate plant selection is done, taking the prevailing climate into consideration. The climate within a city (macro-climate) and areas such as public open spaces, parks, squares, residential areas, shopping areas and cycling paths (micro-climate) influence whether these areas are enjoyed and are effectively utilised (Kleerekoper, Van Esch, and Salcedo, 2011).

There are numerous climatic zone maps for South Africa, ranging from very simplistic rainfall area maps to detailed maps that indicate climate in a more localised manner. Many maps have included other types of data. The climatic map (Figure 2.1) used by the South African Bureau of Standards and the Green Building Council of South Africa (2014) is based on energy efficiency measures for building and is also used to determine rainfall figures used in amenity landscape portion of their water use model (SANS, 2011).

In 2012 the CSIR, using 20 years of precipitation and rainfall data categories, based on the Köppen-Geiger climatic classification, (consisting of the 13 primary climate categories) produced a new detailed map (Figure 2.2), which is a significant refinement of the six-zone model of SANS 204-2, (2008), (Conradie, 2012). It is produced on a very fine 1 km x 1 km grid, based on 1985 to 2005 Agricultural Research Council data.

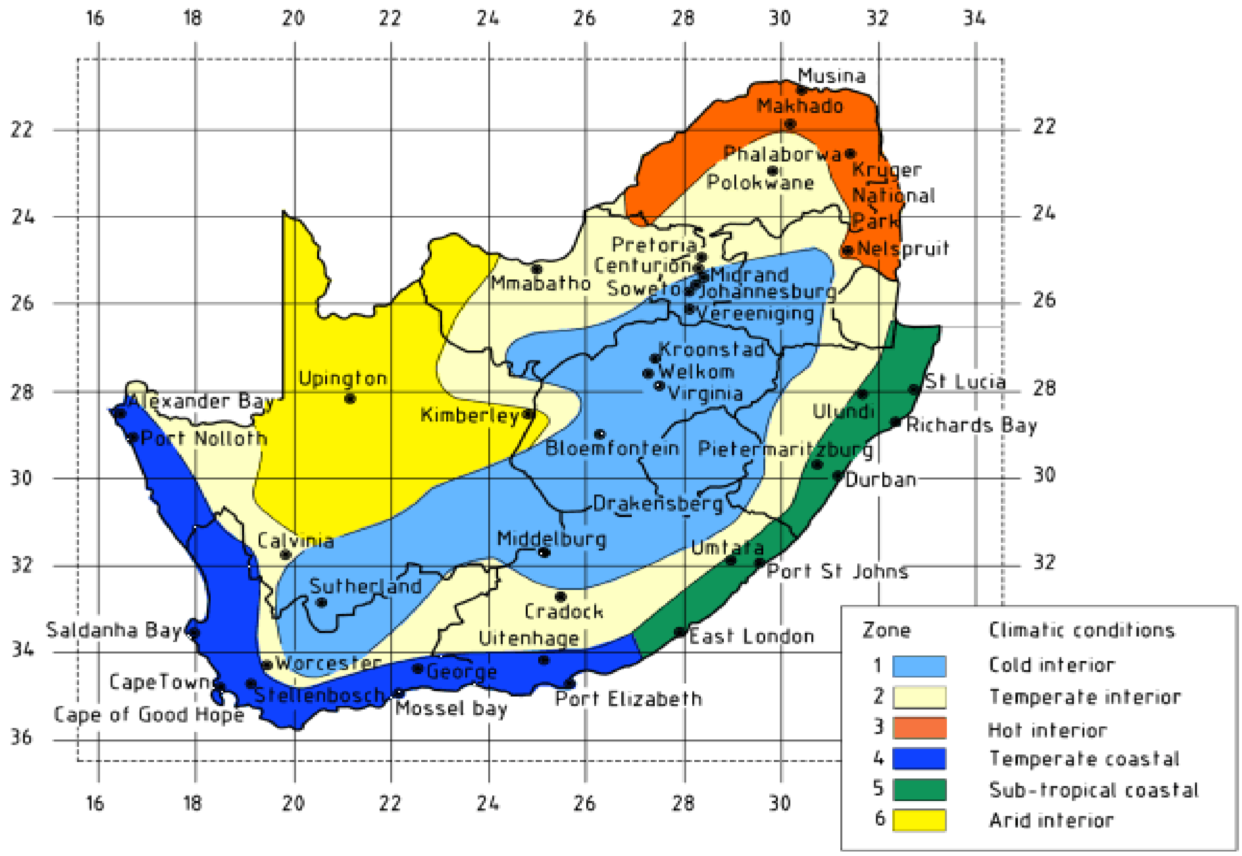

Figure 2.1: Climatic zones of South Africa (South African Bureau of Standards, 2011).

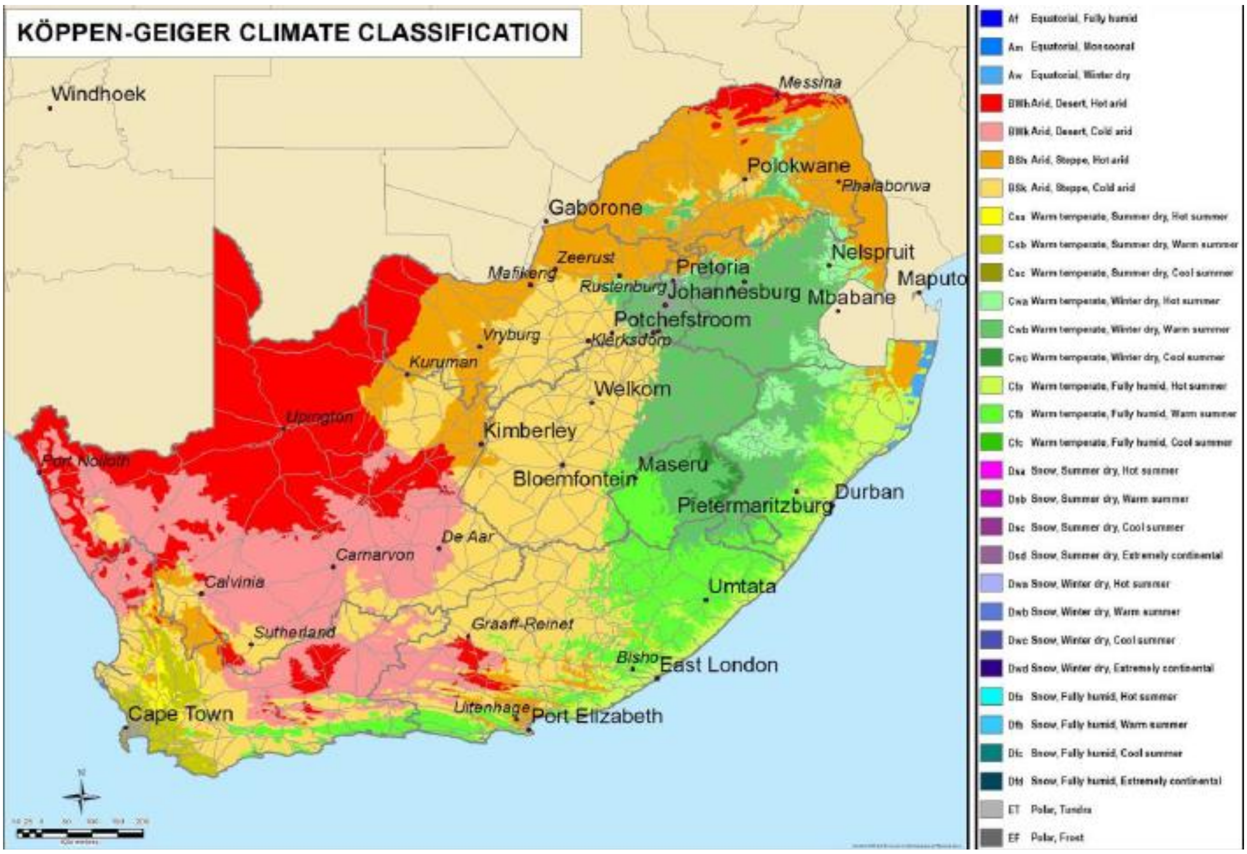

Figure 2.2: The CSIR Köppen-Geiger map for South Africa (Conradie, 2012).

The SA Garden magazine (Montgomery, 2006) produced and used a simple climatic map that represented several different climate areas/zones in the country. It was used in broad terms to guide gardeners/landscapers on their water use, plant selection and propagation requirements (Figure 2.3).

Regardless of which map is used it is essential that rainfall data for sites be based on reliable long term average rainfall figures such as is available from the South African Weather Services.

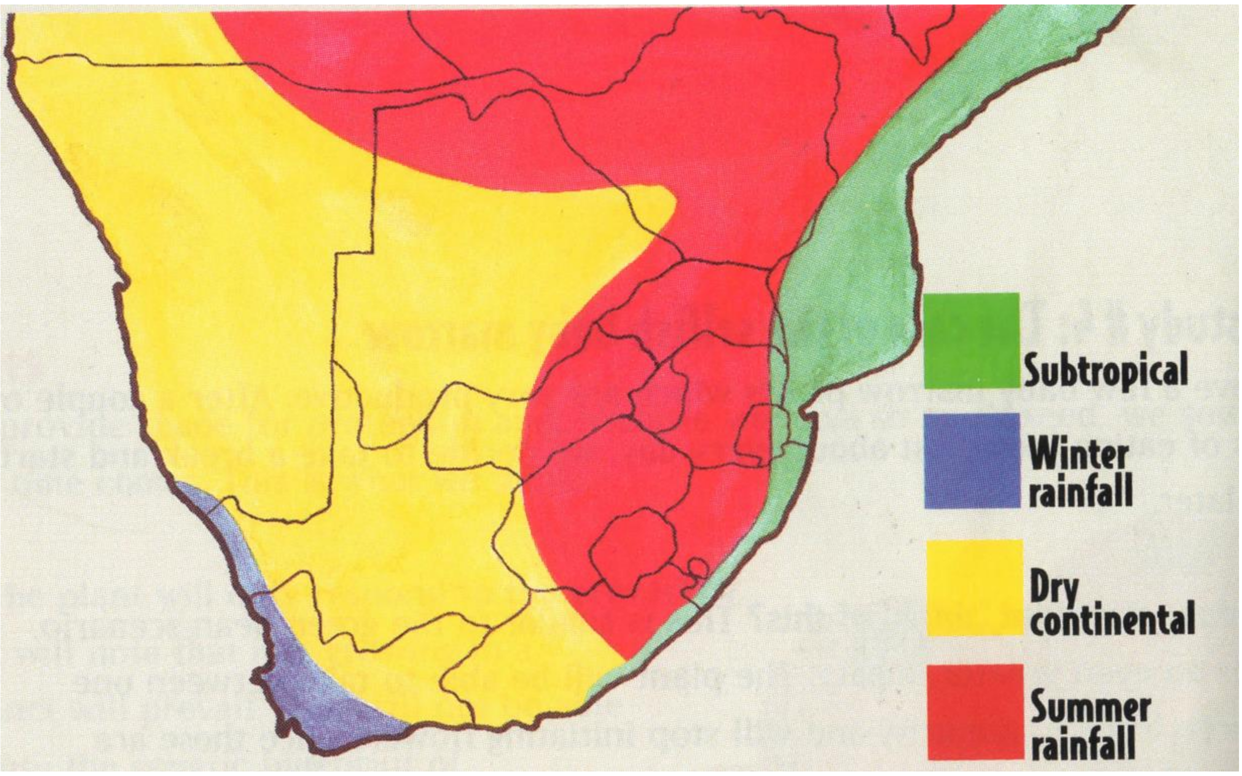

Figure 2.3: Map used by SA Garden Magazine (Montgomery, 2006).

2.5. Site, management and environmental factors associated to amenity landscape water use models

It is not possible to determine the amount of water required for urban amenity landscapes simply by reviewing crop (species) water requirements only. A variety of other associated factors must also be considered. Each site or portion of a site is in itself a complex functioning ecosystem influenced and impacted by biotic and abiotic factors (soils, topography, slope, density, sun exposure/shade, etc.), factors adjacent to the ecosystem (buildings, roads, etc.) and management interventions (over/under watering, irrigation design/use, efficiency of watering devices, application uniformity, and cultural practices such as mowing, etc.). These elements influence water use and water conservation of the site and must be considered in amenity landscape modelling (Barta, et al., 2004; Whiting and Wilson, 2018).

Several complex factors work together to assist with irrigation management i.e. soil water holding capacity, evapotranspiration (ET), rooting depth, a plants ability to extract water from the soil and its water needs (Whiting and Wilson, 2018).

To assist with determining water use on amenity landscapes there are a range of mechanisms and systems (models) available ranging from "Smart water meters" and irrigation controllers to landscape water use models. Some of these are used in isolation, others in combinations, some are dependent on a range of input factors (such as climatic, environmental, design, maintenance and other management factors). This section will address a range of factors that in some way-or-another influence water use on a site and that will play a role in the developed of an Amenity Landscape Water Use Model South Africa (ALWUMSA).

2.5.1. Microclimate

The microclimate of an amenity landscape is an important and essential consideration element (University of California Cooperative Extension California Department of Water Resources, 2000; Randolph, 2005). They can range from areas that are cool, shaded, protected areas to hot, sunny, windy areas. These variations in climate are able to affect plant water loss (University of California Cooperative Extension California Department of Water Resources, 2000). Factors such as local terrain, wind, mountains, valley bottoms (where sinking cold air forms temperature inversions), windward and leeward slopes, solar incident angle, amount of shade on site, and proximity to water bodies impact both macro and micro climates in an amenity landscape (Chen, 2016). The climate of a city will differ from that of the surrounding environment with regards to cloud cover, precipitation, solar radiation, air temperature, and wind. On a more localised "street" scale, spacing between the amenity landscape and structures, orientation of outdoor spaces and buildings all contribute to influencing the microclimate. The microclimate can also vary considerably over a distance of a few meters. Heat islands are the result of factors such as the sun's reflection from buildings; air pollution; heat that is intercepted, absorbed or radiated by surfaces; and heat released by traffic, building heating and industries (Kleerekoper, Van Esch, and Salcedo, 2011). This results in the air temperature of cities being higher than that of surrounding rural areas (Kleerekoper, Van Esch, and Salcedo, 2012). In Phoenix Arizona urbanisation has has resulted in the increase in minimum night-time temperatures (by 5^{o}C) and average daytime temperatures (by 3.1^{o}C), thus increasing the heat stress on amenity plants (Baker, et al., 2003).

For streets that have a high percentage of tree canopy cover, aspects such as air temperature, relative humidity, solar radiation and mean radiant temperature are known to be significantly lower than where a low percentage of canopy cover is evident (Sansui, et al., 2016). Added to this, urban amenity landscape features such as buildings and paving, influence aspects such as temperature, wind speed, light intensity and humidity. Plantings in paved areas (e.g. parking lots) can have a 50% greater water loss than those in a park. Costello and Jones, (2000) classify various site microclimates (Table 2.5) and describe typical examples.

Table 2.5: Examples of microclimate ratings (Costello and Jones, 2000).

Microclimate rating site.	**Typical examples of features of a sites microclimate rating.**	**Impact on Water Usage.**
Low	A courtyard that experiences no wind and no afternoon sun, or landscapes that are protected from wind or that are shaded, or are protected by an overhang, or that are positioned on the South or South East side of buildings.	Reduce
Average	An open field without any extraordinary winds or heat inputs typical for that location and which is not affected by nearby buildings, structures pavements, slopes or reflective surfaces, or a well vegetated park planting which is not exposed to winds uncharacteristic of the area, or where the vegetation aspect of the amenity landscape dominates the landscape by-and-far over hard landscaping.	Negligible impact
High	One that is impacted by heat absorbing surfaces, reflective surfaces, exposed to particularly windy conditions, wind tunnels or North West facing walls, or plantings on traffic islands or in parking lots with an abundance of hard surfaces and reflective surfaces from cars surrounding the amenity landscape, landscapes situated on the North Western side of a building.	Increase

McCabe, (2005) rated specific plant categories against microclimate categories (Table 2.6) which link the plant factor associated with each microclimate category. Selected microclimate aspects need to be addressed in more detail as they are relevant to the study and the ALWUMSA. These principles are similar to Costello and Jones (2000) and should be considered and applied to similar amenity landscape settings.

Table 2.6: Microclimate factors as proposed by McCabe, (2005) for selected plant categories.

Category	High	Average	Low
Description of microclimate.	Hostile microclimate conditions e.g. planting is in/near; direct sunlight near a “hard” surface, affected by reflecting surfaces, heat absorbing surfaces or high wind conditions.	Hard landscaping, shade and reflection don’t influence much.	Friendly environmental conditions e.g. the zone is in the shade, shielded from wind and away from hot and dry surfaces.
Trees	1.4	1.0	0.5
Shrubs	1.3	1.0	0.5
Ground cover	1.2	1.0	0.5
Mixture of trees, shrubs and groundcover	1.4	1.0	0.5
Turfgrass	1.2	1.0	0.8

2.5.1.1. Wind

Wind speed is an important parameter that affects the rate of evapotranspiration (Nouri, et al., 2013). Wind speed and direction is impacted by topography, barriers, paving, shading and vegetation (Weinstein, 1999; Nouri, et al., 2013). It is usually milder in early morning resulting in less water loss (Hartin, et al., 2015). Wind often moves downhill into valleys where it can form pockets of warm or cold air (Weinstein, 1999). Fast moving and hot dry winds that blow across amenity landscapes increase evaporation causing serious damage to plants (Ball, Reilly and Robinette, 1990; Landscape Industries Association Western Australia, 2010). A wind speed of greater than 15km/h has a severe impact on water distribution from sprinkler and micro sprays, but has no impact on drip irrigation (SABI, 2014). According to Sansui, et al., (2016), trees are able to reduce wind speed by up to 70%. Windbreaks are useful to reduce impacts of wind and could be constructed from solid structures, semi-solid structures (sometimes superior) and also large shrubs and trees to protect smaller plants (Ball, Reilly, and Robinette, 1990; Landscape Industries Association Western Australia, 2010). Negative wind influence on irrigation can be reduced by selecting low or adjustable irrigation trajectory nozzles (Carrow, Duncan and Waltz, 2005).

2.5.1.2. Aspect

North and Northwest facing slopes receive more direct and intense sunlight as opposed to South and Southeast facing slopes (Weinstein, 1999). As a result, north facing slopes warm up quicker than South facing slopes, allowing for quicker plant growth (Weinstein, 1999). On northern slopes there is also increased and faster evapotranspiration, and drier soil (Weinstein, 1999). Some South facing amenity landscapes may receive year round shade and are the last to warm up in spring and the first to cool down in autumn (Weinstein, 1999). It is most likely that North and Westerly facing landscapes will require more water than those facing East (Weinstein, 1999). The size of some buildings and extent of shade on southern aspects can result in less solar radiation, which translates into more extreme temperature swings (Weinstein, 1999).

2.5.1.3. Sun and shade

Sun and shade patterns are influenced by aspect and other physical and plant features. It impacts temperature, soil moisture and plant growth, which in turn influences site microclimates. Sites receiving more direct and longer periods of direct sunlight are warmer than shade areas. Shaded areas can be as much as $1^{o}C$ to $7.2^{o}C$ cooler than sunny areas, which in turn impacts the humidity and temperature of these areas (Weinstein, 1999). Plants growing in shaded areas require less watering than the same plants growing in hot afternoon sunlight positions (Ball, Reilly, and Robinette, 1990). At temperatures above $30^{o}C$ growth-inhibiting factors become greater than growth-stimulating factors and growth rates fall with rising temperature (Thornthwaite, 1948). Reflective and radiant heat is also a factor, and as such the nature of the ground-cover can also impact the overall temperature. Lawn in a sunny position can be $5^{o}C$ cooler than bare soil, and as much as $16^{o}C$ cooler than concrete or asphalt (Weinstein, 1999). Radiant heat emanating from the use of rock (as mulch) is able to raise the indoor temperature of adjacent buildings by 10 to 15 degrees (Ball, Reilly, and Robinette, 1990). Fluctuating site temperatures impact water availability, plant choices and functioning within amenity landscapes.

2.5.2. Effective rainfall (precipitation)

Effective rainfall is the amount of rainfall that remains after all losses, for use by amenity landscape plants in the future (Connellan, 2002). The effective rainfall percentage is dependent in part on the soil types, as a portion of rainfall losses are due to run-off, thereby not allowing the vegetation to derive value therefrom. Different authors quote a range of effective rainfall percentages. An effective rainfall figure of 50% is reasonable to assume for use (Connellan, 2002; Carrow, Duncan and Waltz, 2005; McCabe, 2005), while effective rainfall as determined by McCabe (2005) ranges from 44% to 55% for sandy soil, to as high as 49% to 68% for loamy soils, depending on the soil depth (Table 2.7). Du Plessis (2014) in a study of residential water use on gated estates implemented a 75% (0.75) effective precipitation factor, which was adopted from Middleton and Bailey, 2005.

Table 2.7: Effective rainfall estimated from historical monthly rainfall for flat amenity landscapes, based on soil type and root zone depth (McCabe, 2005).

Soil category	Soil Type	Root Zone Depth (mm) (converted from inches)			
		150 mm	300 mm	450 mm	600 mm
		Average monthly effective rainfall (%) (% of total monthly rainfall)			
1	Sand	44	48	52	55
2	Sandy loam	47	53	58	63
3	Loam	49	57	63	68
4	Clay loam	47	55	60	65
5	Clay	45	51	55	59

2.5.3. Evapotranspiration and reference evapotranspiration / potential evapotranspiration

For this study reference evapotranspiration and potential evapotranspiration are collectively given the acronym ETo, whilst evaporation is given the acronym ET. Reference crop evapotranspiration is an estimate of the water used by a well-watered (unlimited soil moisture) vigorously growing full cover uniform cool season grass 8 to 15 cm in height, grown with the goal of optimum growth and development (the reference crop). Reference evapotranspiration is often used for determining water demands of amenity landscape vegetation as well as agricultural plants (Nouri, et al., 2013), and must ideally be adjusted for each microclimate on a landscape, as factors such as grass, soil type, radiation, wind, and other environmental or management conditions differ (Carrow, Duncan and Waltz, 2005). ETo is understood to be influenced by factors such as;

- weather (such as temperature, wind, humidity, and solar radiation),
- the specific stage of plant growth (degree of shading of the crop canopy), crop type, crop characteristics, variety, development stage, crop height, crop roughness, reflection, canopy cover and crop rooting characteristics (Allen, et al., 1998; Kjelgren, Rupp and Kilgren, 2000; Savva and Frenken, 2002; Harivandi, et al., 2009; Nouri, et al., 2013; Whiting and Wilson, 2018),
- soil management, cultivation practices and type of irrigation system used (Savva and Frenken, 2002) as well as,

- environmental practices and management practices all affect evapotranspiration rates (Nouri, et al., 2013). As an example, on hot dry windy days the ETo will be higher when compared to cool humid days.

Potential evapotranspiration for crops is estimated using equations such as Penman-Monteith. However, the potential evapotranspiration of natural vegetation is more difficult to estimate (Rey, 1999). Water authorities and landscapers in western U.S.A use reference evapotranspiration estimates to determine climate-based water budgets and irrigation schedules for large amenity landscape sites (Pittenger and Shaw, 2005). In South Africa potential evapotransiration is used at times, as an example Schulze, et al., 1997.

A correction factor or crop coefficient (Kc) is required to convert evapotranspiration, to the water requirements for a specific crop (Brown n.d.). Crop coefficients for turfgrass depend on the type of grass (warm or cool season), cutting height and desired turf quality (Brown, n.d.; Kjelgren, Rupp and Kilgren, 2000; Pittenger and Shaw, 2004). The same thinking is applied when considering evapotranspiration for other crop coefficients (Pittenger and Shaw, 2004). Both evapotranspiration and resultant crop factors will differ from site to site across seasons given the variables used in their determination.

Water use of some woody landscape plants does not increase proportionally as evapotranspiration increases throughout the day. This is more evident with harsh site conditions such as paved parking lots dotted with trees, as some plant species close their stomata under harsh conditions and use less water. These types of adaptations of different species in an amenity landscape will severely impede the ability of the traditional evapotranspiration equation to accurately reflect an amenity landscape’s water requirements and also make it impossible to determine a precise crop coefficient for each landscape plant species (Pittenger and Shaw, 2004). Hence an approach of using an average annual and average monthly potential evapotranspiration figure is suggested for adoption in ALWUMSA as part of this study. Also to note is that availability of reliable average potential evapotranspiration data for South Africa is problematic.

2.5.4. Amenity landscape assessment aspects that influence water requirements

Amenity landscape site assessment of pedological aspects, assists in maximising water conservation, influences irrigation design, irrigation scheduling and the use of soil sensors (Carrow, Duncan and Waltz, 2005). It is also essential to assess various aspects of the edaphic environment on a site that may impact on an amenity landscape. This in turn also influences plant choices for the site.

2.5.4.1. Soils and soil conditions

Knowing site soil conditions is essential for plant placement and hydrozone allocation in amenity landscapes (Randolph, 2005). With the assistance of detailed information on soil conditions and type on site, it is possible to achieve improved irrigation design, zoning and irrigation scheduling (Carrow, Duncan and Waltz, 2005). In some situations the soil volume in which plants are growing is extremely small/shallow (unable to hold sufficient water) and dries out rapidly (Ash, 1998; Weinstein, 1999; Costello and Jones, 2000; East Bay Municipality Utility District, 2008; Landscape Irrigation Association of South Africa, 2009; Byrne and Associates, 2013; Whiting and Wilson, 2018) or where plants are planted in paved/tarred areas which inhibits water infiltration. Examples could be roof top or containerised amenity gardens. A good growing medium can reduce water needs of plants by up to 50% (Team Watersmart - Regional District of Nanaimo, 2018). The soil textural triangle as produced by Foth (1997) has twelve main categories, namely: clay, silty clay, sandy clay, clay loam, silty clay loam, sandy clay loam, loam, silty loam, silt, sandy loam, loamy sand and sand However, many references to amenity landscapes only refer to a more simplistic method of soil categorization, namely a sandy, clay or loamy soils (Ash, 1998; East Bay Municipality Utility District, 2008; Landscape Irrigation Association of South Africa, 2009; Whiting and Wilson, 2018). Sandy soils allow for good drainage, deep root growth, have high to very high water intake rate and the water retention is seen as low to very low. Loamy soils allow for good to moderate drainage, have moderately high to medium water intake rate and the water retention is seen as low to very low. Clay soils allow for poor drainage, have low to very low water intake rate and the water retention is seen as high to very high (Figure 2.4) (Ash, 1998; East Bay Municipality Utility District, 2008; Landscape Irrigation Association of South Africa, 2009; Whiting and Wilson, 2018). Clay soils are best watered using repeated cycles of small amounts of water rather than one long watering event (Weinstein, 1999). Gravel or rocky soils hold reduced available water and diminished hydraulic conductivity (Saxton and Rawls, 2006).

Soil water infiltration is influenced by soil porosity, compaction, plant cover, impervious surfaces, plant debris (for example compost and mulch) and roughness of the soil surface (Van Roon, 2005). Different plant species will vary in their ability to extract water from the soil and as a result some are vulnerable to water stress sooner than others (East Bay Municipality Utility District, 2008; Whiting and Wilson, 2018) and must be considered in irrigation management. Soils dry out due to aspects such as seasonal variation, drought, resistance to wetting, plant water use (Whiting and Wilson, 2018) and slope. It is important that soil type, slope and any inclusion of compost or soil ameliorants of the site be known and accommodated for, to assist with irrigation planning.

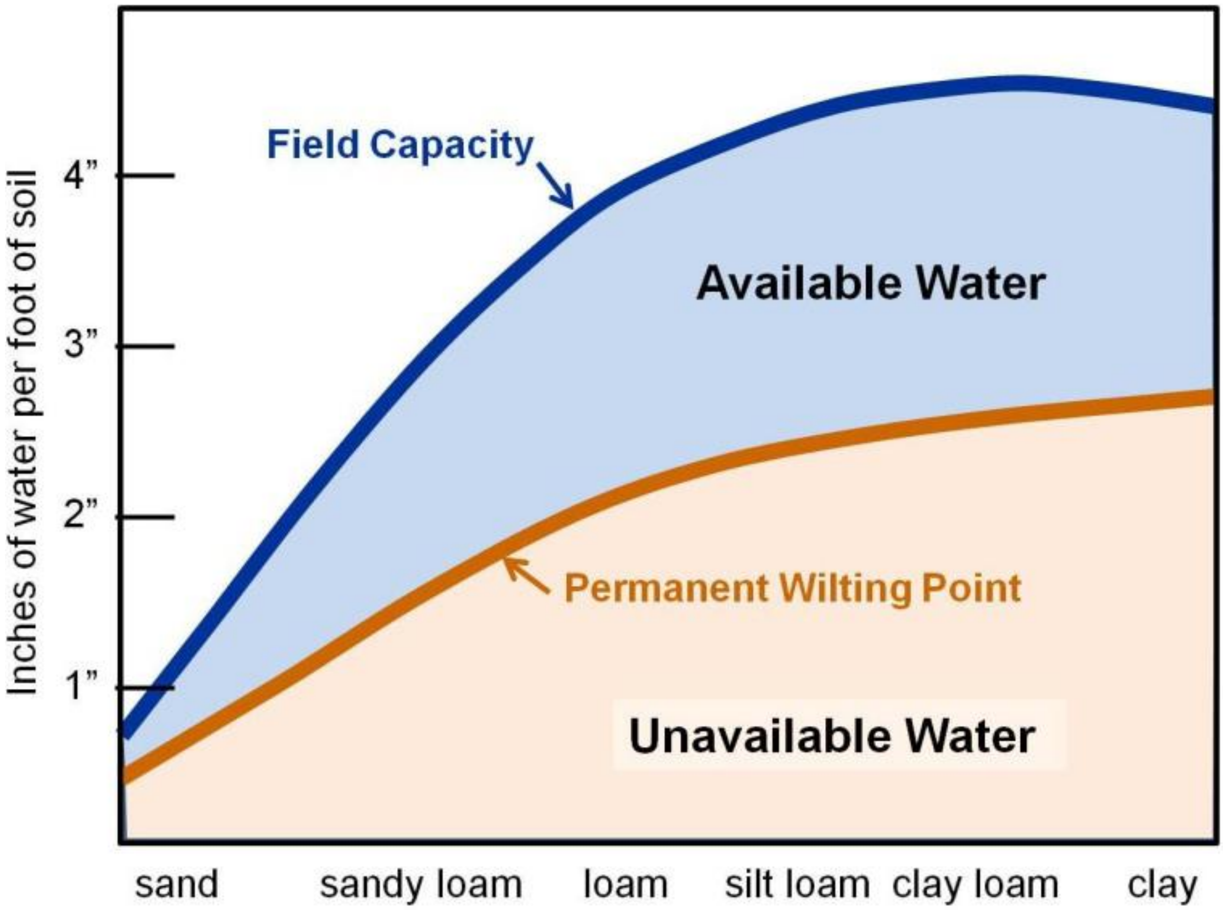

Figure 2.4: Relationship between soil texture (type) and available water (Whiting and Wilson, 2018).

2.5.4.2. Soil wetting and water retention agents

By adding organic matter and or gypsum to clay soils (Landscape Industries Association Western Australia, 2010) or bentonite to other soil types, the soil structure nutrient capacity and water retention can be improved (Johnson, 1984; Landscape Industries Association Western Australia, 2010; Byrne and Associates, 2013). Using compost (organic matter) also aids in developing a stronger more drought tolerant root system (Byrne and Associates, 2013). Adding 10% organic matter to green roofs resulted in plants with stable growth regardless of water regime (Nagase and Dunnett, 2011).

As part of best management practice in amenity landscape design, moisture retaining materials/soil water retention agents/hydrogels absorb hundreds of times their weight in water thus minimizing the need for irrigation (Zureikat and Husseini, n.d.; Weinstein, 1999). Soil wetting agents on the other hand are able to act by breaking down the soil surface tension allowing water to seep into the layers below and not just run off the surface (Byrne and Associates, 2013).

2.5.4.3. Slope, water runoff and infiltration

Infiltration of water into soil is affected by slope, soil structure, surface conditions (compaction) and amount of water applied to the soil (Foth, 1978) and surface tension (Byrne and Associates, 2013). This in turn influences soil treatment, plant selection and irrigation protocols. High infiltration rates increase soil water retention, water availability to plants, and also reduce erosion and flooding (Foth, 1978). Introducing vegetation increases water infiltration thus reducing runoff in the landscape (Nagase and Dunnett, 2012) as opposed to hard surfaces. Shallow infiltration water is available for plant use, while deep infiltration of water goes beyond the root zone and is unavailable for plants.

Very few amenity landscapes consist of sites that are entirely flat and smooth (water runs off these surfaces very quickly). Most often there is a degree of slope with vegetation that needs to be considered when planning irrigation requirements. Water infiltration can be problematic on sloped vegetated areas as water runs off these areas more quickly than off non-sloped (level) vegetative areas (Landscape Industries Association Western Australia, 2010). Sloped areas require as much as 50% - 75% more water than level areas (Zureikat and Husseini, n.d.). A slope of 10^o or less is considered a gentle slope, while a slope of 33^o (or 1:3) is considered the maximum slope angle suitable for lawns. Steeper slopes tend to have a drier soil (Weinstein, 1999). The Landscape Irrigation Association of South Africa (2009) identifies four slope types; gentle (0 - 5^o), medium (5^o - 8^o), high (8^o - 12^o) and steep (12^o and greater). In Madrid (Spain) Gomez-Sal, Belmontes and Nicolau, (2003) classify three different landscape slopes, 0 - 3^o, 3^o - 12^o and slopes greater than 12^o, while the Green Rating for Integrated Habitat Assessment for India (Ministry of New and Renewable Energy, Government of India, and The Energy and Resources Institute (MNRE), 2008) categorises slopes with vegetation on them, into categories of, 0 - 1%, 1^o - 3%, 3 - 10% and >10%. The steeper the slope, the more likely that water from rainfall (rainfall efficiency) will be reduced, which in turn means that more water needs to be applied at a reduced application rate to ensure sufficient soil absorption.

2.5.4.4. Design and maintenance

Each amenity landscape site design is unique according to the designer's experience, interpretation of what is required, an understanding of the environmental constraints for the site as well as client requirements. Correct planning in the design phase of amenity landscape projects is able to reduce water use (Zureikat and Husseini, n.d.). However, mistakes in the design phase due to a lack of experience and under qualified contractors working without supervision results in inefficient water use (City of Kelowna, 2010). Poor amenity landscape design using incorrect plants in correct positions that are maintained using too much water, results in offsetting the benefits for the customer and ultimately contributes towards the degradation of the landscape and surrounding environment (Ash, 1998).

Amenity landscape designs must consider local climate, water efficiency, and soil conditions (U.S. Environmental Protection Agency, 2013), and should be attractive with low maintenance (Keane, 1995). It is important to ensure that design aspects such as hydrozoning and site climate control are considered and included (Keane, 1995). The design should incorporate new technology as well as improved water management strategies (Barta, et al., 2004). As part of the design process, only certified irrigation specialists must be engaged (Byrne and Associates, 2013) to produce high quality irrigation designs and subsequent installation (Connellan, 2002), thus reducing water wastage (Team Watersmart - Regional District of Nanaimo, 2018).

Not adhering to correct design and maintenance principles results in irrigation systems that waste water (Team Watersmart - Regional District of Nanaimo, 2018). It is critical that irrigation systems are regularly checked, tested and repaired (Keane, 1995; Team Watersmart - Regional District of Nanaimo, 2018). In the maintenance phase, factors such as application rates that are too high, leaks, heads that are incorrectly positioned, broken sprinklers or those that are unmatched, incorrect water pressure and spacing of heads can result in an average of 20% to 40% of the water that is applied to lawns and groundcovers, being lost (Hartin, et al., 2015). To overcome this, only certified irrigation specialists should be engaged to achieve a high standard of maintenance coupled with precision management and irrigation scheduling (Connellan, 2002; Team Watersmart - Regional District of Nanaimo, 2018).

The most important aspect of a design should be to carefully consider and plan for the relevant hydrozones (to suite site conditions), as this dictates plant choices, groupings and eventual irrigation.

2.5.5. Amenity landscape factors specific to water use of plants

Various amenity landscape plant related factors impact on water use of the site. Their individual influence is considered as part of the impacts for the water use of the entire site.

2.5.5.1. Plant density factor, plant canopy and canopy cover

The volume of water required by plants is controlled by transpiration from the leaf area and as a result, the plant’s transpiring leaf area needs to be considered (Pittenger, 2014) as an important factor that is influenced by plant and canopy density. A higher density factor points to a more dense vegetation, thus requiring more water (McCabe, 2005). Vegetation density varies considerably across any given amenity landscape (Costello and Jones, 2000).

Vegetation density is used in the Landscape coefficient method to describe the collective leaf area of all plants in an amenity landscape (Costello and Jones, 2000). Some plantings consist of dense multi-layered plant structures whilst others are single dense structures, and yet other plantings can be so sparse that they fit in neither category. Typically the greater the leaf area and volume, the greater the transpiration (Costello and Jones, 2000). Similarly, immature or sparsely planted amenity landscapes will characteristically have less leaf area and thus lose less water (Costello and Jones, 2000; Sun, Kopp and Kjelgren, 2012). When comparing perennials and woody plants in well watered conditions, less dense canopies result in plant factor values being lower than in more dense canopies (Sun, Kopp and Kjelgren, 2012). There are two systems used to determine plant density, namely canopy cover and vegetation tiers. Canopy cover is defined as the percentage of ground surface that is shaded by plant canopy. A 50% canopy cover will provide a shadow over 50% of the soil area whilst a complete canopy cover will provide a 100% cover of the soil surface (Costello and Jones, 2000). Data from orchard plantings indicates that water loss from the orchard does not decrease when canopy cover is between 70% - 100% (allocate an average waiting), whilst anything below 70% results in a progressive increase in water loss from the orchard (thus allocate a low category rating). Adding a cover crop in orchard plantings, increases evapotranspiration from 25% to 80% above a bare soil condition. Similarly, additional tiers/levels of vegetation in a planting (e.g. ground cover or shrubs under trees) results in an increase in water use. Multiple tiered planting (trees, shrubs and groundcover) without a complete cover will result in a “medium” density rating whilst a newly planted multi-tiered planting should be rated as low. Where a ground cover with a 90% and greater covering containing a few widely spaced trees and shrubs, or where a grove of widely spaced trees and shrubs with a canopy cover of greater than 70%, constitutes an average density cover. For plantings to be rated as high density, the planting must be mixed, for example mature ground cover at 100% cover with trees or additional shrubs. Mixed vegetation with increased layering increases the potential for water loss. The highest density factor would be achieved when all three layers of plants exist in substantial numbers, adding extensive depth and density to this aspect (Costello and Jones, 2000). Woody plant canopies should be allocated a greater value than grass canopies (Sun, Kopp and Kjelgren, 2012).

McCabe (2005) developed a rating scale for density factors to suit different planting types that range from high (1.3) to low (0.5) density (Table 2.8).

Table 2.8: Vegetation types and associated density factors (McCabe, 2005).

Vegetation category	High density	Medium density	Low density
Trees	1.3	1.0	0.5
Shrubs	1.1	1.0	0.5
Ground cover	1.1	1.0	0.5
Mixtures of trees, shrubs and groundcover.	1.3	1.0	0.6
Turfgrass	1.0	1.0	0.6

Added to the complexities of individual hydrozone plantings, is that the density of vegetation in amenity landscapes varies as the seasons change, resulting in different evapotranspiration rates (Nouri et al., 2013).

2.5.5.2. Plant age

As plants grow and age so their density, size, root growth and spread change. This impacts water use (and required irrigation) as well as their water loss and is therefore, essential to consider when determining amenity landscape water use. Water is mainly lost through evaporation, when plants are still young and small as opposed to mature plants where water loss is mainly due to transpiration (Nouri, et al., 2013). Likewise, as plants mature their root system develops deeper and wider, enabling plants to survive during dry periods. In general, new plantings need even more water than mature plantings, which is influenced by the smaller (mainly limited to the root-ball) and shallower rooting system of younger plantings (Costello and Jones, 2000). To reduce the impact of evaporation in young plantings mulching is recommended (Andrews, 2004).

2.5.5.3. Mulching

Mulch or vegetative cover is effective in maintaining a high infiltration rate of water into the soil (Foth, 1978) thereby improving the ability of soils to store water. Mulches reduce evaporation, increase water infiltration, improve aesthetics, reduce weed growth, reduce soil compaction and conserve water (Ball, Reilly, and Robinette, 1990; Water Use It Wisely, 2005; Team Watersmart - Regional District of Nanaimo, 2018). It is therefore, important that continual site maintenance and management be implemented. To assist in the maintenance of a mulch layer, leaves should be allowed to drop and remain in beds, as would be the situation in natural areas (City of Kelowna, 2010; Team Watersmart - Regional District of Nanaimo, 2018). Mulches applied to the bases of plants should be regularly augmented or replaced to ensure desired results are achieved (Zureikat and Husseini, n.d.).

Different sources quote slightly different depths of organic mulch required in the landscape, ranging from 38 mm to 76 mm (where a groundcover is present) (Riverside County Transportation and Land Management Agency, 2009), 50 mm to 100 mm (Van Jaarsveld, 2000) and 100 mm to 300 mm (Hodges, 2008). It is important that in young plantings, mulch is applied at the recommended cover thickness. This should at the very least be continued until full cover (100%) of plant cover is achieved, preferably indefinitely. Rocks as mulch are reflective and radiate heat out to nearby plantings and buildings, increasing their temperature substantially (Ball, Reilly, and Robinette, 1990) and as such should be used with caution. This will increase water use.

Depending on the source, study and application, mulch is able to save varying amounts of water. This aspect is important when considering an amenity landscape water use model. Examples of various applicable statements and studies being:

- On average, for every 50 mm of mulch, 16 mm of rain water is retained (Davey, 2004),
- Mulching can reduce evaporation by as much as 70% (Buckle, et al., 2003),
- Straw mulch used in millet is able to conserve 55% more water when compared to controls (Ranjan, et al., 2017),
- Mulch will reduce evaporation and runoff by as much as 90% (Moffat, and Schiller, 1994),
- Studies in Namibia on the use of leaf litter as mulch, indicate that without mulch, 83% of precipitation that falls is evaporated, 10% runs off, and 7% penetrates the soil; whilst adding a mulch results in only 10% evaporation, 10% runoff and 80% penetrating the soil (Savory, 2005),
- Using mulch reduces evaporation and can reduce irrigation needs by up to 50% (Waskom and Neibauer, 2014).

2.5.6. Irrigation

Many amenity landscapes require some form of supplementary watering to assist the amenity landscape to survive; even if it is merely for the establishment phase of the landscape. To achieve a more efficient watering system there are various factors that need to be considered to ensure it is as efficient as possible and effectively waters the areas required, these are discussed below.

2.5.6.1. Amenity landscape irrigation – water use

Urban irrigation demand for watering of domestic gardens, business office gardens, public and privately owned parks and sporting fields, form a large component of the total urban water demand. Because of its complex nature, urban irrigation (outdoor) demand is difficult to analyse (Devi, 2009). Irrigation design is an important part of water conservation (Carrow, 2006). Irrigation management requires that the correct amount of water at the correct frequency is supplied to meet the water needs of plants (Zoldoske, Solomon and Norum, 1994; Whiting and Wilson, 2018). The supply of additional water would be wasted as it leaches below the rooting zone (Whiting and Wilson, 2018) or simply runs off. Amenity landscape irrigation typically uses twice the amount of water that the plants actually need (Whiting and Wilson, 2018). Thus the success of any irrigation system is affected by the design, installation, operation and maintenance thereof (Weinstein, 1999). The soil moisture level that ensures that plants are maintained in the desired condition is managed by appropriate irrigation; however some water stress may be acceptable (Connellan, 2002).

Irrigation scheduling devices and efficient watering systems do not necessarily convert into water savings, "*unless they are supported by benchmarking and budgets that are indicative of the irrigation demand of the landscape"* (Research Foundation and American Water Works Association (AWWARF), 1999; Devi, 2009).

For most plants (including bulbs) in the amenity landscape to remain healthy and aesthetically pleasing they usually require a period of irrigation to supplement the insufficient rainfall received (Barnhoorn, 2013; Pannkuk and Wolfskill, 2015). In support of this concept, the SA Green Star model encourages projects to schedule irrigation supply via controls and according to seasonal demand or rainfall. However the notional building for Green Star assumes that best practice defines different irrigation rates for different rainfall seasons. Hence their model is based on seasonal adjustments that are based on the specific rainfall for that area (Green Building Council of South Africa, 2014). Thus an improved understanding of the macro and micro climate of the area is important.

It is crucial that once a site has been landscaped into various hydrozones, that the irrigation system then be designed to match these zones. Also, to consider on sites, is that the tops of slopes are often drier than the valley bottom (Team Watersmart - Regional District of Nanaimo, 2018) due to accumulation of run-off water in the valley bottom.

Being able to accurately apply the correct volume of water where and when required on the basis of real time and seasonal fluctuations (Environmental Protection Agency Water Resources Agency, 2002; Bartlett, 2006; Du Plessis and Jacobs, 2015) as well as site specific conditions will reduce water use. It will also prevent irrigation runoff (Bartlett, 2006). During autumn over-watering is very common, mainly because summer schedules have not yet been adjusted down

(Environmental Protection Agency Water Resources Agency, 2002). On-site weather stations can however assist in estimating ETo for each microclimate (Carrow, 2006).

2.5.6.2. Factors understood to be important for efficient irrigation operation

For efficient irrigation design and installation, and to ensure that the irrigation system functions effectively, a number of sprinkler and irrigation design and management aspects need to be taken into account (Carrow, Duncan and Waltz, 2005; Riverside County Transportation and Land Management Agency, 2009; City of Kelowna, 2010). Some of these aspects considered in the model development and interpretation being;

- Head to head coverage,
- precipitation rates (matched precipitation is best),
- preventing overspray,
- automatic rain shut-off devices (save 15% - 20% water),
- pressure regulating devices (can save 6 - 8% water),
- automatic controllers (Smart Water Application Technologies) with water conserving functions (water budget features, soil, weather or ET based programming),
- correct design prevents errors in water application uniformity in all zones,
- ensure uniform application rates in all areas of a zone,
- irrigation systems must be zoned according to plant water use, slope aspect and sun/shade microclimate, and
- high efficiency irrigation methods (for example, drip, 'MP rotators', micro-sprays) should be used (Connellan, 2002; Carrow, Duncan and Waltz, 2005; St. Hilaire, et al., 2008; Riverside County Transportation and Land Management Agency, 2009; City of Kelowna, 2010; Cabrera, et al., 2013; Team Watersmart - Regional District of Nanaimo, 2018).

Irrigation application is influenced by amongst others climatic conditions, soil water holding capacity and depth of the root system. Rooting depth of grasses and plants vary seasonally, with deeper rooted grasses and plants requiring less frequent irrigation (Carrow, Duncan and Waltz, 2005). The watering requirements of plants needs to be matched by the watering system installed (Landscape Industries Association Western Australia, 2010). The coefficient of uniformity (CU), the distribution uniformity (DU), irrigation efficiency (IE) and the scheduling coefficient (SC) are four common methods of calculating water application uniformity for amenity landscapes (Burt, et al., 1997; Landscape Irrigation Association of South Africa, 2009; SABI, 2014). Irrigation efficiency considers both design and maintenance aspects (SABI, 2014), while

CU and DU are affected by the design aspects of the system and SC is affected by the management of the system.

Regardless of the best design intentions, irrigation efficiency is influenced by human behaviour and as a result actual water use will not necessarily correlate with the theoretical irrigation requirements of a site (du Plessis and Jacobs, 2015). Examples of human behaviour being; how long they decided to leave the sprinkler system on for, when they decide to change over from a summer to a winter watering regime and how often to irrigate a section of the landscape.

2.5.6.3. Coefficient of uniformity and distribution uniformity (DU)

The coefficient of uniformity (CU) of 100% is considered as an ideal. However, industry suggests that anything above 84% is acceptable. For the same set of readings CU will always have a higher percentage than distribution uniformity (DU) (Connellan, 2002). However CU fails to distinguish between over and under watering (Burt, et al., 1997). DU is used to calculate how much additional water is needed to allow a planted area to receive the required minimum amount of water, delivered uniformly and accurately to the plant root zone (Connellan, 2002; Pittenger, 2014). DU is provided as either a decimal value or a percentage value and is never greater than 1.0 or 100% (Connellan, 2002; Carrow, Duncan and Waltz, 2005; Pittenger, 2014). DU can be impacted negatively by aspects such as incorrect spacing of sprinklers and sprayers, poor distribution profiles, excessive wind, incorrect watering pressure, incorrect nozzle size, poor valve and pipe sizing and ineffective functioning sprinkler heads or equipment (Connellan, 2002). If the lower quartile DU is determined as poor or fair, then the system should be redesigned (Table 2.9). A good DU of an irrigation system ensures that water is applied evenly over the entire site thus ensuring that water is applied (distributed) uniformly over the site/area (McCabe, 2005).

Table 2.9: Rating of lower quartile distribution uniformity (McCabe, 2005).

Irrigation type (zone)	Excellent (%)	Very good (%)	Good (%)	Fair (%)	Poor (%)	Lower quartile (Lq) or Emission uniformity (Eu)
Fixed spray	75	65	55	50	40	Lq
Rotor	80	70	65	60	50	Lq
Impact	80	70	65	60	50	Lq
Micro Spray	80	70	60	50	40	Eu
Drip Standard	80	70	65	55	50	Eu
Drip Pressure compensating	95	90	85	80	70	Eu

2.5.6.4. Scheduling coefficient (SC)

It is important for amenity landscape irrigation contractors to consider that irrigation uniformity distribution depends on sprinkler profile and field spacing for example head to head spacing (Solomon, 1988; Connellan, 2002; St. Hilaire, et al., 2008; Team Watersmart - Regional District of Nanaimo, 2018). The SC is expressed as the ratio of extra time that is required to irrigate the required rate of precipitation (ROP) to the average "worst case" areas, in that irrigation zone, that have been identified by the CU. ROP is the rate at which water is applied to an irrigated area per unit time (Gordon, 1997).

To obtain SC the amount of water applied to the driest area in the zone is divided into the average amount of water applied throughout the irrigated area. SC will usually have numbers greater than 1, such as 1.5, or 2.2. If perfect uniformity were attainable, the SC would be 1.0. The SC is influenced by the management of the irrigation system of the site, rather than a result of irrigation design tool such as distribution uniformity. As an example, for an ideal irrigated hydrozone that requires an irrigation system to run for 30 minutes application time, if the SC (based on design and management) for that hydrozone was determined to be a ratio of 1.8, this would require an actual run/application time of 54 minutes (30 x 1.8 = 54) (Solomon, 1988).

2.5.6.5. Irrigation efficiency (IE)

Irrigation efficiency is not the same as irrigation/distribution uniformity. An irrigation system may display high uniformity yet have a low efficiency. Efficiency measures both equipment (physical performance of the irrigation system) and management (the manager applies suitable and economical management practices to the system), while uniformity is mainly related to the mechanical performance of the irrigation system (Styles, n.d.; Solomon, 1998; SABI, 2014).

Factors that affect irrigation efficiency for watering of amenity landscapes being; water droplet size, air temperature, wind velocity, relative humidity, solar radiation precipitation rate and soils (Landscape Irrigation Association of South Africa, 2009) as well as runoff, drainage below the root zone, poor uniformity, wind drift and evaporation (Connellan, 2002). The ARC-Institute for Agricultural Engineering (2003) describe it as the total process of irrigation from the water source to the water becoming available in the plant root zone. It is also seen as the water beneficially used by comparison to the amount of irrigation water applied/supplied to the site. This is expressed as a percentage (Baum-Haley, 2014). For example 90% efficiency is approximately 11% more water required and similarly a 75% efficiency is approximately 33% more water required (Baum-Haley, 2014). Different authors tend to state different irrigation efficiencies of the same watering systems (Table 2.10).

Table 2.10: Examples of various irrigation efficiencies quoted for irrigation systems.

Irrigation system	**Melbourne (Connellan, 2002).**	**SABI (SABI, 2014)**	**The Green Rating for Integrated habitat Assessment - India (**MNRE, **2008)**	**Manhattan- Kansas (Rodgers, et al., 1997)**	**Riverside County Transportation and Land Management Agency (2009)**
Drip	80%-95%	90%-95%	85%	75-95%	90%
Micro-spray	No data	80%-85%	80%	No data	70%
Spray	60%-70%	No data	No data	No data	60%
Sprinkler	70%-80%	75%-90%	75%	85%	75%
Surface flooding	50%-70%	60%-86%	50%	No data	No data

2.5.6.6. Specific watering times and seasonal adjustments

Newly planted plants require specific additional frequent watering to allow them time to adjust and to develop a root system that supports water uptake (Ash, 1998). Different sources require different periods of watering for plants to settle and mature. Riverside County Transportation and Land Management Agency, (2009) suggest 90 days before plants should be weaned off and only receive the water as required by the specific hydrozone, while SAGIC suggests that for South Africa the settling in period for plants in amenity landscapes (were the amenity landscape is provided with additional water) be a minimum of 12 months and a maximum of 24 months (SAGIC, 2018). In the country Jordan, it is recommended that specific categories of plants be given a set amount of water at set intervals per month, for example newly planted drought tolerant shrubs 20L each, eight times per month and established drought tolerant shrubs 30L each, 3 times per month (Zureikat and Husseini, n.d.).

In South Africa generic watering times recommended by Water Wise as part of it's Standard Operating Procedures for normal use times in summer are: no watering between 10h00 and 14h00 (to avoid the heat) and in winter in frost prone areas water only between 09h00 and 15h00 (to avoid frost damage) (Rand Water, n.d.; Hoy, 2009; Hoy, et al., 2017). Municipalities have implemented different watering times, during periods of drought. Depending on the severity and the level proclaimed, the times change. Examples being;

- Level 2 restrictions, Johannesburg – "*no watering or irrigating of gardens from 06h00 to 18h00*" (Johannesburg Water, 2016).
- Level 2 restrictions, Midvaal – "*All forms of watering of gardens, sports fields, parks, lawns and other open spaces is restricted to two hours per premises per day between 6:00pm and 06:*00am" (Midvaal, 2016).
- Level 2 restrictions, City of Tshwane – "*No watering/irrigating gardens with a hosepipe or sprinkler from 06h00 to 18h00*" (City of Tshwane, 2016).
- Hoy (2009) recommended four levels of water restrictions saving between 8% and 40% of water applied to the amenity landscape. Each level has different irrigation and other landscaping requirements that need to be progressively implemented. Level one would be introduced on a permanent basis whilst level two to four would be introduced as and when drought/water shortages are experienced.

Seasonal adjustment of irrigation systems is essential to save water (Ash, 1998; Kjelgren, Rupp, and Kilgren, 2000; Water Use It Wisely, 2005; Symes, et al., 2008) and irrigation controllers that adjust watering times as seasons and prevailing weather change, should be used (Landscape Industries Association Western Australia, 2010; Byrne and Associates, 2013). As an example lawns can be over-watered in spring and autumn by as much as 40% (Whiting and Wilson, 2018). However, smart controllers set by technically knowledgeable persons assist in reducing seasonal water use (Pittenger, Shaw and Richie, 2004; U.S. Environmental Protection Agency, 2013). For South Africa summer rainfall regions irrigation schedules should be changed according to the seasonal weather conditions as recommended by Water Wise Standard Operating Procedures. As an example the high water zone should receive no more than 25 mm per week in summer whilst in winter it should receive no more than 12 mm per week (Rand Water, n.d.). By contrast many references from Australia and United States refer to system run-time rather than amount of water applied (Shaw and Pittenger, 2009; Byrne and Associates, 2013).

2.5.6.7. Water saving devices for irrigation systems

To ensure that automatic irrigation systems are more efficient at water application, instruments such as controllers/smart controllers (allowing for season adjustments), rain sensors, soil moisture probes/sensors or weather stations should be used (Connellan, 2002; Environmental Protection Agency Water Resources Agency, 2002; Carrow, Duncan and Waltz, 2005; Team Watersmart - Regional District of Nanaimo, 2018). A well-designed automatic irrigation system needs to consider including the following;

- Water meters (electronic flow rates) - To monitor water use and to detect leaks.
- Automatic rain shut-off sensors – to shut down the system after a specific amount of rain has fallen, which can result in a saving of 15 - 20% on water use.
- Soil moisture sensors - monitor the potential for soil moisture capillary rise, and then modify/reduce the pre-set runtime. Multiple sensors at different soil levels and at selected locations are best and can save 14.7% water use.
- Isolation valves - assist with isolating specific areas when repairing leaks.
- Pressure regulating devices – assist with controlling and reducing misting.
- Weather stations – measure ETo (based on wind, humidity, solar radiation and temperature) to improve scheduling.
- Coupling sensors with the control system using 2-way communication (Ball, Reilly, and Robinette, 1990; Ash, 1998; Carrow, Duncan and Waltz, 2005; Symes, et al., 2008; St. Hilaire, et al., 2008; Harivandi, et al., 2009; Riverside County Transportation and Land Management Agency, 2009; City of Kelowna, 2010; Carpenter, 2012; Byrne and Associates, 2013; Team Watersmart - Regional District of Nanaimo, 2018).

By applying and combining irrigation efficiency devices water use can be reduced by as much as 30% (Bartlett, 2006). Automated irrigation systems initially cost more, but in the long term save water and money (Carrow, 2006; Riverside County Transportation and Land Management Agency, 2009; Byrne and Associates, 2013).

2.5.6.8. Specific irrigation sprinklers/devices

Many different types of irrigation systems and sprinkler type devices are available. Some are more effective at delivering specific amounts of water very accurately to exact locations in the amenity landscape than others. Also, the radius and area of delivery varies according to each devices design. Each device or system is chosen according to factors such as the type of amenity landscape, planting type, soils, slopes, cost, type of application required and aesthetics. There is no “One size fits all”. Each system/device should be uniquely chosen to achieve the most suitable end result, taking water use and water savings into account. Designers must understand the use, design requirements and how to achieve the most efficient water use from each system and device used in the amenity landscape (Landscape Irrigation Association of South Africa, 2009). Some devices used in South Africa are:

- Bubblers - non-rotating sprinklers for watering shrubs, flowers, boxes and trees. Water is “sprayed” in a downward angle from the sprinkler head.
- Drippers - either in-line or plug-in type emitters. Able to operate under 1-2 bar water pressure, at rates of between 2 and 24 L/hour.
- Micro sprays - consist of fixed or rotating heads and are used for small to medium flower and shrub beds and require longer watering times. Not suited for windy conditions.
- Cone sprays - consist of overhead or pop-up, non-rotating stream spray or fan type spray with a high precipitation rate.
- Rotating sprinklers - are either reaction or gear driven and can be either overhead or pop-up. Suitable for use on medium flower and shrub beds as well as grassed areas. Sizes range from mini, medium to large rotating sprinklers.
- Overhead sprinklers – riser pipes are used mainly in shrubberies where they are positioned above the plant height.
- Pop-up sprinklers are used mainly in grassed areas, kerb ways and pedestrian walkways (Landscape Irrigation Association of South Africa, 2009).

2.6. Assessment of amenity landscape water use formulas/models

To assist landscapers and gardeners with their overall water usage of amenity landscapes there are many very simple water use or water footprint calculators available on the internet. In their simplest form they take into account factors such as size of the garden, the location and a volume of water is estimated for the specific site. Some examples being Water Corporation (n.d.), City of Cape Town, (n.d.), Smart Water Gardening (2010), Hunter Water (2011) and United Utilities (2017).

More complex overseas examples that consider other aspects being; Landscape Coefficient Method, (University of California Cooperative Extension California Department of Water Resources, 2000) and Green Star Potable Water Calculator Guide (Green Building Council of Australia, 2012). Two known South African examples of water use calculators have been developed and that address the potential water use situation of a given site/amenity landscape. The first being the Green Building Counsel of South Africa's Green Star rating system (Green Building Council of South Africa, 2014). This system consists of 5 basic parameters, the size of the area to be calculated, irrigation type, microclimate, irrigation system controls, rainfall and location. The Green Star rating system includes a list of approximately 50 most commonly used amenity landscape plants indicating their hydrozones. The second system in South Africa has been developed for determining water requirements of residential housing estates (SA Outdoor Water Model). This considers types of vegetation (crop coefficients), irrigated area, irrigation type, evapotranspiration and size of swimming pool. The model can be used for both water demand, making predictions, as well as estimating possible water conservation volumes, should water restrictions be implemented (Du Plessis, 2014).

Some challenges identified with some of the models investigated being;

- The Australian Green Star method is not broad enough to analyse site environmental factors that could influence water use and assumes that all indigenous plants use less water than exotic plants, which is not necessarily tested or correct.
- The Green Building Council of South Africa's Green Star rating system:
    - Plant choice is extremely limited (only 51 plants species listed) and not necessarily checked against any specific methodology.
    - Of the five plant hydrozones (xeriscape, low, medium/low, medium, medium/high and high), xeriscape requires that the irrigation system be removed after one year. This is linked to no specific plant choice listed. The amounts of water allocated for the different zones do not correlate to industry understanding or norms.
    - For irrigation system enhancement efficiency, only one of three options is allowed for use as any one option per zone, either precipitation sensors, no controls, or seasonal adjustment timing (irrigate 100% in dry season and 50% in rainy season).
    - The weekly amount of water required per zone does not necessarily reflect what is accepted with the landscaping industry as norm (the model is generally in excess of industry norms).
    - The microclimate aspect considers only three broad ranges namely exposed (no shade during the day, high temperatures, full wind exposure on all sides), normal, (this is not defined by GBCSA) and protected (full shade, no direct sun during the day, high wind protection, shelter on 3 to 4 sides). The consideration of aspects for microclimate are very limited.
    - Aspects such as the influence of soils, use of mulches, wind, slope, maintenance and specific location within the site are omitted and as a result could pose a challenge for the site water requirement calculation.

- The aspect of evapotranspiration as a measure of water loss from the system has not been included, however rainfall and the number of rain days has been included.
- The climatic map used is the SANS 204:201 which is based on climatic zones that have been adjusted to simplify use of the energy efficiency measures may not correlate with localised ETo or water requirements.
- The model was last updated in 2014.

- The SA Outdoor Water Model as developed by Du Plessis (2015) determines outdoor water demand based on some factors that lack detail. Some concerns are explained. A concern with the model is that since some automated irrigation systems do not take rainfall into consideration and operate on a strict time schedule, seasonal fluctuations are not accounted for. The aspect of requiring data on, time per irrigation event and events per week (when irrigation efficiency is not available), is that the model could be considered less of a predictive tool, and more of a confirmation tool for water use in the amenity landscape. Specific aspects related to amenity horticulture such as plant density, details of hydrozones, soil types, slopes, amenity landscape maintenance, mulches etc. were not considered by the model. Also, very limited plant types (5 broad categories: turf, cool season grass, non-turf trees and shrubs, vegetable gardens and xeriscaping) have been listed with a species factor (crop coefficient). The irrigation efficiency (Ie) of 65% was recommended by Du Plessis (2018), this is a low assumed efficiency rate when compared to other data (Table 2.10).

2.6.1. Other selected models

There are several other models that are available, however it is not within the ambit of this study to discuss these models. Some examples being;

- Irrigation budget – Code of Practice for Irrigating Public Open Space (Australia) Devi (2009).
- Simplified Landscape Irrigation Demand Estimation (SLIDE) (Pittenger, Kjelgren, and Shaw, 2012; Pittenger, 2014).
- The Irrigation association USA (McCabe, 2005).

2.6.2. Some general comparisons of various models

When comparing amenity landscape water use models it is evident that although their goals are the same, the methodology and factors used is different (Table 2.11). There is yet to be a single approach to amenity landscape water modelling in South Africa that is agreed to across the scientific/landscaping community.

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Table 2.11: Comparison of methods for estimating irrigation water requirements of urban amenity landscapes.

Method name and reference / Aspects considered in the method:	USA-Modified landscape coefficient method. (University of California Cooperative Extension California Department of Water Resources, 2000).	Simplified landscape Irrigation demand Estimation (SLIDE) (Pittenger, Kjelgren, and Shaw 2012; Pittenger, 2014); University of California, 2017).	Riverside County (Riverside County Transportation and Land Management Agency, 2009).	USA-The Irrigation Association (McCabe, 2005).	Green star – Australia (Green Building Council of Australia, 2012).	Australia - Large turf areas. (Devi, 2009).	Rational method proposed by Devi (Devi, 2009) (Note: this was only proposed and not developed).	Green building council of South Africa (Green Building Council of South Africa, 2014).	Estimating domestic outdoor water demand for residential estates (du Plessis 2014; Du Plessis and Jacobs 2015).
Evapotranspiration (ETo)	Yes	Yes	Yes	Yes	Yes	Yes*	Yes	Yes	Yes
Rainfall/Effective rainfall	No	Yes (optional)	No	Yes	No	Yes	Yes	No (50% of Irrigation in rain months)	Yes (75%)
Soil Type	No	No	No	Yes	No	No	Yes	No	No
Species (Ks) or plant factor (PF) of plants.	Yes	Yes (very generalised)	Yes	Yes	Yes (limited)	Yes (Turfgrass only)	Yes	Yes (limited)	Yes (very limited)
Root zone depth	No	No	No	Yes	No	No	Yes	No	No
Microclimate	Yes	No	No	Yes	Yes	No	Yes	Yes	No
Plant density	Yes	Yes	No	Yes	Yes	Yes (visual)	Yes	Yes	No
Irrigation efficiency or Distribution	N/A	Yes (optional)	Yes	Yes	Yes	No	N/A	Yes	Yes

Method name and reference → / Aspects considered in the method: ↓	USA-Modified landscape coefficient method. (University of California Cooperative Extension California Department of Water Resources, 2000).	Simplified landscape Irrigation demand Estimation (SLIDE) (Pittenger, Kjelgren, and Shaw 2012; Pittenger, 2014); University of California, 2017).	Riverside County (Riverside County Transportation and Land Management Agency, 2009).	USA-The Irrigation Association (McCabe, 2005).	Green star – Australia (Green Building Council of Australia, 2012).	Australia - Large turf areas. (Devi, 2009).	Rational method proposed by Devi (Devi, 2009) (Note: this was only proposed and not developed).	Green building council of South Africa (Green Building Council of South Africa, 2014).	Estimating domestic outdoor water demand for residential estates (du Plessis 2014; Du Plessis and Jacobs 2015).
uniformity (DU)									
Slope	No	No	No	No	No	No	No	No	No
Irrigation system modification e.g. rain sensor/soil moisture meter	N/A	No	No	Yes	No	No	No	Yes (Rain sensor)	No
Automated irrigation	N/A	No	Yes	Yes	No	No	No	Yes (seasonal)	No
Plant list	1900 plants	10 plant categories		6 Plant categories	106 Plants and plant categories	Unknown	Unknown	50 plants	5 plant categories

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CHAPTER 3 – METHODOLOGY

This mixed method study combined both qualitative and quantitative approaches within different phases of the research project (Plano Clark and Creswell, 2008). Literature was acquired, evaluated and incorporated into the study; data was collected and analysed; and engagement with industry professionals to assess aspects of data required that all contributed towards the eventual amenity landscape water use model (ALWUMSA) was undertaken. A list of 2 529 plants suitable for South Africa and that are available for sale in South Africa was developed each with its own hydrozone data, as well as a range of Evapotranspiration and rainfall maps to aid the amenity landscape designer/manager. Finally a South African amenity landscape water use model was developed, field tested, and compared to other existing models as well as scenarios.

3.1. Methodology used for the literature review, industry engagement, including climatic, plant and model data gathering as well as development and testing of the Amenity Landscape Water Use Model (ALWUMSA)

The research process was undertaken in various stages (Figure: 3.1). Each stage being interlinked. For the first four steps (Plant list, Site aspects, Irrigation/watering aspects and Climatic aspects) it was not necessary to wait for the prior step to complete before proceeding to the next. For these steps it was necessary to engage with industry specialists and members.

The methods used involved a preliminary exploratory phase which involved conducting a literature review and comparative studies of available research data and existing information. This was followed by the research phase consisting of the following:

- A literature review into the most common plants sold for use in amenity landscapes in South Africa.
- A literature review into available information on the climatic and water requirements (as well as aspects that influence water use) of plants used in amenity landscapes.
- A literature review to determine the most complete information for evapotranspiration for South Africa.
- A literature review of available models from South Africa, USA and Australia. These countries were chosen due to the accessibility of data and completeness of models found.

- Meeting various Green Industry groups to obtain specialist volunteer representative individuals and buy-in from the groups themselves that would assist with aspects such as (but not limited to);
    - Supplying lists of plants together with their hydrozones that are most commonly sold in South Africa by growers for the Green Industry.
    - Workshops to obtain an agreement on the recommended site, design, management and environmental related aspects and factors to be considered and included in the proposed model, as well as limited parameters of each.
- Testing and the refining (based on current designs and water use) of the aspects to be included into the proposed ALWUMSA.
- Testing the ALWUMSA on sample amenity landscape site designs to determine consistency of the proposed model and to refine the model where required.
- Testing the ALWUMSA on existing other models (from SA, USA and Australia) to determine any similarities or areas of improvement.
- Testing the ALWUMSA on simulated (scenarios) of the landscape site against which ALWUMSA was tested. Scenarios were selected to determine application from a design perspective of the proposed model, to consider consistency of results and to refine where required.
- Testing the ALWUMSA against anticipated savings that would be achieved with the introduction of water restrictions in October 2016 on the test amenity landscape sites.
- Finalising the proposed ALWUMSA and associated elements.

A combination of the modified Delphi technique (Kahan, 2001; Hsu and Sandford, 2007; Yousuf, 2007) and a Stratified sampling approach (Collins, 1998) was used for the initial data gathering process.

Stratified sampling was used because the Green Industry (SANA, SALI, LIA, IERM, SABI and ILASA) consists of numerous subsets of specialist industry members. Amongst them they represent a homogeneous subset of the Green Industry as described by Collins (1998). Only selected subsets of SAGIC and other Green Industry role players were used in the process of determining aspects that fed into different levels/aspects of the proposed model. These groups of experts were used because they are seen as experts in their field and because they were able to volunteer time to attend meetings and workshops.

The reasons for using and implementing a stratified sampling method and in particular disproportionate stratification for the proposed study include:

- A stratified sample often requires a smaller sample, which saves money.
- A stratified sample can guard against "unrepresentative" samples.
- With disproportionate stratification, the sampling fraction may vary from one stratum to the next.
- If variances differ across strata, disproportionate stratification can provide better precision than proportionate stratification, when sample points are correctly allocated to strata.
- With disproportionate stratification, the researcher can maximise precision for a single important survey measure.
- Within the Green Industry it is known that members do not have the funds or time to allocate to focus groups working through questionnaires and workshops, and as a result methods other than stratified sampling (disproportionate stratification) would not have allowed for selected representatives from the Green Industry subset to represent and decide on their member's interests. The Green Industry organisations invited to participate were; South African Nursery Association (SANA), Institute of Landscape Architects (ILASA), Landscape Irrigation Association (LIA), South African Landscapers Institute (SALI), South African Irrigation Institute (SABI) and Institute for Environment and Recreation Management (IERM).
- As a result, disproportionate stratification allowed the researcher to use only selected (volunteer/co-opted) members of the Green Industry subset in focus groups (Stat Trek, 2018).

Focus groups were also used in this research because they are an accepted method of social scientific research and they provide consistent results (Kahan, 2001). This was evident towards the end of the focus group meetings where despite coming from different regions, similar answers and requirements for the model were supplied and requested by members.

During actual workshop sessions for model requirements, the modified Delphi technique was used. This allowed for opinions and judgments of experts and practitioners to be elicited through a process of self and group exploration (Yousuf, 2007).

As explained by Hsu and Sandford (2007), the Delphi technique is specifically designed to be used as a group communication process that aims at conducting detailed examinations and discussions of specific real world issues for the purpose of reaching consensus (convergence of opinion). This is achieved by using multiple repetitions to collect data from a panel of selected subject experts. The repetitions could be undertaken in the form of questionnaires, group discussions and feedback sessions. The Delphi study does allow for a phased approach where information gathered from participants/panellists in one round will be summarised and then used in the next round. The outcomes of the previous round are presented to participants in the next round. Each successive round allows for consensus to be achieved and where consensus is not achieved on items, it then allows an opportunity for panellists to revise their judgments, thus gradually moving all panellists towards a more agreeable solution. The Delphi technique generally allows for three to five rounds but there could be more or less depending on how much consensus has been reached or not. The Delphi technique focuses on eliciting expert opinion in each subject's area of discipline and expertise.

According to Hsu and Sandford (2007), there has been no consensus reached in the literature specifically on the optimal number of participants in a study using the Delphi technique. Hsu and Sandford (2007), suggests that ten to fifteen participants could be sufficient if the background of the selected Delphi participants is homogenous. Hsu and Sandford (2007), indicate that a Delphi panel is generally less than 50 people. The downside to having a larger group would be that a potentially low response rate may be achieved, this added to the relatively large amount of time that is required to work through each Delphi phase (Hsu and Sandford, 2007).

For the workshops, members were invited to several workshops in Johannesburg (three workshops), Pretoria (one workshop), Stellenbosch (one workshop), Durban (one workshop), Nelspruit (one workshop) and Bloemfontein (one workshop). Where required, experts that were not members of any official Green Industry subset were also invited as individuals to participate in the study and their input formed part of the Delphi technique process.

For workshops, the ideal was to obtain full consensus from all participants in the study; this was possible for the concept of the model, however, it was practically impossible for all aspects of the detail required in the model. Full consensus would be recommended where possible, as the model is one that would be used by the industry as a whole. Consensus, up-front in the form of industry chairpersons being signatory to a document agreeing that their industry was in support and would work with the researcher, together with all workshop participants also signing agreement documentation, was obtained. This would contribute towards promoting the eventual use of ALWUMSA in the "field". Hsu and Sandford (2007) recommended that 80% of participants votes must fall within two categories on a seven-point scale. Hsu and Sandford (2007), suggests that at least 70% of Delphi participants need to rate three or higher on a four point Likert-type scale and that the median has to be 3.25 or higher. Hsu and Sandford (2007), indicate that percentage measures are inadequate and that a more reliable alternative is to measure the stability of participant responses in successive iterations (or repeats of the same process). In support of this, the workshop phase of this research used the approach of consensus agreement by members, to reach agreement on and recommend specific aspects (elements) that would be suggested for use in the proposed model. Added to this, as already indicated the workshops were repeated in various locations with different participants which again allowed for repeated “iterations”, in which case similar answers were provided by members.

There are several potential shortcomings and weaknesses as highlighted by Hsu and Sandford (2007) that could be experienced when using the Delphi technique. Some of these being, participants leaving early, fatigue, lack of participation and varying expertise with the group. This was circumvented where possible by limiting workshops to two and half hours, encouraging all participants in each workshop to participate and add value, engaging some participants/specialists on a one-on-one basis, and gleaning information from all participants/specialists who attended each workshop.

Figure 3.1: Research process flow chart.

3.2. Climatic maps and figures that are associated with amenity landscape water use modelling

3.2.1. Determination of an appropriate potential ETo map and database

Evapotranspiration (Potential evaporation) data was obtained from Prof Schulze of Pietermaritzburg University. It was "calculated" using the Penman-Monteith method as adopted by the Food and Agriculture Organization (Allen et al., 1998). The data originated from historical average data for the period 1950 - 1999. The data is not aimed at providing specific data for an exact location and "values at a specific point should thus not be viewed in relative but rather in absolute terms". The data provided was matched to 5 838 quinary catchments in South Africa, Lesotho and Swaziland. Each quaternary was provided with an unique code (Schulze, et al., 1997; Schulze, 2016) and was overlayed and imported into ArcMap. A polygon shapefile with all the national quinary (Sub-Catchment) boundaries was provided for the purpose of this exercise. This is the spatial dataset to which the calculations from the excel spreadsheet were joined. In ArcMap the attribute table included the SUB_CAT *unique code*, this code was also contained in the excel spreadsheet and the two tables were joined using this field. The excel sheet was then added to ArcMap. The excel spreadsheet is added as a table to ArcMap. To undertake the join process the national quinary attribute table and the excel spreadsheet tables are opened simultaneously, select the spreadsheets to be joined. In ArcMap select the drop-down button at the top of the tables, then select "Join and relates" and fill in the details e.g. SUB_CAT. The two spreadsheets are then joined. The new shapefile is then exported and saved with a unique name. To add orientation, intelligence and clarity to the map as well as to provide locations to this new table, a town shapefile was added to ArcMap. The original town shapefile contained 1685 towns. For this purpose only Level 1 towns (which are capital cities in each province) and the Level 2 towns (Level 2 towns are smaller towns that provide goods and services to the surrounding areas and may also have an airport.) were selected. To select only the level 2 towns, the "select by attributes" option was selected and fields completed. The same process is repeated for level 1 towns. To join these to the quinary table calculations, the ArcToolbox is used. The resultant new table will now have the sub catchment identification, the town name as well as the evaporation calculations.

Towns were joined to the national quinary shapefile and calculation table to include some locational information, such as the names of the towns (Details of the 160 Quinary mapped towns are in Annexure 5). This assists in providing orientation and allows the map to be user friendly. It was also used to generate the database and the model.

Thematic mapping is used to display the evapotranspiration taking the data from the calculations as it focuses on the spatial variability of the evapotranspiration data. The evaporation figures were classed into 9 different ranges, because the minimum and the maximum values varied throughout the year. By creating these 9 ranges it provides for consistency to all maps (Table 3.1).

Table 3.1: List of evapotranspiration ranges included in the maps produced.

Series number	**Evapotranspiration range used on map**
1	31.01 mm – 62 mm
2	62.01 mm – 93 mm
3	93.01 mm – 124 mm
4	124.01 mm – 155 mm
5	155.01 mm – 186 mm
6	186.01 mm – 217 mm
7	217.01 mm – 248 mm
8	248.01 mm – 279 mm
9	279.01 mm – 310 mm

Within ArcMap, the colour symbols were created using the customize option on the main menu bar. From the drop down menu the option “style manager” is selected to create the different colour ranges by selecting styles. To add the symbol to the style, the style option is opened allowing the type of symbol to be selected. The next step is to select “Fill symbol” and choose the colour required, and label the colour according to the range selected. This process was repeated for all the required colours. For each new map once the symbol selector icon is opened, the new colours are automatically added to it. The symbology classification was undertaken manually using the symbols that were created by allocating them to each of the 8 classes.

To symbolize the thematic maps for each month the evaporation figures per month and the symbology was based on quantified graduated colours. The “Value” was changed by month (the detailed step by step process is displayed in Annexure 3).

3.2.2. Determination of an appropriate rainfall map and database

Amenity landscapes rely on effective rainfall to supplement plant growth. Effective rainfall being that portion of rainfall that remains in the plant root zone for use by plants after a rain event (Connellan, 2002). It is hence crucial for consideration in any amenity landscape water use model.

To supply data for this aspect of the model, rainfall data for South Africa is required for matching the level 1 and 2 towns (as was used for the ETo figures). South African Weather Service (SAWS) provided rainfall figures for the same towns/locations. Data supplied was for average rainfall (mm) for the period 1981 and 2010 inclusive of monthly and mean annual data (South African Weather Service, 2017). The SAWS was only able to supply data for 152 of the 160 identified towns/locations, due to the positioning of the SWAS data capturing sites. Data for the remaining 8 towns/locations was obtained from several different internet sites (Climate-Data.org, n.d.; Meteoblue, 2018; Weather2visit, 2018; Yandex Weather, 2018). In some cases, data was available from more than one internet site. In these instances the average monthly figures were determined by comparing the data sets. The final list of 160 sites was included into the data base. For ease of end user use, thematic maps for rainfall distribution were developed using GIS software.

Thematic maps were produced using the rainfall figures representing both summer and winter rainfall regions. Using GIS ArcMap, point data shape files for South Africa (from the Rand Water GIS Database system) were used together with the excel files containing both summer and winter rainfall data. All ArcGIS/ArcMap processes followed are standard operating processes used within the ArcGIS tool within Rand Water. Using ArcMap software an “attribute join” was performed, based on the town name and the excel data where the monthly readings were added to the shape file attribute data. The towns’ shapefile (as per the evapotranspiration shapefile) is selected and the option “join”, from the joins and relates tab is then selected. The required data is typed in. The data is then joined to the shapefile. Using the monthly reading fields Inverse Distance Weighted (IDW), interpolation was performed to create the raster coverage for the area. IDW interpolation determines cell values adjacent to the known value cell using a linearly weighted combination of a set of rainfall sample points and assists in creating the raster coverage for the required area. (The weighting is a function of inverse distance. The surface being interpolated should be that of a geographically locationally dependent variable.) Next, Open Arch Toolbox, select “Interpolation” then IDW. Input data of the map to be created (e.g. summer rainfall areas, January etc.). The result of IDW interpolation is a series of monthly raster data sets for the summer and winter rainfall regions. Finally, the raster data was categorized (symbolise) per hydro-zone for the summer and winter rainfall regions. To do this, the data was classified into four groupings and relevant colours applied to the final map. This produced a map of South Africa that exhibited a complete colour gradient across the region.

To produce the colour groupings on the maps, tables were produced, based on the percentage rain received for each season (Summer, Autumn, Winter and Spring as defined by South African Weather Service, 2018). The values as linked to each season are based on the hydrozone data (as per Rand Water's Standard Operating Procedures (SOP), (Rand Water, n.d.; Hoy, et al., 2017). This provided an estimate of the anticipated rain that could be received for that area for that month/season. This should allow for basic visual guidance to plan for watering requirements for each hydrozone (Table 4.3). The methodology for determining the value for each month for each season to produce the colour gradient maps being;

- The number of months per season were determined from South African Weather Service (2018).
- The average percentage of rainfall received (based on rainfall data) for that season based on the total for that region (summer versus winter region) was determined.
- Based on the hydrozone categories the maximum amount of water (rainfall and irrigation) that could be anticipated for that zone was used and then multiplied by the average percentage of rainfall anticipated for the region.
- As an example, for the no water zone a maximum of 300 mm of water is required. For the summer rainfall region 52% of rain is received in the summer months (Dec to Feb), therefore 300 x 52% divided by 3 = 52 mm for each of the three summer months.
- Similarly for the low water zone a maximum of 500 mm of water is required. For the summer rainfall region 20% of rain is received in the autumn months (March to May), therefore 500 x 20% divided by 3 = 33.3 mm for each of the three summer months.
- Based on these calculations colour gradient monthly maps were produced for both summer and winter rainfall region linked back to rainfall anticipated linked to hydrozone requirements (see Chapter 4, for the results, tables and maps).

In developing the maps, some minor areas such as far northern Limpopo, far eastern Kwazulu Natal, far southern Western Cape and far northern Northern Cape were not able to display the relevant colours matched to Hydrozones. These areas have no raster coverage and no rainfall readings despite that fact that other towns (not in the 160 town database) may exist in these areas. Hence no calculations in ArcMap could be performed. This meant that for these limited areas it was therefore not possible to produce data using IDW, unless data was "created" outside these areas. Creating unknown data was not part of the scope of this project (the detailed step by step process is displayed in Annexure 4).

3.3. Plant data base and hydrozones associated to landscape water use models

3.3.1. Plant selection, process matched to hydrozones

Hsu and Sandford (2007) indicate that the Delphi technique allows for extensive use of newer, more modern technologies, such as e-mail, tele-conferencing and other electronic technology to obtain and gather data from participants. As this study covered the whole of South Africa, these technologies were used where possible for the plant hydrozone information detail part of the project.

Initial meetings with various industry players indicated that no single member would be able to review the entire list of plants (due to time, lack of knowledge/experience and the running of their businesses).

3.3.1.1. Plant lists for sale in South Africa for inclusion in the database

The process commenced with listing plants from available South African wholesale nursery grower catalogues, international and local literature. Plants used in the proposed database had to be available for sale in South Africa during the data gathering period. During each data collection period from literature and internet sources, their definitions used for hydrozones were compared and correlated as closely as possible to those definitions supplied by the researcher to wholesalers/growers (from all over South Africa). As a result it was necessary to use personal judgment. The data for the plant hydrozones was gathered from a total of 65 sources. The data for plants sold in South Africa was gathered from a total of 36 sales/availability lists obtained at four SANA tradeshows (in Gauteng only), which included those wholesalers who had responded to the plant list hydrozone definition query as well as those that did not. This allowed for a more complete list of "available" plants in South Africa. The researcher obtained data from wholesalers who supplied plant sale lists at four different SANA trade fairs (August 2015, March 2016, August 2016 and March 2017). Via the South African Nursery Association all registered growers were requested (via e mail) to supply data regarding which plants were suited to specific hydrozones. Due to an initial slow response, wholesale growers were approached at the trade fairs to request feedback. Some growers contacted the researcher directly while others were referred to the researcher to contact. A total of 17 responses were received (list of respondents Annexure 14) from a total of 79 wholesale nurseries registered (Growers Association) with SANA (South African Nursery Association, 2017), representing a 22% industry response rate.

3.3.1.2. Data gathered from plant lists for inclusion in the database

To ensure comprehensive and sound data gathering, data were obtained from as wide a field as possible. The process of undertaking field trials to determine a specific plant factor (species factor) is extremely lengthy, time consuming and costly and involves the use of complex instruments/methods such as lysimeters or gravimetrical methods (Niu, et al., 2006; Jansen Van Vuuren, 1997). It was not possible within the parameters of this project to obtain the data using field trials. A variety of internet sites, books and wholesaler responses were used as sources of data for hydrozone ratings in the plant database. Only plants available for sale in South Africa, both indigenous and exotic plants in a range of plant types (e.g. bulbs, perennials, shrubs and subshrubs and trees), were assessed from these sources. These plant lists were then used as the premise for the collection of data for the database.

The process undertaken to determine plant hydrozone listing, in this research project was different (see Chapter 5.3.) from the process as described by Water Use Classification of Landscape Species (WUCOLS). The production of the WUCOLS list involved committees of suitably qualified and experienced horticulturists from six different regions in California (Costello and Jones, 2014). Determining the WUCOLS plant database involved a consensus based approach to evaluate the plants and each plant was assigned either high, moderate, low or very low water needs (Costello and Jones, 2014).

3.3.1.3. Internet plant lists for inclusion in the database

A total of 16 internet sites were used to obtain data (Annexure 11). Thirteen sites were international sites and three were South African sites (based on the origin of the site). The number of plants from these internet sites that matched with those plants of the research plant database, ranged from 20 to 672 plants per internet site. Examples of the internet sites being Keith Kirstens, n.d., Utah State University Cooperative Extension, 2003; Salt Lake City Public Utilities, 2013 and Green Building Council of South Africa, 2014.

3.3.1.4. Book plant lists for inclusion in the database

A total of 32 books were used for data collection (Annexure 11). Books were defined as printed media inclusive of traditionally printed books (included under books was one plant list produced by a Green Industry representative (Montgomery, 2014)). Fifteen books were internationally produced and 17 were South African. The number of plants from the books reviewed that matched with those plants of the research plant database, ranged from 22 to 661 plants per book. Examples of books used being, Chatto, 1980; Pienaar, 1991; Denver Water, 1998 and Johnson, Johnson and Nichols, 2002.

3.3.1.5. Wholesaler and other response list for inclusion in the database

All suppliers of wholesale plants that are members of SANA were requested to supply plant data for the research project. Data was obtained from 17 wholesalers and other growers (Annexure 14). The number of plants from the suppliers that corresponded with those plants of the research plant database, ranged from 20 to 471 plants per supplier (plants from wholesalers were listed on their, for sale or growing list).

3.3.1.6. Cleaning up of the database

The total plant list of data gathered from all sources was checked, duplicates were removed and all species lists were condensed. In some cases plant species were listed as the same species but with different colours or trademark names or variety names, examples being various *Alstroemeria, Viola* and *Camellia* species. In these instances plants were amalgamated and the newly listed plant was then listed using the suffix varieties e.g. *Alstroemeria* 'Princess' varieties, *Viola* 'Malanseuns' varieties and *Camellia sasanqua* varieties. In some cases a supplier listed different varieties as having different water requirements. In these instances the highest listed hydrozone was awarded to the generic variety in the final list. This is in support of Barta, et al., (2004) who indicate that amenity landscapes are rather over than underwatered.

Due to the growth habit, type and nature of plants, it is possible that a plant could be listed in more than one category. During the process of cleaning up the database, the researcher and Coetzer (2018) used the books from which plant data was obtained and personal experience to clarify which category each plant should be placed in. Examples of categories being annuals, bulb like, fruit, herbs and shrub-subshrub.

Since the final plant data list is to be used by industry role players, the aim was to reduce the list down to a more manageable and realistic quantity. All data was analysed through various comparisons. All plant species were assessed and where needed reduced considering the following criteria;

- Exotic plants where information was available only from literature or internet sources and that were not listed as grown and sold by South African industry were removed.
- Plants species where many subspecies were provided were reduced and consolidated.
- Plants of the same species, being sold under two different genus or specie names were amalgamated (As plant nomenclature change of the years not all wholesale growers update their name lists). This should also be seen as part of the data cleaning process.

Plant species that were obtained from the sales lists of wholesalers at tradeshows, but where no hydrozone information was available were moved to a separate data base (not part of these study results) to provide a more complete list and to allow for future data to be captured. There were also 24 plant species defined as alien invasive plant species (National Environmental Management: Biodiversity Act (NEMA), 2004) that were listed as category 1a and 1b as per NEMBA in the final list, that were removed. Category 1b plants that are allowed to be grown and sold in certain areas of South Africa (as per the legislation) were left in the final list. The plant lists were then formatted resulting in a total of 2 529 plants consisting of no water, low water, medium water and high water hydrozone plants (Annexure 13).

3.3.2. Defining water requirements of plant hydrozones and allocation of factors

For industry and specialists as well as the researcher, to provide their professional opinion into which hydrozone each plant should be placed it was extremely important that the water use of plant hydrozones be specifically and clearly defined. The hydrozones as described by Rand Water's Water Wise program (Water Wise basic hydrozone model) and that form part of their Standard Operating Procedures (SOP) (Rand Water, n.d.; Hoy, et al., 2017), were used as the basis. All plant wholesaler growers were instructed to define the plant species they grow and sell, against the following criteria;

- To rate each plant sold against one of the four Hydrozones, as defined by Rand Water.
- Not to rate plants in the manner in which they grow them in the production process but rather in which zone (as per the Rand water definition) they would advise customers to plant the plants.
- To provide hydrozone data limited to and based on their local growing area requirements. As an example for a grower in Britz (Northwest Province) the hydrozone advice would be for Britz and not in Durban (Kwazulu Natal Province) where some of their plants may be sold.
- The definitions supplied by the researcher were presented in two formats (to suite possible different understandings). The first was an annual amount of water required by plants in that hydrozone, and the second format demonstrated water requirements based on seasonal requirements (Table 5.7).

To determine seasonal rainfall it was necessary to determine the specific months for each season (inclusive of the number of weeks). For this purpose information from the South

African Weather Service (SAWS) was obtained regarding the duration of each season. The seasons being; Summer - 13 weeks (1 Dec - 28/29 Feb), Spring - 13 weeks (1 Sept – 30 Nov), Winter - 13 weeks (1 June - 31 August) and Autumn - 13 weeks (1 March - 31 May) (South African Weather Service, 2018). SAWS do not distinguish season as differing in date or duration across the country, but rather provide one date definition for the seasons for the entire country.

Plant hydrozone information taken from literature and internet sources had definitions that were not necessarily the same as those provided by the researcher. All definitions of water requirements were matched as close as possible to those definitions supplied by the researcher (Standard Operating Procedures (SOP) of Rand Water, n.d. and Hoy, et al., 2017) to wholesale nursery growers.

The final plant database consists of plants each linked to a specific hydrozone. As a second phase to this portion of the research it was necessary to use the plant hydrozone information and incorporate it into the ALWUMSA in a manner that will facilitate calculations. In order to do this it was necessary to allocate a factor for each zone. This was determined and allocated by comparing other existing models and the factors allocated. The factors advocated by University of California Cooperative Extension California Department of Water Resources (2000) and Costello and Jones (2014), were selected for use as a base in the model.

3.4. Amenity Landscape Water Use Model (ALWUMSA)

3.4.1. Determination of design, management and environmental aspects to be included in ALWUMSA

This part of the research focused on two main areas namely workshops with industry experts and reviewing of existing models from other areas around the world. Many examples were found from USA, but limited examples from Australia and South Africa. The four models chosen were the Landscape Coefficient Method (LCM) – California USA (University of California Cooperative Extension California Department of Water Resources, 2000), Green Star Potable Water Calculator – Australia (Green Building Council of Australia, 2012), Green Star Potable Water Calculator – South Africa (Green Building Council of South Africa, 2014) and Outdoor Water Demand Model – South Africa (du Plessis, 2014). Each model was “broken down” into its individual portions with each site and environmental element reviewed for possible incorporation into the proposed model. To obtain as much data as possible from industry experts, workshops were arranged. Firstly, various meetings were held with executive members of the Green Industry, such as South African Nursery

Association (SANA), South African Landscape Institute (SALI), Institute of Landscape Architects (ILASA), Landscape Irrigation Association (LIA), South African Irrigation Institute (SABI) and Institute of Environment and Recreation Management (IERM), to determine their receptiveness to the project and obtain verbal and written consent to proceed.

The process for these workshops was that the researcher met with various industry players to obtain advice as to where sessions should be arranged. As a result sessions were arranged for the cities of Pretoria, Stellenbosch, Durban, Johannesburg, Bloemfontein and Nelspruit. Prior to the official workshop sessions a pilot session was held in Johannesburg with qualified Horticultural/Environmental staff from Rand Water.

Workshop dates and venues were based on availability of a local coordinating person as well as venues. Attendees signed attendance registers, completed a questionnaire and completed consent documents for workshop participation. The workshop session process (in line with the Delphi technique as described previously) took the form of introducing members to the need and reason for the workshop as well as the long term impacts of climate change on urban amenity landscapes. The general aim of the model was also explained using designs of various landscapes to explain the broader concepts without providing actual specific site or environmental elements. The process followed was that participants were asked what physical, environmental, pedological, flora, management, design and climatic elements they felt influenced water use in an amenity landscape. Once listed, participants were then informed of four model examples (as listed above) and what generic elements are used in these examples. With this additional knowledge, participants were then asked if they wanted to add any additional elements to the list they already provided. Once completed, all elements were again interrogated by workshop attendees, to determine whether they were in fact relevant or not and for those where participants agreed clarity was sought. Some elements that were later felt by group members to be not essential were removed through consensus. The final list of proposed elements from each workshop session was presented to the group for acceptance. This process was repeated at all workshops. At no stage were workshop attendees informed on what to include or not. Active debate was however encouraged as this facilitated clarity between proponents of both positive and negative elements that influence amenity landscape water demand at various sites.

Attendance of the workshops for all areas is listed in Table 3.2. All workshops were arranged by means of sending open invitations to Green Industry members in an area. To ensure completeness, a separate meeting was held with three selected LIA members as this was requested by them (they were unable to attend workshop sessions). Attendance of affiliated members was not verified at the workshop, but rather assumed since the area of expertise meant specific affiliation. A total of eight workshops/meetings were held that included a total of 73 attendees.

Table 3.2: Numbers of attendees for all workshops across South Africa.

Workshop location	Date	Total number attendees	Attendance number by affiliation.						
			SANA	**SALI**	**LIA**	**SABI**	**ILASA**	**IERM**	**Other**
Johannes-burg South (Pilot)	4/5/ 2016	4	0	0	0	0	0	0	4 (RW)
Pretoria University	10/05/ 2016	19	0	2	1	1	13	0	1 (SAGIC) 1 (RW)
Stellen-bosch	06/06/ 2016	9	0	4	0	2	2	1	N/a
Durban	22/08/ 2016	10	0	7	0	0	1	2	N/a
Bloemfon-tein	29/8/ 2016	10	0	4	3	0	0	0	3 (Windmill Casino management -Ground)
Midrand	23/08/ 2016	5	0	4	0	0	1	0	N/a
Nelspruit	14/09/ 2016	13	0	2	1	0	1	3	1-Forestry 2-Tropical research 1-SANPARKS 2-Unspecified
LIA meeting	29/09/ 2016	3	0	0	3	0	0	0	N/a
TOTAL		**73**	**0**	**23**	**8**	**3**	**18**	**6**	

All the elements suggested for inclusion in the model during the workshops were grouped into the following categories;

- Design
- Management
- Microclimate
- Pedology
- Plant information
- Irrigation
- Rainfall
- Evapotranspiration
- Size of hydrozone

This initial list of elements suggested at the workshops consisted of a total of 94 different elements. It was necessary to reduce and consolidate the elements, as participants in workshops and individual meetings with specialists had indicated that the number of elements to be used in the final model needed to be minimal and relatively simple to implement. No actual number of elements was suggested as a minimal amount. Participants indicated that having only a few elements in the model would encourage use of the model, and allow for ease of use. Brace (2018) suggests for interview type questions that after 15 minutes respondents reduce their response due to fatigue, while Malhotra, (2006) states that no scientific principles guarantee an ideal or optimal questionnaire length.

To reduce the list of elements from 94 elements it was necessary to rank them in order of “importance” by the researcher. Other model systems already in use in USA, SA and Australia have not provided methodologies as a guide on how they arrived at a final list of reduced elements for inclusion in the their models. As a result, a list of ranking questions with a scoring system was then developed to determine suitability and appropriateness for use in a potential model. The questions developed and used to rate each parameter was:

- Is it always possible to assess in the field or on plan with either complete or partial data of the site (rating, 1 - 10)?
- Is it a practical Water Wise aspect to consider for a site or portion of a site (rating, 1 - 10)?
- Is it practical to include in a simple tick box model (rating 1 - 10)?
- Could it lead to direct water saving or influence water use (rating1 - 20)?

- Was the aspect included in other models (e.g. Landscape Coefficient method, Australian Green star and South African Green star) (rating range 0-20)? (None = 0, one model used = 10, two or more models used this element = 20)

The exact scoring of each element was at the discretion of the researcher. As no specific existing methodology was available to suggest at what score the cut-off should be to decide which elements to include or not, it was decided by the researcher the a “rounded off score” of 40 out of a possible 70 points (being 57%) would be the cut-off point for inclusion of elements. The final model contains a total of 30 elements (questions) that require input data/answers.

Table 3.3: Examples of Elements used with answers required of the model user.

Elements			
Main element category	**Main element/ questions**	**Element/questions**	**Sub-element**
Landscape design aspects	Design by trained professionals	Is landscape designed by an accredited professional (correctly)?	Yes/no
Landscape design aspects	Microclimate - rain	Is the landscape screened from the predominant rainside by buildings?	Yes/no/partial
Landscape design aspects	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings?	Yes/no/partial
Landscape design aspects	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun?	Yes/no/partial
Plant factors	Mulch (choose only one)	Is bare soil on site covered by mulch (organic i.e. can it decompose)?	Yes/no/ partial
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath)?	Yes/no/ partial
Pedology aspects	Soil type	Using the basic soil test what is	Yes (must

Elements			
Main element category	**Main element/ questions**	**Element/questions**	**Sub-element**
	unmodified (choose one only)	the predominant soil type on site - Sand?	choose one only) or N/A
		Using the basic soil test what is the predominant soil type on site - Clay?	
		Using the basic soil test what is the predominant soil type on site - Loam?	
		Using the basic soil test what is the predominant soil type on site Rocky or stony soil?	
Plant factors	Plant density (choose only one)	Dense (less H2O) > 80% cover	Yes (must choose one only)
		Normal - 50% - 80% cover	
		Sparse < 50% cover (more H^2O)	
Irrigation factor	Irrigation - system-soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No
	Irrigation - system- changed to season	Is the irrigation system set to change according to seasonal rain expectations e.g. summer vs. winter?	Yes/No
ETo (Evapotranspiration)	ETO	Potential evapotranspiration	Choose the town from the closest town on the list.

To use the elements in the model it would be necessary to ask the user a question to answer (each element would be awarded a factor/coefficient, as implemented by other models, (University of California Cooperative Extension California Department of Water Resources, 2000; Green Building Council of South Africa, 2014). Each element statement was then changed to ensure that it asked a question that could be used in the final model.

Once elements were “finalized” where possible, simple answers such as yes/no/partial were developed for each element question, whilst others were more complex offering several possible answers. Examples of the final elements together with the range of answers for those specific elements are listed in Table 3.3.

A rating factor (coefficient) was then determined for each element answer developed. Factors (coefficients) ranged from below one (but above zero) to above one (but not above two). To determine possible element coefficients it was necessary to consider;

- Existing element coefficients used in other similar models (the four considered in this study).
- Literature that described elements in either a positive or negative view or both.
- The researchers own experience and understanding of an aspect based on 35 years of industry/horticultural based experience.
- Discussions with industry professionals.
- An elements ability to influence the water use of the site. In some cases it was necessary to align factor (coefficient) values to allow for a more accurate water use. This resulted in factor (coefficient) values either being increased or decreased.

The range of coefficient values varies for each element question and answer. As the questions asked indicate either a positive aligned or a negative aligned answer the coefficient value is reflected in the answer which then in-tern impacts the model. The positive /negative aligned question and answer are all linked back to the potential for either more or less water being used and therefore required on the hydrozone or site. For example to the question “Is landscape designed by an accredited professional (correctly)?”, a yes answer is actually positive, hence the coefficient value is low. By contrast to the question “Is site impacted by increased temperature of surrounding buildings?”, a yes answer is actually negative and hence the coefficient value is higher. Examples of some of the more “simple” element questions and the coefficients applied to each answer are listed in Table 3.4.

Table 3.4: Examples of element questions requiring only a yes/no/partial answer.

Element/questions	Coefficient value range		
	Yes	**No**	**Partial or n/a**
Is landscape designed by an accredited professional (correctly)?	0.85	0.95	0.9
Is the landscape screened from the predominant rainside by buildings?	1.05	0.8	1
Is site impacted by increased temperature of surrounding buildings?	1.1	0.8	1.05
Is site impacted by increased reflection of surrounding buildings (solar radiation)?	1.1	0.8	1.05
Have water retention granules/polymers been added to soil on site?	0.9	1.1	1

Some questions have a larger range of potential answers required from the user and as a result the coefficient range and number of options increases. Again here coefficient values are linked to question/answers that are aligned to either positive or negative aligned to water requirements of the site (Table 3.5).

Table 3.5: Examples of element questions requiring a large range of answers.

Question to be answered	Coefficient value range				
	Sand	Clay	Loam	Rocky or stony soil	N/A
Using the basic soil test what is the predominant soil type on site - **Sand?** Using the basic soil test what is the predominant soil type on site - **Clay?** Using the basic soil test what is the predominant soil type on site - **Loam?** Using the basic soil test what is the predominant soil type on site **Rocky or stony** soil?	1.25	1.25	0.9	1.2	1
Question to be answered	**Coefficient value range**				
	North	South	East	West	N/A
What is the (predominant) main aspect of	1.05	0.8	0.9	1.1	1

Question to be answered	**Coefficient value range**				
	Sand	Clay	Loam	Rocky or stony soil	N/A
the area on the site concerned?					
Question to be answered	**Coefficient value range**				
Is the site a traffic island impacted by car fumes & heat?	Free flow	Traffic Island	Traffic Island at Robot	Tree in paving	N/A
1. Free flowing areas/roads	1.05	1.1	1.2	1.2	1
2. Traffic islands					
3. Traffic islands -standing areas (robots etc.)					
4.Type of landscape design used for this portion of the site - trees surrounded by paving/hard surface (e.g. parking lot)					
Not applicable					
Question to be answered	**Coefficient value range**				
	Drip	Micro spray	Rotary/ Gear/Stream sprinklers	Cone/ Fixed Sprayer	Hand or other
What irrigation system is used in this hydrozone? • Drip, Micro spray, Rotary/Gear/Stream sprinklers, Cone/Fixed Sprayer, Hand or other	0.95	0.90	0.80	0.75	0.50

ARC-Institute for Agricultural Engineering (2003) describes irrigation efficiency to be less than the 50% of long term average monthly rainfall. Connellan, 2002; Carrow, Duncan and Waltz, 2005; McCabe, 2005 and Pittenger, 2014, all indicate that an effective rainfall figure of 50% is reasonable to assume for use and was hence adopted for inclusion in the model calculation.

During the workshop at Nelspruit it was specifically requested that when considering wind that that it should be irrelevant as there was no wind to note. This was however found not to be correct as Van den Berg and Deacon (1989) found that over a 10 week period the wind speeds varied from 61.2 km/day and 200.1 km/day which also corresponded with other research in Nelspruit. As a result this element was not included in the final model.

3.4.2. Formulation of ALWUMSA

The process of developing the model involved taking the workshop criteria, information from existing models, the plant hydrozone information, as well as the climatic data, and assigning factor (coefficient) values (as described in 3.4.1) to each as required. This involved testing, changing some factor (coefficient) values and retesting of the model. This was to ensure that within the model result, the factor (coefficient) values would produce a result that would be able to determined water use (positively or negatively). To determine the methodology of the various calculations used within ALWUMSA, the existing combinations of mathematical equations used with the Landscape Coefficient Method (LCM) – California USA, Green Star Potable Water Calculator – Australia, Green Star Potable Water Calculator – South Africa, and Outdoor Water Demand Model – South Africa were considered. The model (ALWUMSA) is excel based, and relies on some complex formulas. The model resulted in several groupings of data (elements) used in the model, that are either multiplied or divided to achieve the total water required for the zone and site. These broad groups of elements being:

- Landscape design and management elements
- Pedology elements
- Plant elements
- Irrigation elements
- Evapotranspiration elements (*Potential evaporation* based on Penman-Monteith method)
- Size of zone and
- Effective rainfall.

The process for the user to actually apply the use of the model involves the answering of a range of elements/questions for each hydrozone of the site. For the various elements/questions to be able to be used in the model each is awarded either a coefficient value or a specific value (e.g. millimetres or meters squared). Each answer is selected from a dropdown menu that has the coefficient values attached (on a separate portion of the sheet) to each answer. The multiplication of various elements each with a coefficient/factor/value results in an element with a factor/value. The model formula calculation process then automatically determines a landscape coefficient, the effective rainfall as well as the Irrigation required. Finally the irrigation requirement is also automatically multiplied by the size of the specific hydrozone. The volumes of water required for the site are then automatically converted and displayed in both Litres and Kilolitres. This is demonstrated in the model calculation steps in Chapter 6.

The model calculation therefore determines the water use per hydrozone and for the total site, based on an average monthly figure as well as a total anticipated use for the year (in both Litres and Kilolitres).

The range of elements developed in this study is not matched in any of the models compared to and includes elements that are completely new for consideration in water use. The influence of these elements on the water use on the site (as discussed below) demonstrates and concurs in principle, with literature sourced (see Chapters 2 and 6). The development of the model is unique in that it involved a range of industry role players (as buy-in was essential) from a broad spectrum of locations to have input into the initial design and elements that needed to be included.

Where possible guidance from existing coefficients of other models was considered in determining the coefficients used in the ALWUMSA and in some cases even duplicated. This was to avoid a situation where Landscape coefficient rates used in models that are set too low it can result in the death of plants and trees as occurred in the Royal Botanical Gardens Melbourne Australia in 2007 (Symes, et al., 2008).

3.5. Testing of ALWUMSA against sites, scenarios and other models

Each site is evaluated according to its own unique elements and input within each site, each hydrozone is also evaluated against each of the 30 elements and given a coefficient depending on assessment. This allows for a broad range of elements to influence the site water use. To allow for each site and hydrozone to cater for their distinctive elements, in some cases certain elements have been given more options than merely yes/no/partial. As an example the inclusion under the element, soil type, it allows for the choice of sand, loam, clay and rocky or stony soil. Similar variations are catered for when considering the predominant wind on site that allows for high, medium, low, constant, sporadic and no wind decision. All the three sites assessed were weighted as being under 3 years old, which accounts for the higher watering requirements for younger sites.

3.5.1. Testing of ALWUMSA on a case study experimental site

Proposed available amenity Landscape case study sites were initially chosen based on availability of the site and feedback from the Green Industry namely LIA, SALI and ILASA. The criteria that were required to assess sites were based on;

- availability and access to the site by the researcher,
- the site should preferably be in Gauteng for ease of access for data collection (sites in other provinces would also be considered),
- available detailed information about the site design, including scaled drawings of the site, and
- access to accurate, recent historical water use figures for the site.

To obtain information on possible available sites the researcher engaged Green Industry members during the workshops as well as engaging the industry bodies of LIA, SALI and ILASA directly.

Unfortunately only one site of the 10 sites visited was suitable. The one site chosen consisted of several large apartment blocks each with its own assigned amenity landscaped gardens around each apartment block. The site is situated in Centurion adjacent to Pretoria in the province of Gauteng, South Africa. As the site was still in a long term development phase only a portion of the site had been landscaped since November 2015 and water use figures were available. The site had 3 sets of amenity landscape areas each separately metered that provided historical data obtained via the automatic meter readers from the landlord. The sites chosen for assessment being;

- Residential apartment complex A in Centurion Gauteng province.
- Residential apartment complex B in Centurion Gauteng province.
- Residential apartment complex C in Centurion Gauteng province.

The water use information from apartment block A covered the period November 2015 to December 2017, for apartment block B from February 2016 to December 2017 and for apartment block C from June 2016 to December 2017.

Once official approval for the use of the sites was received, each site was visited to assess the site and determine the criteria for the site. Site landscape maps were obtained for each site from the landscape architect. Printed copies were taken to site to verify plan versus on-site features (in some cases there were differences between the design and actual on the ground. These were mapped and noted to ensure correct data was input into ALWUMSA).The landscape maintenance team for the site were involved in the site visits and through testing of irrigation system each zone for each block was mapped. The 30 questions used in ALWUMSA were also answered for each zone on each of the three sites. All data was then relayed into the excel version of ALWUMSA.

To determine the actual size of each zone, it was necessary to engage the services of the Rand Water GIS department. The following process (as outlined below) was used as per the standard operating process applied within Rand Water;

The use of Geographic Information Systems (GIS) including the use of Autocad/CAD (Computer aided design) have been used by researcher where subareas within each parcel/polygon in urban amenity landscapes can also be calculated separately (Sinske and Jacobs, 2013; Du Plessis and Jacobs 2015). This supports the methodology engaged with in this study.

3.5.1.1. Georeferencing process

Georefencing is the process of assigning a spatial coordinate system to vector or raster data (spatial data) that possesses no explicit geographic or projected coordinate system (Geomatica, 2013). This process was applied to assign a correct spatial reference to the CAD drawings and thus a projection was assigned (wgs29). This enables for the production of corresponding/equivalent geographic coordinates i.e. degree of longitude and latitude and thus features of the coverage can be positioned onto a real world context. The georeferencing of the CAD drawings was performed by importing the drawings into ArcGIS. The CAD files were converted into shapefile - a format compatible with ArcMap in which features are represented as either points, lines, or polygons. The features were georeferenced using aerial images retrieved from ArcGIS online. By selecting the project tool opens up a pop up window. This allows the layer to be projected to be placed under input raster or feature class. The desired coordinate system is then specified. A geographic or projected coordinate system is then specified from the list by expanding corresponding folders on the open document. A system commonly or frequently used can be accessed again easily under favourites. The process creates a new layer and the user has to then specify the location.

3.5.1.2. Digitising of hydrozones

Once the CAD drawings had the correct spatial reference system, the hydrozones were digitized in ArcMap 10.3.1. The spatial boundary of the zone was digitised based on hand-depictions of the hydrozones on A0 print outs of the CAD drawings. These hand drawings were sketched by the researcher based on onsite observations of hydrozones (based on sprinkler placement) as well as knowledge of the study area and the zones themselves. All the zones were captured into an attribute table containing the following information, Area [text], Tittle [text], Zone [Integer], and hydrozone [text]. The zones were also assigned a coordinate system. The WGS84 is a standard national system which is based on Clark 1880 modified ellipsoid. Conventionally, Longitudes 17°East, 19°East, 21°East, 23°East, 25°East, 27°East, 29°East, 31°East and 33°East are used as the mid-points of each 2° projections. Presently, these coordinate zones are referred to as Wg17, Wg19, Wg21, Wg23, *etc.* The coordinate zone used in the projection of the hydrozones is Wg29. This is because Longitude 29°East runs through, closest in range to the study area (Mitchell, 2011).

3.5.1.3. Calculating geometry

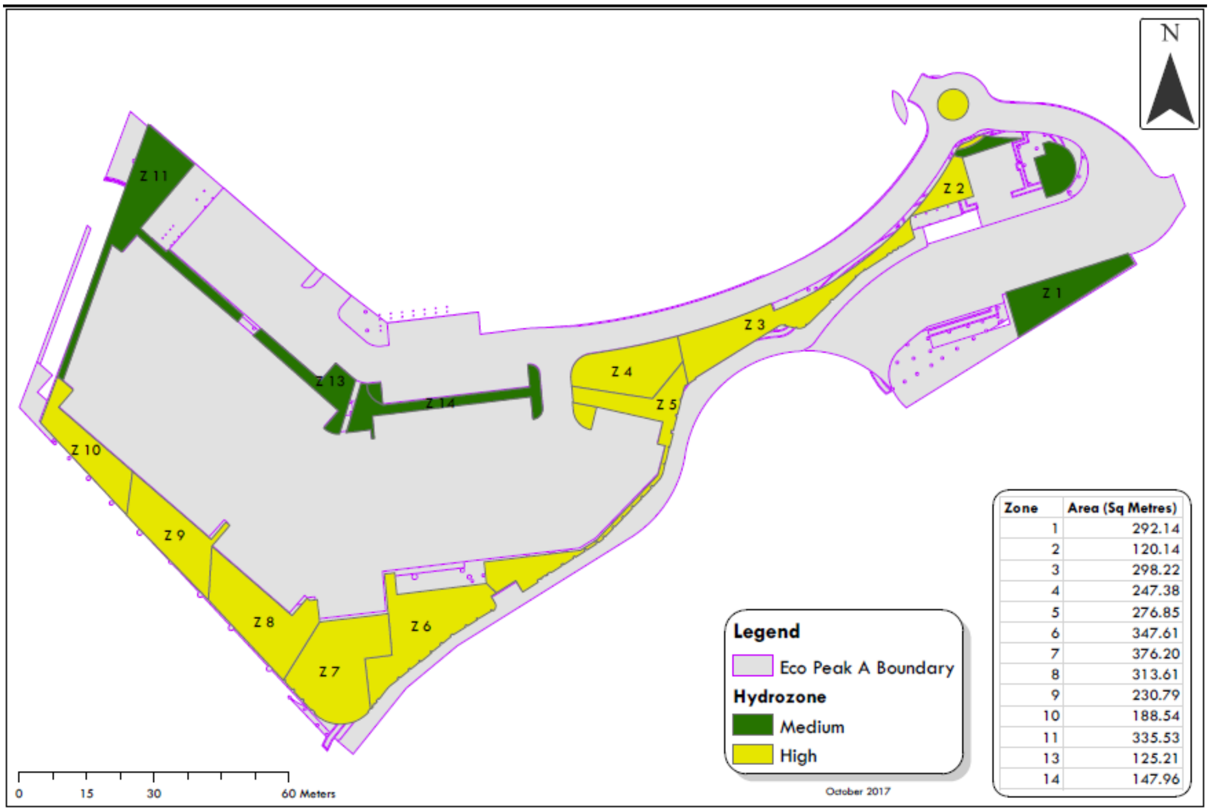

Figure 3.2: Example of map depicting zones on site with area per zone.

A new field was added on the zones attribute table and the “Calculate Geometry” tool in ArcMap 10.3.1 was used to generate area for the zones in square metre units to populate the new field. This is done (in ArcToolbox) by opening the attribute table and selecting the column to be calculated. Select the field calculator tool. The resultant attribute table containing computed zone area was converted into excel format for further interrogation. The tool opens a pop up window containing an input and an output table. The input table is the one to be converted and output table will be saved at the user defined location in excel format. A map showing each of the zones was also produced. Figure 3.2 provides an example of the type of maps produced for each of the amenity landscapes for each of the three apartment blocks (including zones and the square meters for each zone).

3.5.2. Testing of ALWUMSA on other existing models

Each of the three sites tested were also evaluated against the landscape coefficient method (USA), the Australian Green Star method, the South African Green Star method, and the Outdoor Water Demand Model by Du Plessis (2014). The Rand Water basic hydrozone model (used as part of the standard operating procedure at Rand Water) only consists of one parameter and therefore it was not considered suitable to use as part of the testing analyses.

For the Australian Green Star and the South African Green star methods the original excel models were obtained from source. The data from each site was input into the models to determine their values of water us. For the Outdoor Water Demand Model, the model was recreated and the researcher engaged Du Plessis (in 2017 and 2018) to ensure correct understanding of the application of the model. For the landscape coefficient method descriptions of the model calculations were used to reproduce to determine the values. Data from the different models was compared and is discussed in Chapter 6.

As is standard for the Green Star rating systems (Australia and South Africa) that calculated water use of the site is always compared to an “ideal” watering requirement for that site. For the Australian Green Star method, it is termed a Standard Practice Building, and for the South African Green Star method it is termed a Notional building. The Notional building includes what is considered as best practice for external water uses such as irrigation including water saving practices, seasonal default schedules, watering requirements and microclimate for a site the same size as the project building/site being assessed (Green Building Council of South Africa, 2014).

3.5.3. Testing of ALWUMSA using a range of scenarios

Once the model (ALWUMSA) was developed and tested on each of three test sites it was necessary to also test it against a range of scenarios for each of the three sites. Each scenario involved taking the original site input data and changing one element and in some cases several element answers to either another or the opposite answer. This allowed for ALWUMSA to be tested to ensure that modelling would predict a change in water required for the site based on whether the elements answer was changed to be positive or negative from the original site. A total of 25 different scenarios were developed and tested for each of the three sites under review. The elements for these scenarios were randomly chosen from the four broad main element categories to ensure that a range of scenarios with potential different water requirements could be observed. For the main element categories of amenity landscape and design and irrigation 5 scenarios were selected from each and for pedology and plant factors 4 elements were selected from each (as they have less listed elements).

Examples of some of the elements that were tested including the change in answer are demonstrated in Table 3.6.

Table 3.6: Examples of some of the elements that were tested.

Element that was changed	*Original answer supplied on site*	*New answer(s) tested for in the scenario*
Is bare soil on site covered by mulch (organic i.e. can it decompose)?	Yes	No
Is landscape designed by an accredited professional (correctly)?	Yes	No
Is the irrigation system set to change according to seasonal rain expectations e.g. summer vs. winter?	Yes	No
Landscape age (choose one only) If user does not know use professional judgment to decide.	Age < 3yrs	Age > 15yr
Irrigation - watering time (Choose only one the most suitable)?	10h00 to 14h00 (10am - 2pm)	18h00 to 6h00 (6pm - 6am)
Have water retention granules/polymers been added to soil on site.	No	Yes

Some testing of scenarios (best case and a worst case) involved changing more than one element in the model for example the consideration of changing those elements that were viewed as could be changed by either management or design factors. Factors such as soil type, slope, impacts adjacent buildings and predominant aspects (north, south etc.) that could not be changed by the landscape designer were left as per the results from the actual site. All other parameters that could be changed through design or maintenance were changed in a scenario first positively and then negatively. This presented both a best case scenario and a worst case scenario.

Other scenarios that were tested involved changing the location of the site. In this case all elements barring the town in which the original test site was located were changed. Changing the town meant that the effective rainfall and ETo data would change to suit that location with all other factors being constant. This was tested against four major towns namely Durban, Cape Town Port Elizabeth and Bloemfontein (noting that the ALWUMSA test sites, Block A, B and C, are situated in Tshwane).

Data from the 25 scenarios developed and produced was compared and is discussed in Chapter 6.

3.6. Specific methodology relating to Northern and Southern hemisphere referencing as well as referencing method used

Many landscaping design principles referenced in the literature review have their bearings in the northern hemisphere. The principles themselves when referenced where changed to accommodate the Southern hemisphere. For example all references requiring an understanding of orientation have been converted to accommodate Southern Hemisphere requirements. Similarly, all measurements have been converted from imperial (e.g. pounds and inches) to metric measurements (e.g. kilograms and centimetres).

The referencing system used is based on Harvard Style Referencing - Anglia Ruskin (Anglia Ruskin University, 2011).

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CHAPTER 4 – CLIMATE MAPS AND FIGURES ASSOCIATED WITH AMENITY LANDSCAPE WATER USE MODELLING

4.1. Introduction

Climatic, environmental, edaphic, landscaping, management and plant factors all impact the water use in a landscape. As a result, various pertinent factors were selected and included into the Amenity Landscape Water Use Model (ALWUMSA). As part of the ALWUMSA development process it was necessary to obtain evapotranspiration and rainfall data, which are presented in this chapter as a series of maps and figures. For ease of end user use, produced maps were created to assist with understanding monthly and seasonal changes in 160 locations/towns and/or cities (referred to as towns).

4.2. Climate

The challenge is to, where possible, develop a reference map/s that are simplistic, encourage ease of use but still being sufficiently detailed to cater for the geographical climate that influences amenity landscaping in South Africa.

For ALWUMSA specific climate maps have been developed. The maps for evapotranspiration and rainfall are linked to the specific data used in ALWUMSA. The maps themselves are aimed at providing a visual guide to the user of what rainfall and/or evapotranspiration should be anticipated for the town in question. The information supplied in these maps is considered as the most up to date and relevant data from reliable sources (Schulze, et al., 1997; Schulze, 2016; South African Weather Service, 2017) for the identified 160 towns around South Africa.

4.2.1. Potential evapotranspiration

With new or young plants evaporation accounts for around 100% with transpiration being close to 0%. As the plant matures and grows in size these figures change to being 10% evaporation and 90% transpiration (Savva and Frenken, 2002). Factors ranging from climatic constraints, characteristics of the plants, as well as management and environmental factors all influence evapotranspiration (Savva and Frenken, 2002). Stomatal conductance is intricately linked with stomatal conductance which is essential for plant growth and survival (Mu, et al., 2007). As a result of the critical role of evapotranspiration (Potential evaporation) in the landscape, it is necessary to compute and include an aspect of this, both in ALWUMSA itself, but also diagrammatically, to demonstrate its importance to model users. Evapotranspiration (ETo) varies depending on the complex diversity of the landscape, including topography, soil characteristics, type of vegetation and climate (Mu, et al., 2007). It is affected by a very broad range of on-site factors such as, crop/plant factors (species, variety and developmental stage, plant height, plant leaf surface roughness, reflectance, ground cover and plant rooting characteristics), management factors (soil salinity, poor soil fertility, use of fertilizers, hard or impenetrable soil horizons, the absence of control of diseases and pests, and poor soil management) and weather related factors (radiation, air temperature, humidity and wind speed) (Allan, et al., 1998; Pittenger and Shaw, 2013).

ETo (based on the Penman-Monteith method) data were obtained for 5 838 quinary catchments in South Africa, from Schulze, (2016). Each quinary was provided with a unique code (Schulze, 2016). A quinary can be defined as a sub-catchment of a quarternary, are associated with a 1:500 000 river reach and is a fifth level GIS catchment layer with linked hydrology (Maherry, et al., 2013). The data were determined from average ETo information gathered over a 49 year period between 1950 and 1999.

To reduce the number of quinaries and to match them to the closest town, the quinary data was overlayed and imported into ArcGIS. Towns listed as level 1 and 2 towns (based on levels preset in ArcGIS) were selected. A spatial join of quinaries (polygons), linked to each of the level 1 and 2 towns/locations, was undertaken, thus adding a new field/attribute to the data base. The spatial joining process took all the ETo figures of each of the quinaries around each selected town and calculated an average ETo figure for each town. Each town was then given the average ETo assigned to it by ArcGIS. In addition, monthly maps were created demonstrating ETo variation across Southern Africa. To improve the visual appearance of maps, some town names for example in Gauteng, that were visually positioned overlaying one another, were removed from the map only and not the data base. This would allow for a more visual pleasing map. The spatially joined ETo data was incorporated into the ETo database and indicated on the maps using various colour codes. The average figures for each of the 5838 quinaries were spatially joined for the 160 towns. In some instances only 2 quinaries were joined into a town/location, while for others (more remote locations) as many as 110 quinaries were joined. The reason for this is that the "average ETo" for that group of spatially joined quinaries would cater for an average ETo figure for all developments that could occur anywhere within these quinaries (developed as per the standard operating procedure for Rand Water GIS Department). Using the evapotranspiration figures and ArcGIS spatial joining process, as described above, for each month thematic maps (Figure 4.1 to Figure 4.5) were created where the figure legend (symbology) was based on quantified graduated colours in nine different ranges (each consisting of minimum and maximum values) (Table 4.1). The mean evapotranspiration per year for South Africa was also mapped (Figure 4.5). The extreme ranges in data expressed in Table 4.1 coincide with the ranges of monthly data received. A full set of monthly evapotranspiration maps is attached as Annexure 9. All GIS work undertaken during the study was in line with standard operating procedures at Rand Water.

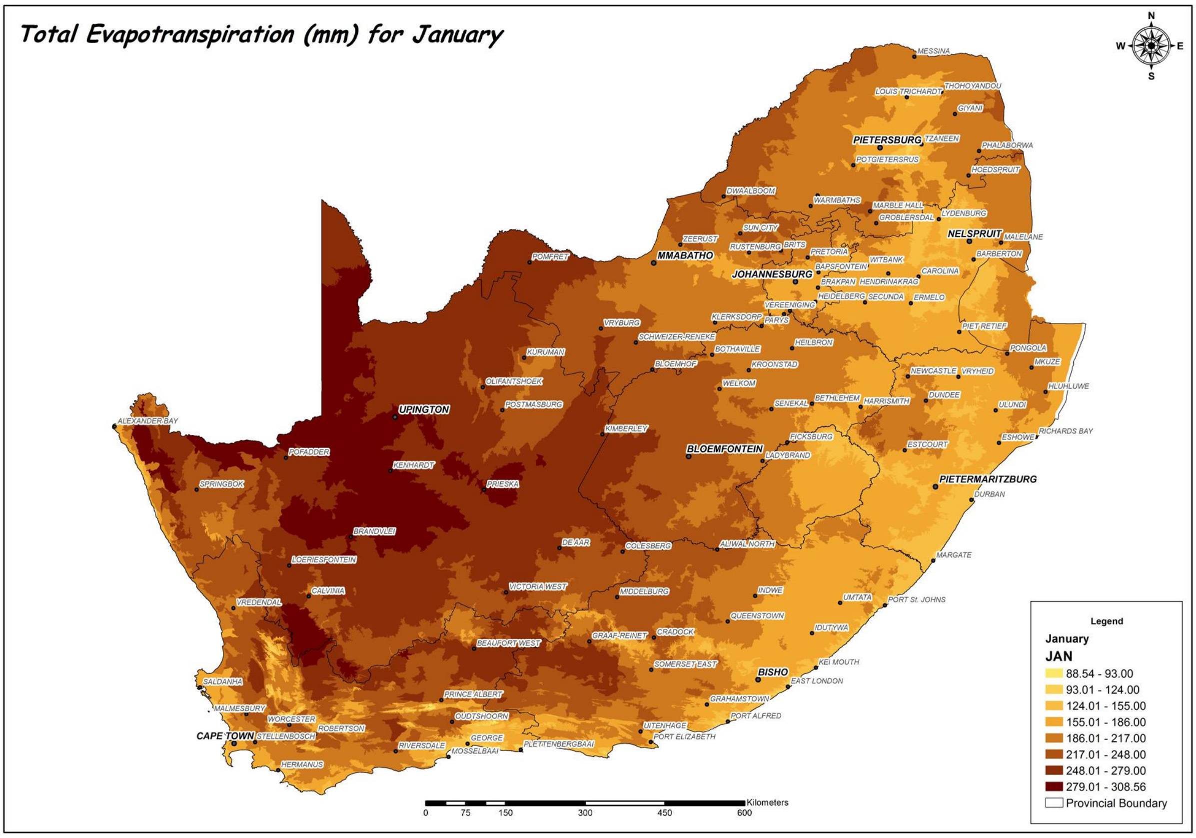

Figure 4.1: January evapotranspiration.

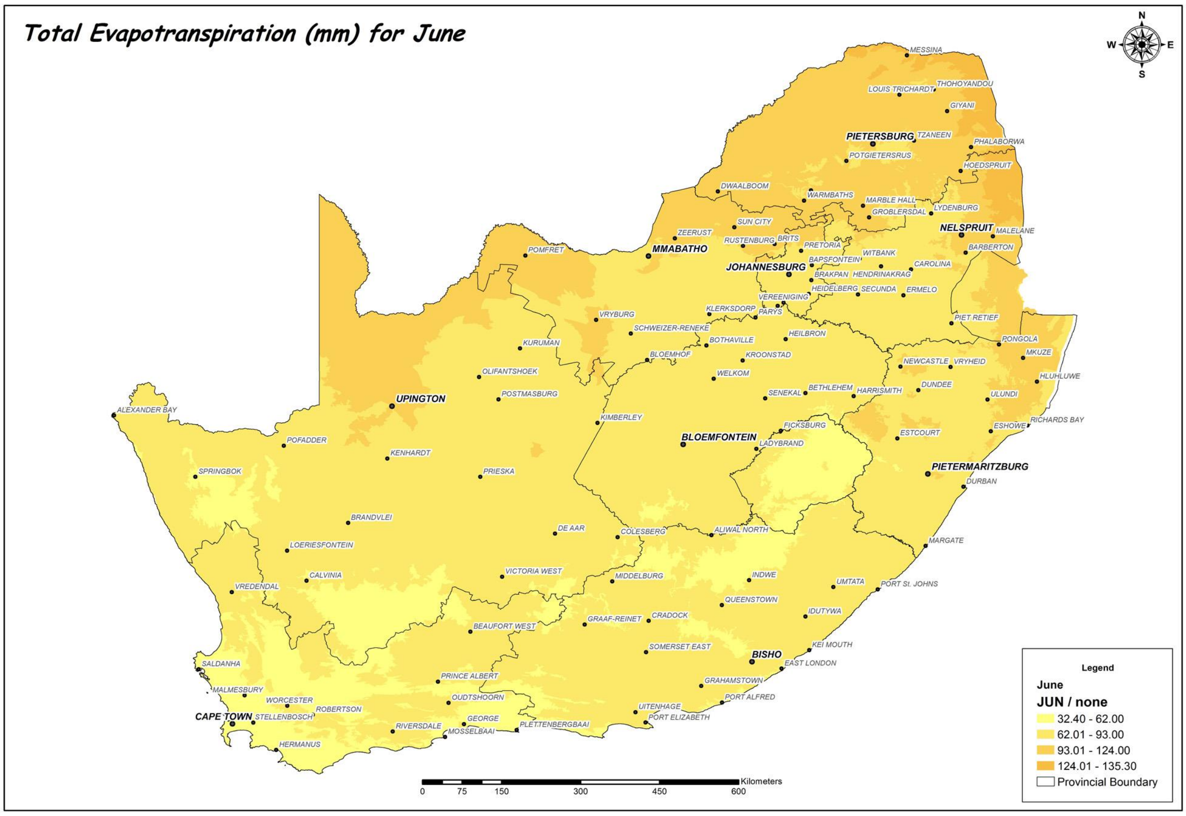

Figure 4.2: June evapotranspiration.

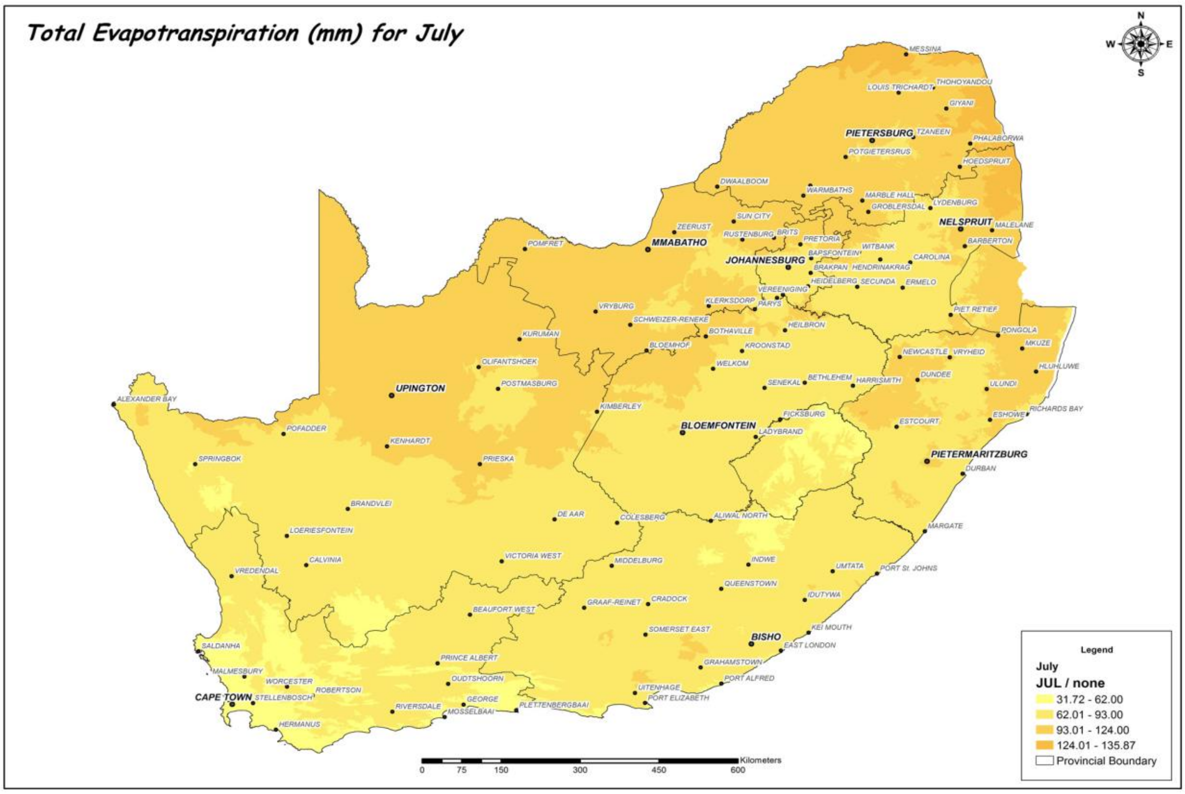

Figure 4.3: July evapotranspiration.

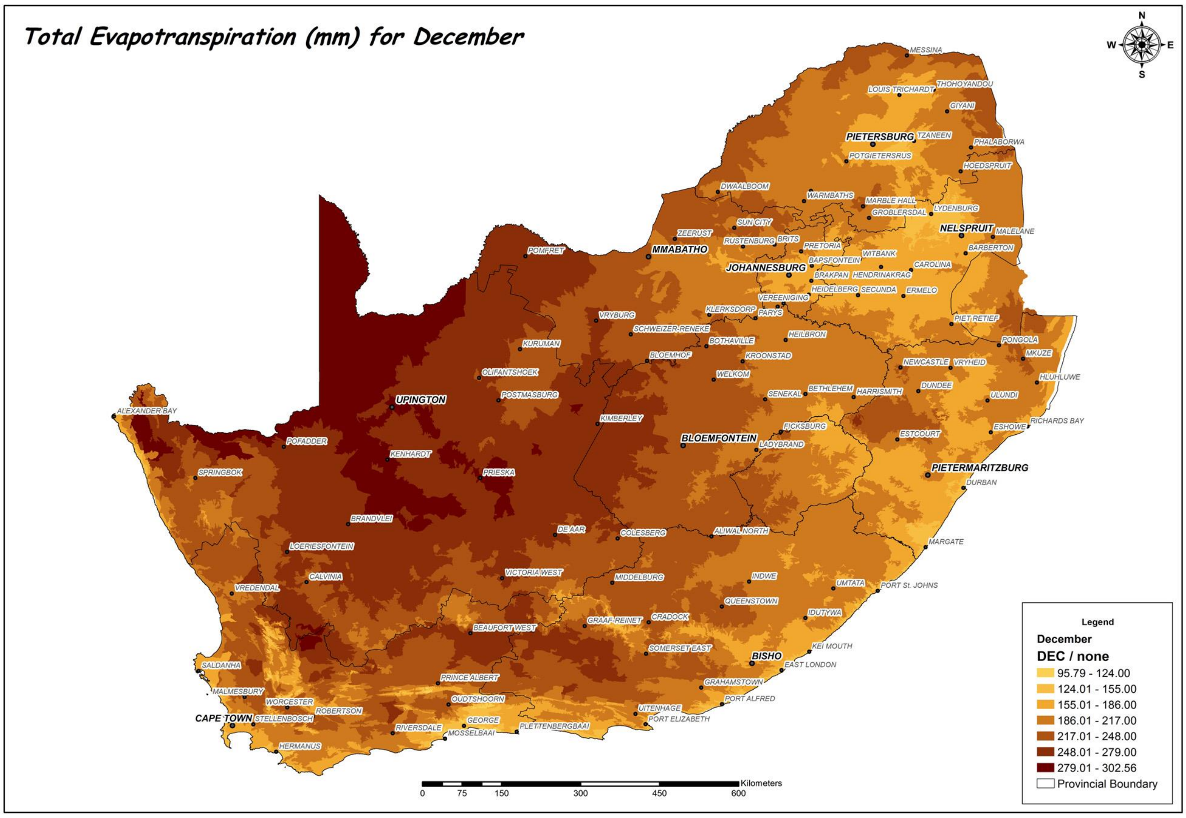

Figure 4.4: December evapotranspiration.

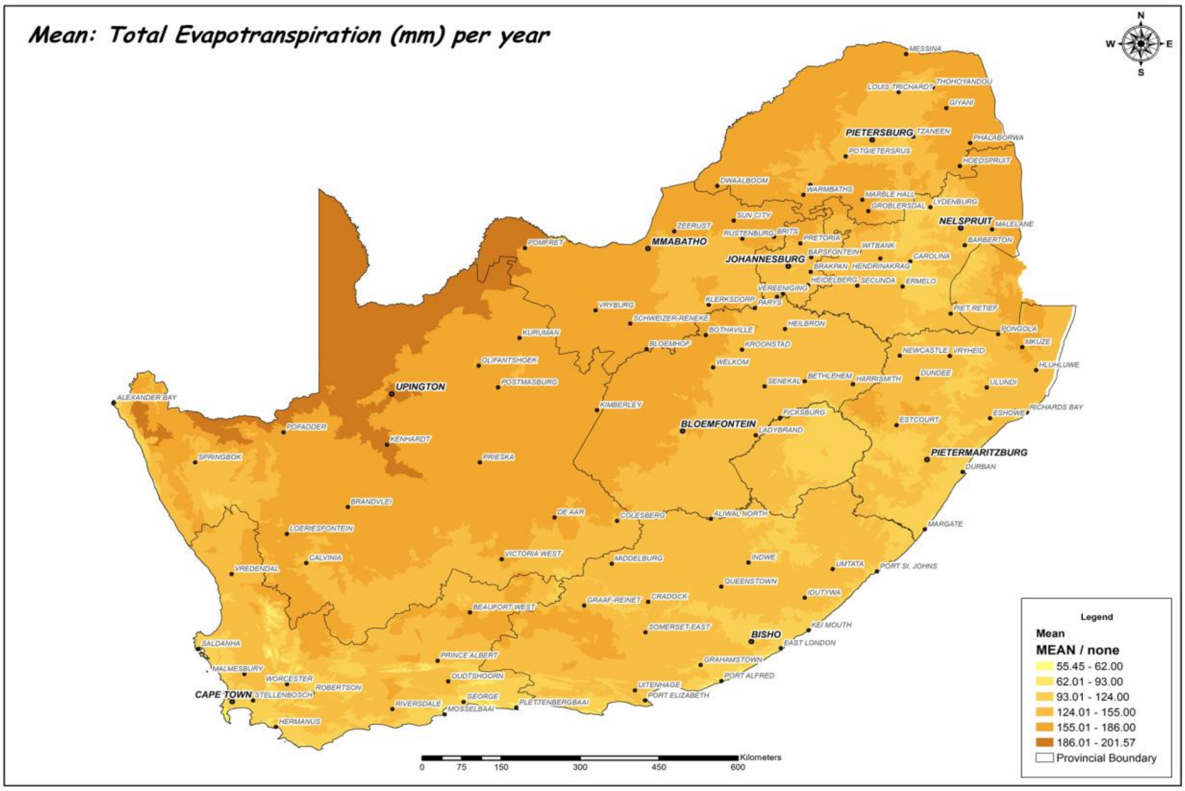

Figure 4.5: Mean evapotranspiration per year for South Africa.

Due to the ETo range varying throughout the year, the number of classes displayed on each month map varies throughout the year. The full range of ETo figures (monthly, average, annual total and mean) are attached in Annexure 6.

Table 4.1: Minimum and maximum ranges of monthly evapotranspiration.

Classes	Monthly Min and max range (mm)
1	31.01 – 62
2	62.01 – 93
3	93.01 – 124
4	124.01 – 155
5	155.01 – 186
6	186.01 – 217
7	217.01 – 248
8	248.01 – 279
9	279.01 – 310

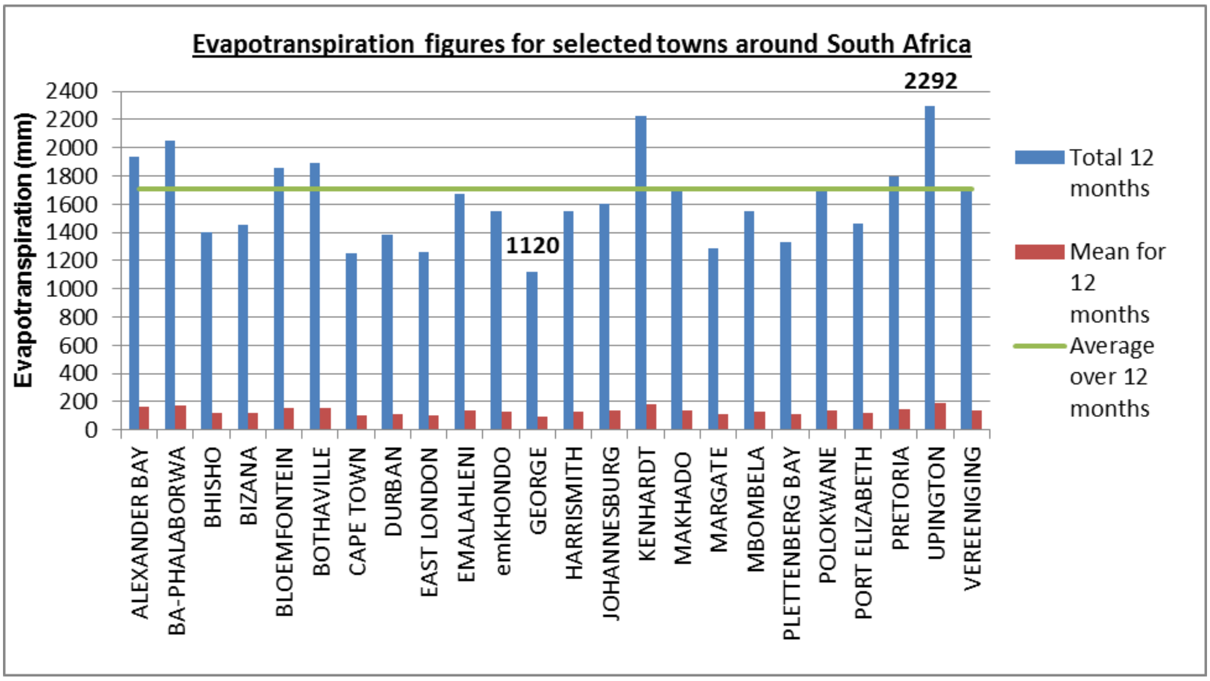

Figure 4.6: Evapotranspiration figures for selected towns around South Africa.

In assessing the ETo figures of the 160 towns selected, towns from each province have been chosen for illustration purposes (Figure 4.6). In the initial review of the data it is interesting to note that the town with the highest ETo is Upington at 2 292 mm/year (North

West) and George with the lowest at 1 120 mm/year (Western Cape), with the average ETo for all 160 towns being 1 708 mm/year (Figure 4.6).

The town with the lowest monthly ETo for any single month is Cape Town at 45 mm in June (Western Cape) and the highest monthly ETo for any single month is Kenhardt with 287.5 mm in January (Northern Cape) (Figure 4.7).

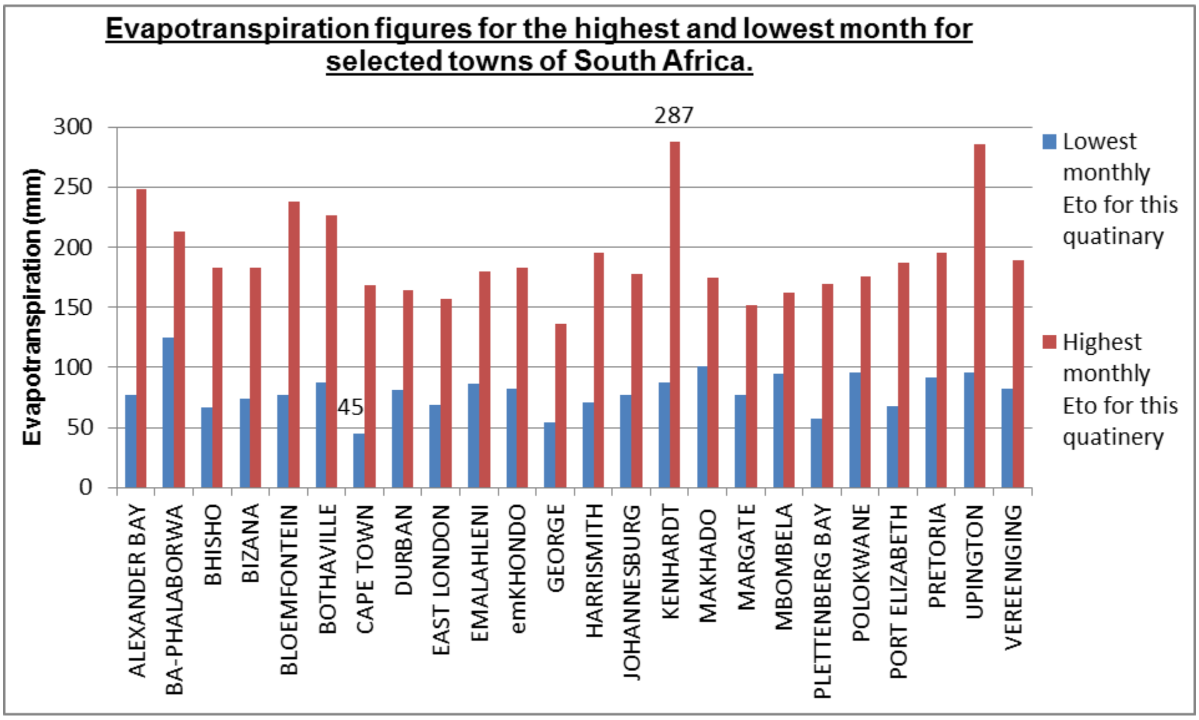

Figure 4.7: Evapotranspiration figures for highest and lowest month for selected towns of South Africa.

When considering those towns that fall within the winter rainfall period (as defined for this study) the average potential evapotranspiration rate is 1587.59 mm/annum, while for the towns catogorised in the summer rainfall period the average potential evapotranspiration rate is 1720.39 mm/annum.

4.2.2. Rainfall

Rainfall is an important component of amenity landscape functioning, plant growth and plant development. Rainfall is able to supplement the water used in a landscape, over and above water applied via irrigation sources (Shaw and Pittenger, 2009). Determining average rainfall values for various areas in South Africa allows for an average effective rainfall (available water) value to be used in a model for determining amenity landscape water use.

The effective rainfall can be described as that portion of rainfall that is available for plant root uptake and excludes rainfall that has run off the soil surface and the part that has percolated deep into the soil beyond the root zone (Natural Resources Management and Environment Department FAO, n.d.). It is important to determine effective rainfall for an amenity landscape site as this will influence possible water requirements for these sites. For this study, the model was tested at an effective rainfall rate of 50% based on information from Connellan (2002), Carrow, Duncan and Waltz, (2005) and Mccabe (2005). To ensure consistency, rainfall data was sought for the same 160 towns used for evapotranspiration determination. Average rainfall (mm) data for the period 1981 to 2010 was obtained from SAWS (South African Weather Service, 2017), for 152 of the 160 identified towns. Data for the remaining 8 towns was obtained from several web sites (Climate-Data.org, n.d.; Meteoblue, 2018; Weather2visit, 2018; Yandex Weather, 2018). These towns being Arnot, Bapsfontein, Germiston, Giyani, Gravelotte, Hoedspruit, Mmabatho (Mahikeng) and Tutuka. In some cases data were not available from the exact same sites as for the ETo town data. In these cases, the closest possible rainfall sampling station was used.

To cater for different rainfall seasons the data and thematic maps cater for summer and winter rainfall regions only (those areas that receive either predominant rainfall in summer or winter). The duration of each season was taken from South African Weather Service (2018). For ease of producing data and monthly maps, the seasons were limited to specific months as depicted in Table 4.2. The total amount of rain for the summer and winter rainfall regions was determined for each season. Based on rainfall data, the summer rainfall region receives 52% of its rain in the designated summer months and 25% in spring, whilst the winter rainfall region receives only 37% of its rain in the designated winter months, with 28% of the rainfall in summer (Table 4.2).

Rainfall regions that receive “all-year round” rainfall have been classified into the summer rainfall region. To guide the end user, monthly tables were produced, based on the percentage rain received for a season. This provides an estimate of the anticipated average rainfall that could be received for that area for that month/season. This should allow for basic visual guidance to plan for watering requirements for each hydrozone (Table 4.3).

Table 4.2: Amount of rain received per season for summer and winter rainfall regions.

Breakdown of Seasons.	Percentage (%) of time of year for this season	Percentage of rain received in this season (based on total for **summer** rainfall towns)	Percentage of rain that received in this season (based on total for **winter** rainfall towns)	Percentage of all rain received in this season.
Summer = 13 weeks (1 December - 28/29Feb)	25%	52%	28%	51%
Autumn = 13 weeks (1 March - 31 May)	25%	20%	25%	20%
Winter = 13 weeks (1 June -31 August)	25%	6%	37%	9%
Spring = 13 weeks (1 Sept -30 Nov)	25%	25%	20%	24%

By taking information from Table 4.3 and comparing it to maps in Annexure 10 and Figures 4.8 to 4.16, it is possible to obtain a guide for water requirements of the amenity landscape. By way of example for the summer rainfall region for Gauteng, considering (Annexure 10 - March), the rainfall is anticipated to be equivalent to what is generally required by high hydrozone plants in that month. This implies that no watering should be required in all zones. Similarly, for Gauteng, in July (Fig 4.10) the rainfall is anticipated to be equivalent to what is generally required by low hydrozone plants in that month. This implies that watering should be required in the medium and high hydrozone. Also, for the winter rainfall region, rainfall in Cape Town in July (Fig 4.14) is anticipated to be equivalent to what is generally required by medium hydrozone plants in that month. This implies that watering should be required in the high hydrozone only. These estimates exclude any other determinants including effective precipitation (at 50%).

Using rainfall figures for each month, thematic maps representing summer rainfall regions (Figure 4.8 to Figure 4.11, and Annexure 10), as well as thematic maps representing winter rainfall regions (Figure 4.12 to Figure 4.15, and Annexure 10), and mean annual rainfall (Figure 4.16) were created. The hydrozone rainfall information from Table 4.3 (linked to the mean lowest and mean highest rainfall figures) was correlated and expressed in Figure 4.16.

Table 4.3: Monthly summer, winter and annual precipitation figures linked to hydrozone data.

Hydrozone	Summer rainfall region				Winter rainfall region				Hydrozone	Annual rainfall
	Dec - Feb (mm/month)	March - May (mm/month)	June - Aug (mm/month)	Sept - Nov (mm/month)	Oct-Feb	March-April	May- July	Aug-Sept		Jan - Dec
No water (No watering required unless in extreme cases.)	0 to 52.0mm				0 to 28.0mm				No water	0 - 300
		0 to 20.0mm				0 to 25.0mm				
			0 to 6.0mm				0 to 37.0mm			
				0 to 25.0mm				0 to 20.0mm		
Low	52.01 to 86.67mm				28.01 to 46.67mm				Low	300,1 - 500
		20.01 to 33.33mm				25.01 to 41.67mm				
			6.01 to 10.0mm				37.01 to 61.67mm			
				25.01 to 41.67mm				20.01 to 33.33mm		
Medium	86.68 to 130.0mm				46.68 to 70.0mm				Medium	500,1 - 750
		33.34 to 50.0mm				41.68 to 62.50mm				
			10.01 to 15.0mm				61.68 to 92.50mm			
				41.68 to 62.50mm				33.34 to 50.0mm		
High	130.01 to >130.01mm				70.01 to >70.01mm				High	750,1 - >750,1
		50.01 to >50.01mm				62.51 to >62.51				
			15.01 to >15.01mm				92.51 to >92.51mm			
				62.51 to 62.51mm				50.01 to >50.01mm		

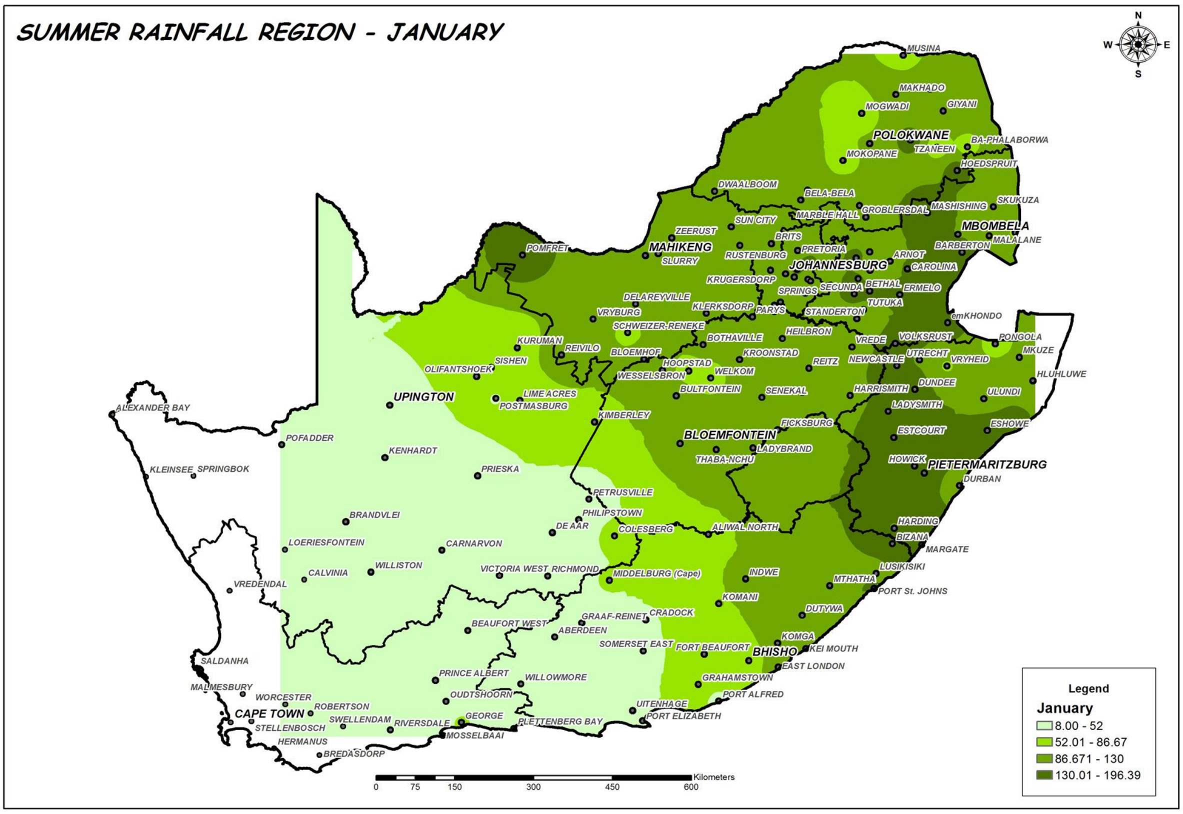

Figure 4.8: January summer rainfall region (monthly average rainfall & hydrozone data).

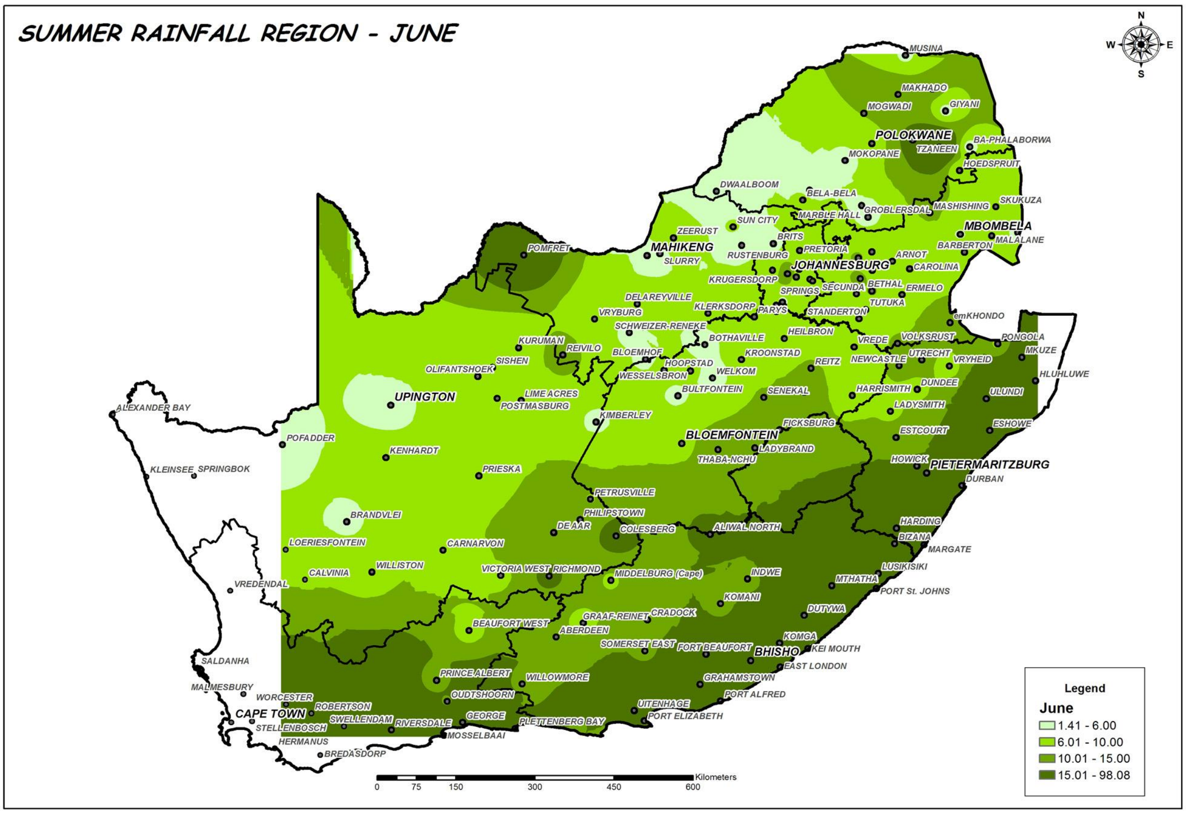

Figure 4.9: June summer rainfall region (monthly average rainfall & hydrozone data).

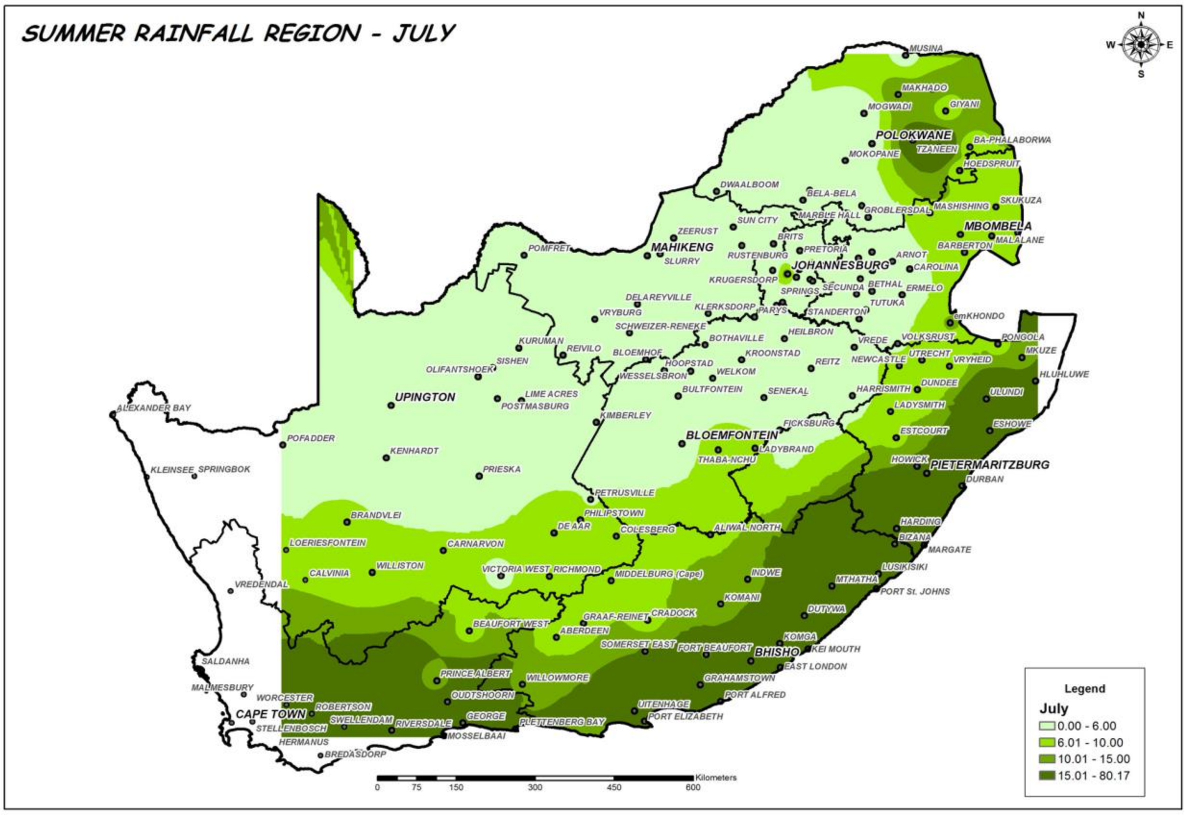

Figure 4.10: July summer rainfall region (monthly average rainfall & hydrozone data).

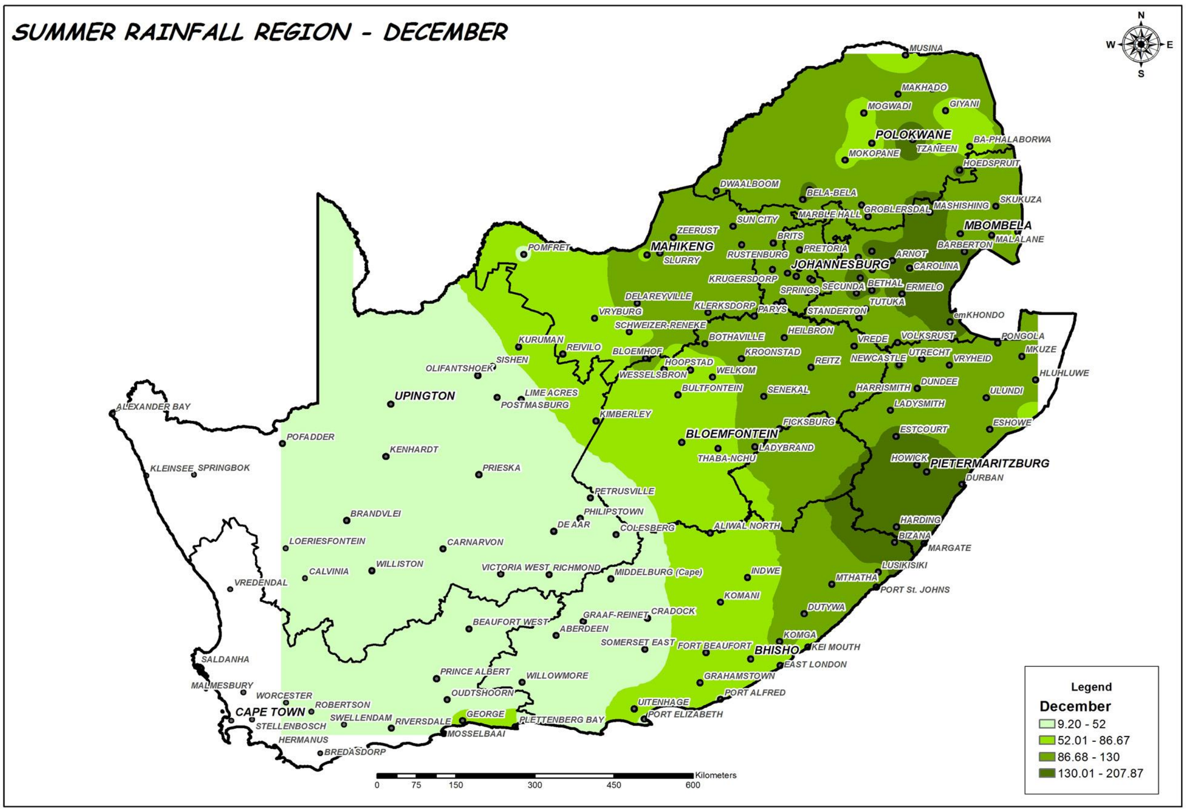

Figure 4.11: December summer rainfall region (monthly average rainfall & hydrozone data).

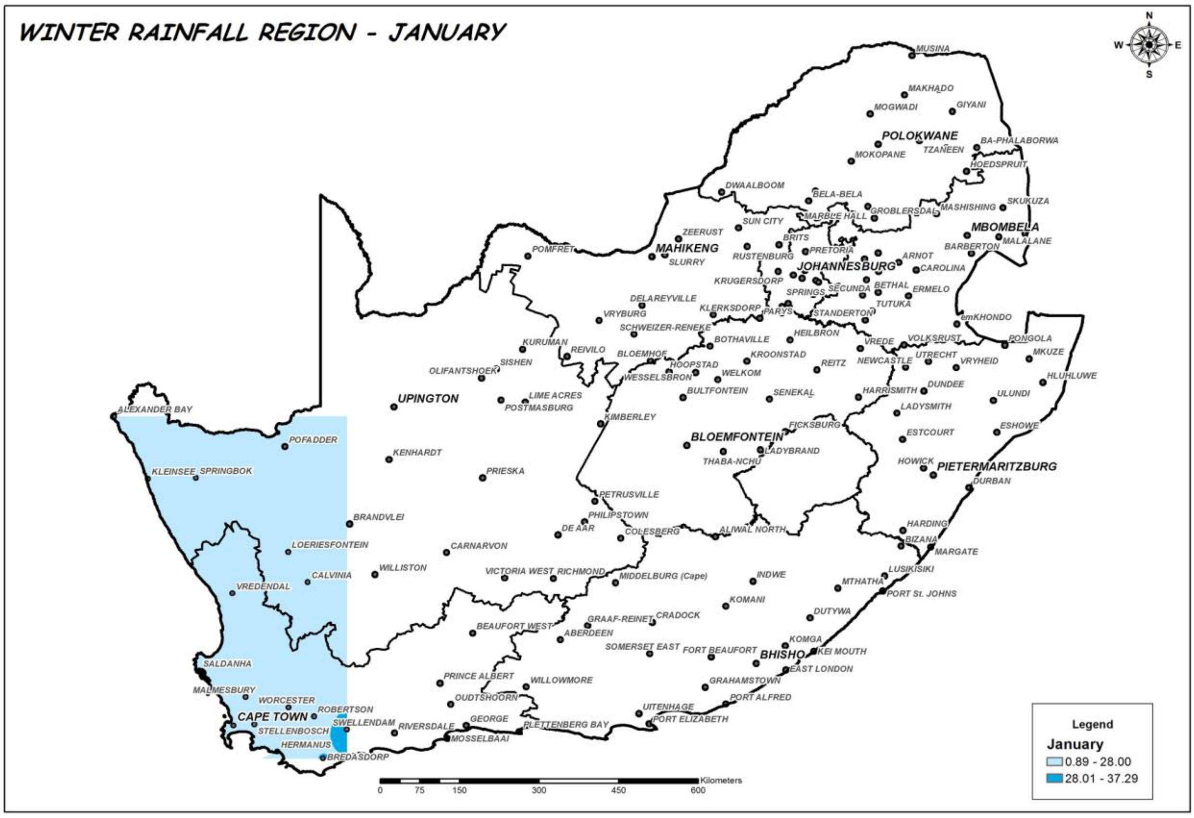

Figure 4.12: January winter rainfall region (monthly average rainfall & hydrozone data).

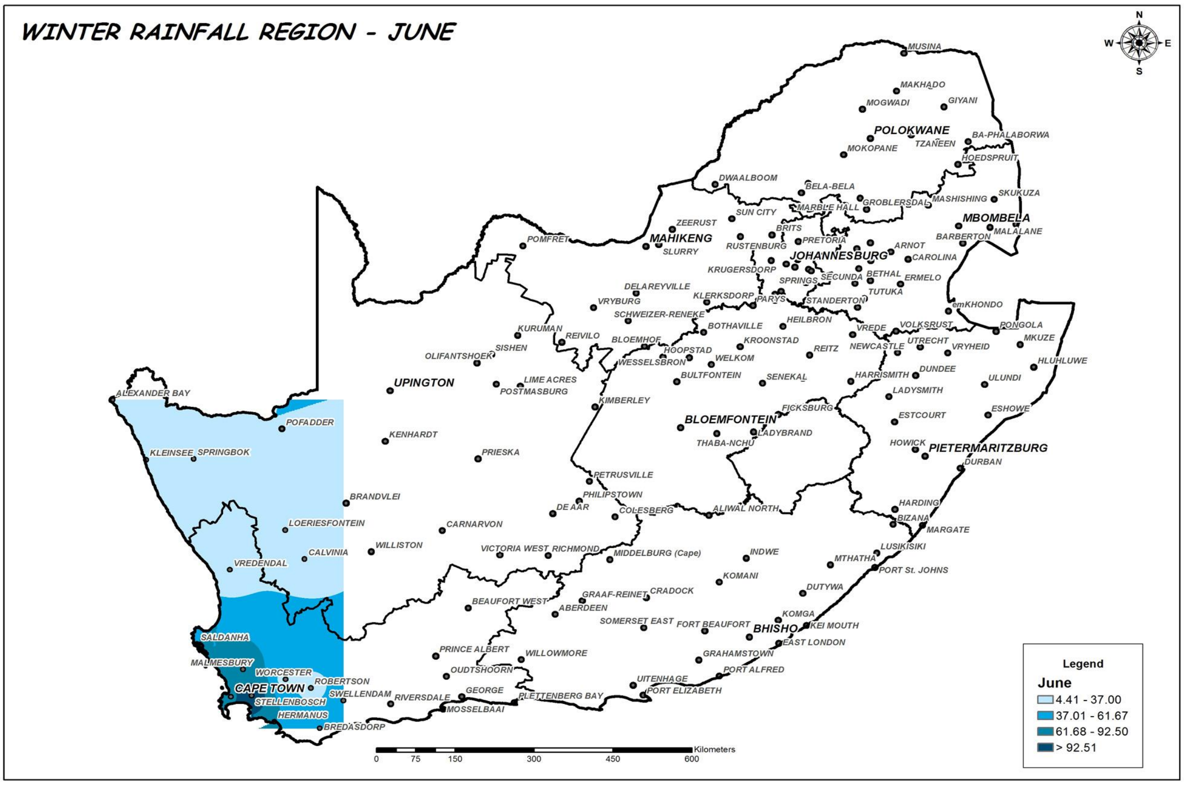

Figure 4.13: June winter rainfall region (monthly average rainfall & hydrozone data).

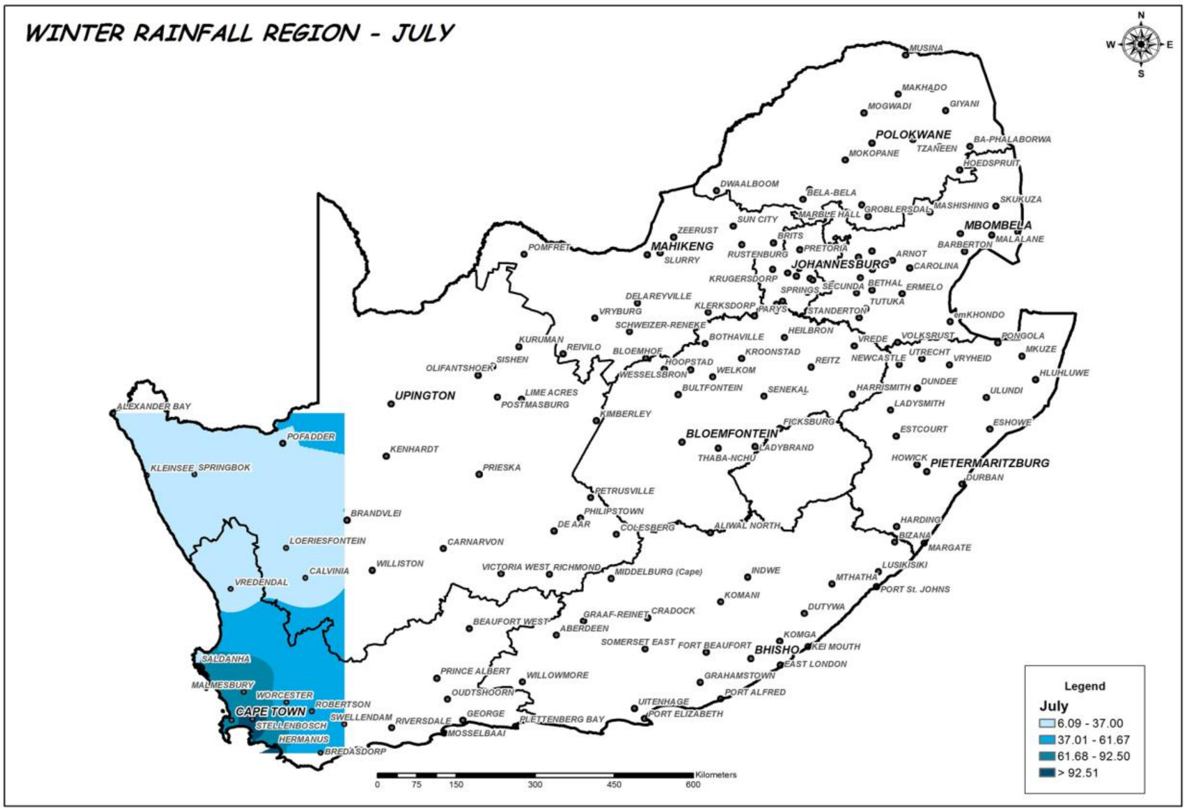

Figure 4.14: July winter rainfall region (monthly average rainfall & hydrozone data).

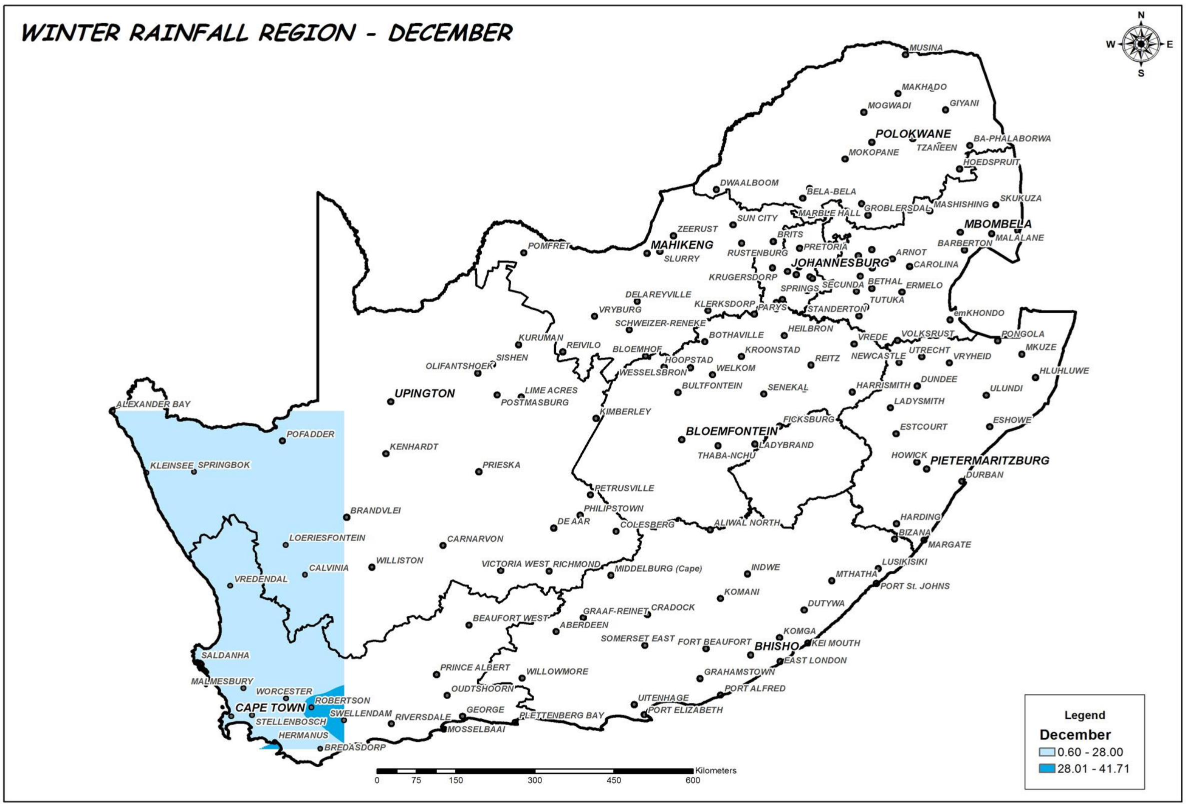

Figure 4.15: December winter rainfall region (monthly average rainfall & hydrozone data).

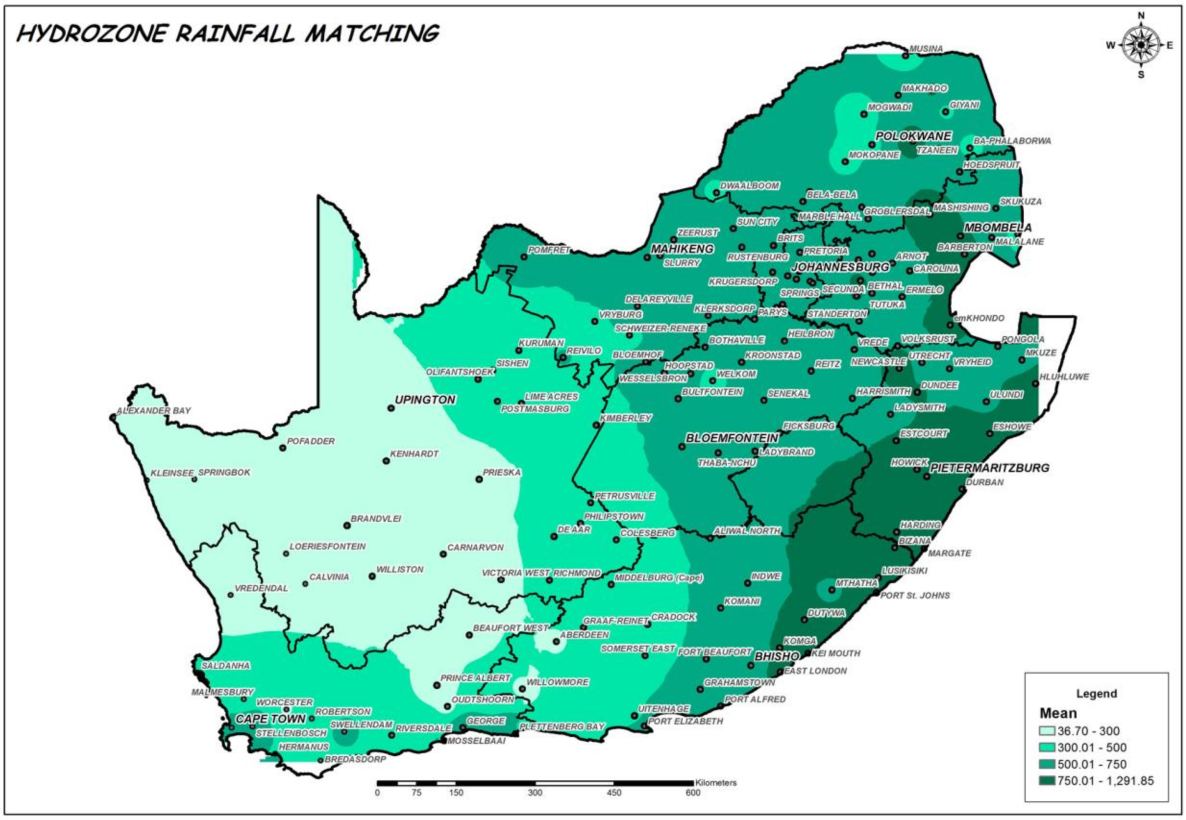

Figure 4.16: Mean rainfall per year for South Africa linked to hydrozone data.

Of the 160 towns used in the database, a total of 15 of the towns are listed in the winter rainfall season (Annexure 8), while the remaining 145 were listed in the summer rainfall season (Annexure 7). This aspect was not applied to the evapotranspiration.

Monthly summer, winter and annual precipitation figures were linked to hydrozone data which was classified into four groups as per the Table 4.3 and relevant colours were applied to achieve the final map. To produce a map of the entire South Africa that exhibited a complete colour gradient across the entire region, it would be necessary to have data for points outside of the continent. The Arch GIS system used was not able to interpolate data for these missing areas. As a result, some minor areas such as far northern Limpopo, far eastern Kwazulu Natal, far southern Western Cape and far northern area of the Northern Cape are not able to display the relevant colours matched to Hydrozones.

The four different colour ranges used on the maps (each consisting of minimum and maximum values) (Table 4.4), were matched to suite the hydrozone definition as supplied by Rand Water's Standard Operating Procedures (SOP) (Rand Water, n.d.; Hoy, et al., 2017), and adapted for this study (Tables 4.4 and 4.5). Due to the rainfall range varying throughout the year, the number of classes displayed on each month's map (Figure 4.8 to 4.15) varies throughout the year. The full range of rainfall figures (monthly, average, annual total and mean) are attached in Annexure 7 and 8.

Table 4.4: Parameters used for mean annual rainfall figures.

Hydrozone	Definition
No water	Receive less than 300 mm rainfall per annum. Water in severe dry situations.
Low	Receive annual rainfall of between 300 – 500 mm rainfall. Water every 6-8 weeks.
Medium	Receive between 500 - 750 mm rainfall a year. If they show signs of distress in dry times water. Water once a month in winter.
High	Receive over >750 mm of annual rainfall. Water once a week in general, and two or three times a week during very hot dry spells.

Table 4.5: Parameters used for mean monthly annual rainfall figures.

Hydrozone	Definition for summer rainfall areas	Definition for winter rainfall areas
No water	No watering required unless in extreme cases.	No watering required unless in extreme cases.
Low	Summer-12 mm/week Spring/Autumn-7 mm/week Winter-12 mm every second week (including lawns but not at all if dormant)	Winter-12 mm/week Spring/Autumn-7 mm/week Summer-12 mm every second week (including lawns but not at all if dormant)
Medium	Summer-15 mm/week Spring/Autumn-12 mm/week Winter-7 mm/week	Winter-15 mm/week Spring/Autumn-12 mm/week Summer-7 mm/week
High	Summer-25 mm/week Spring/Autumn-15 mm/week Winter-12 mm/week	Winter-25 mm/week Spring/Autumn-15 mm/week Summer-12 mm/week

Analyses of selected summer rainfall region towns, indicates that Bizana in the Eastern Cape has the highest rainfall of 208.4 mm for December, and Ba-Phalaborwa in Limpopo has the lowest rainfall of 0.1 mm for August (Figure 4.17).

Analyses of selected winter rainfall region towns to determine which have the highest and lowest average monthly rainfall, indicates that Stellenbosch in the Western Cape has the highest rainfall of 124.0 mm for June, and Alexander Bay in Northern Cape has the lowest rainfall of 0.6 mm for December (Figure 4.17). Refer to Annexure 7 for the average rainfall data for the summer rainfall region for each of the level 1 or 2 towns selected in South Africa and Annexure 8 the average rainfall data for the winter rainfall region for each of the level 1 or 2 towns selected in South Africa.

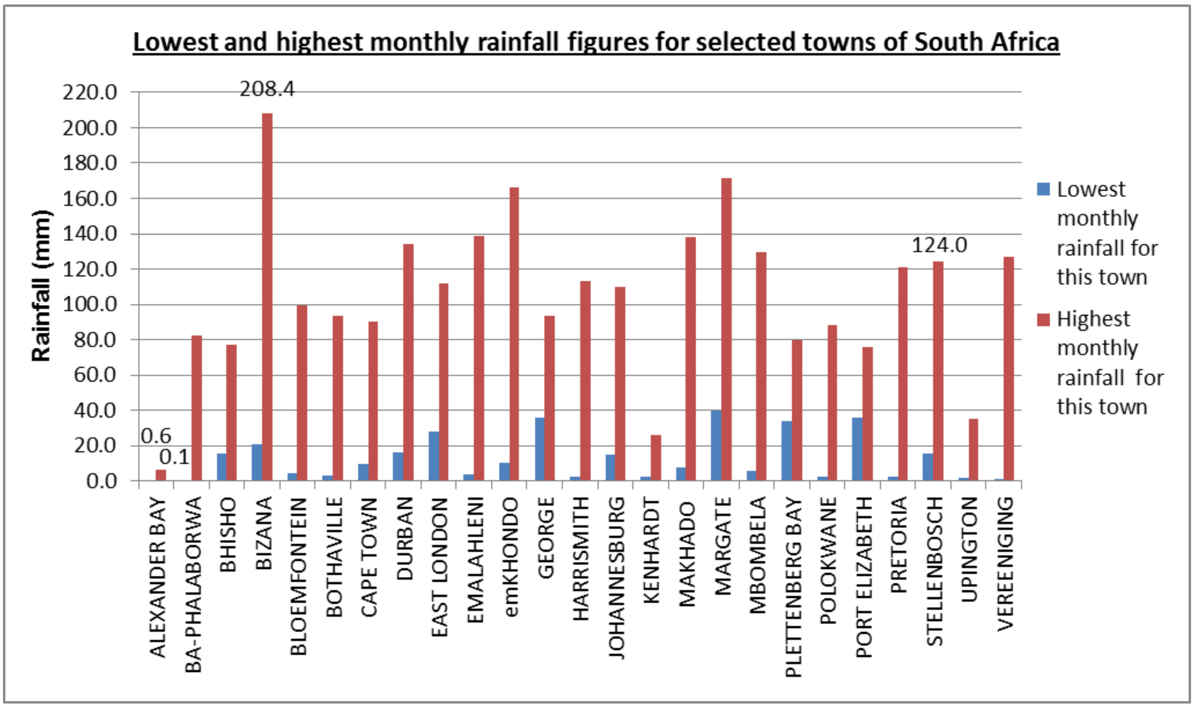

Figure 4.17: Lowest and highest monthly rainfall figures for selected towns in South Africa.

Rainfall figures for South Africa reveal that the town with the highest average annual rainfall is Margate in Kwazulu Natal, found in the summer rainfall region, with 1294.1 mm, and the town with the lowest average annual rainfall is Alexander Bay in the Northern Cape, found in the winter rainfall region, with a 36.6 mm (Figure 4.18).

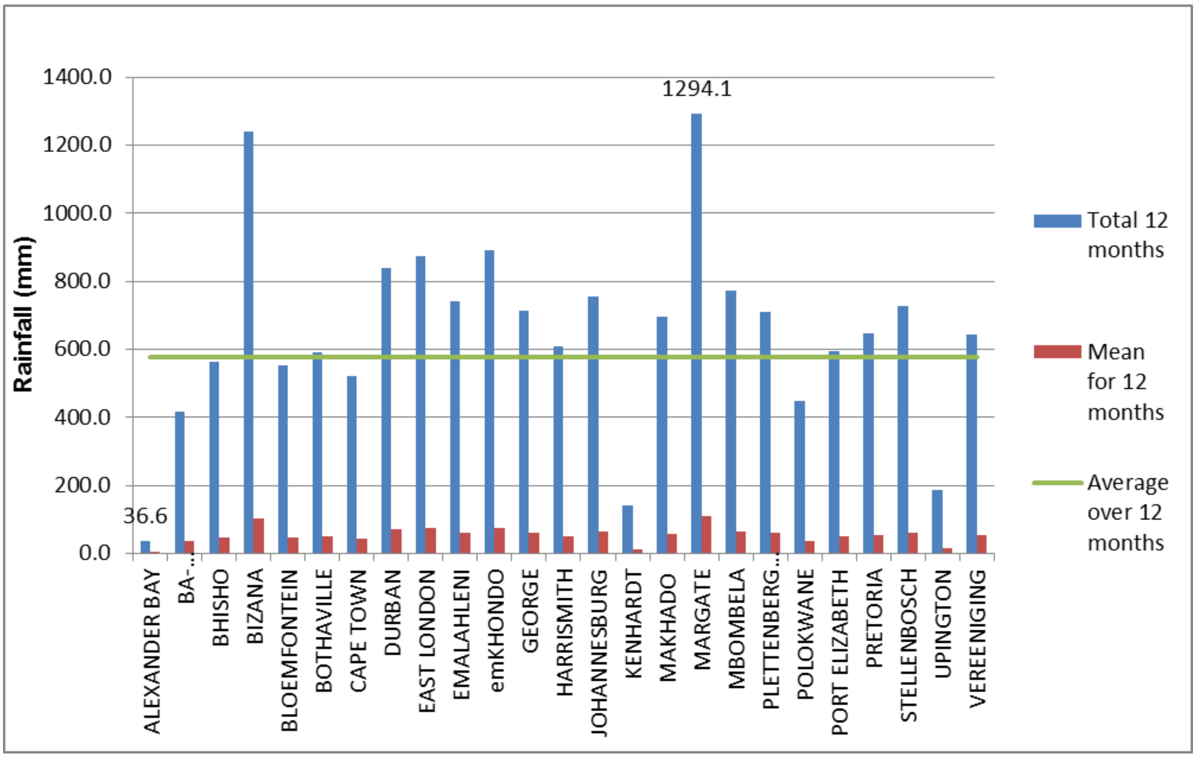

Figure 4.18: Rainfall figures for selected towns in South Africa (based on annual data).

4.2.3. Rainfall compared to evapotranspiration

Of the rain that falls (based on a range of site and environmental factors), only between 44% and 75% is available for plant use (McCabe, 2005; Du Plessis, 2014). Evapotranspiration results in further loses of available soil moisture. It is important to understand the dynamics of rainfall and evapotranspiration for South Africa as this impacts amenity landscapes. Of the 160 towns used in the study, selected towns (25) were used for analyses, some towns represent the main metropolitans (e.g. Johannesburg, Pretoria, Cape Town, Durban and Bloemfontein), whilst others represent areas that receive the highest and lowest rainfall (e.g. Margate and Alexander Bay) or those that receive/experience the highest and lowest evapotranspiration (e.g. Upington and George). Alexander Bay receives only 36.6 mm of rain per annum, while it experiences 1938.4 mm of evapotranspiration (rainfall being 2% of evapotranspiration) compared to Margate which receives 1294.1 mm of rainfall and experiences 1285.3 mm of evapotranspiration per annum (rainfall being 101% of evapotranspiration)(Table 4.6).

Table 4.6: Comparison of rainfall and evapotranspiration for 25 of the 160 towns.

Evapotranspiration compared to rainfall					
Province	**TOWN**	**Total evapotranspiration 12 months**	**Total rainfall 12 months**	**Difference, rainfall minus evapotranspiration**	**Percentage rainfall of ETo**
Northern Cape	ALEXANDER BAY	1938.4	36.6	-1901.8	2%
Limpopo	BA-PHALABORWA	2053.9	416.5	-1637.4	20%
Eastern Cape	BHISHO	1397.6	564.2	-833.4	40%
KwaZulu-Natal	BIZANA	1450.5	1239.1	-211.4	85%
Free State	BLOEMFONTEIN	1853.8	551.7	-1302.1	30%
Free State	BOTHAVILLE	1894.3	590.3	-1304.0	31%
Western Cape	CAPE TOWN	1250.4	522.7	-727.7	42%
KwaZulu-Natal	DURBAN	1385.7	840.0	-545.7	61%
Eastern Cape	EAST LONDON	1259.4	873.6	-385.8	69%
Mpumalanga	EMALAHLENI	1673.6	742.8	-930.8	44%
Mpumalanga	emKHONDO	1546.7	889.8	-656.9	58%
Western Cape	GEORGE	1120.3	714.4	-405.9	64%
Free State	HARRISMITH	1547.1	609.3	-937.8	39%
Gauteng	JOHANNESBURG	1604.8	755.1	-849.7	47%
Northern Cape	KENHARDT	2226.2	140.6	-2085.6	6%
Limpopo	MAKHADO	1686.2	694.8	-991.4	41%
KwaZulu-Natal	MARGATE	1285.3	1294.1	8.8	101%
Mpumalanga	MBOMBELA	1552.0	773.1	-778.9	50%
Western Cape	PLETTENBERG BAY	1331.3	709.1	-622.2	53%
Limpopo	POLOKWANE	1687.4	447.5	-1239.9	27%
Eastern Cape	PORT ELIZABETH	1458.0	595.8	-862.2	41%
Gauteng	PRETORIA	1798.0	647.2	-1150.8	36%
Western Cape	STELLENBOSCH	1361.5	727.7	-633.8	53%
Northern Cape	UPINGTON	2291.8	186.7	-2105.1	8%
Gauteng	VEREENIGING	1689.1	644.8	-1044.3	38%
Average		1613.7	648.30	-965.4	40%

When comparing the metropolitans of Cape Town, Durban, Port Elizabeth, Johannesburg and Pretoria, in all cases the total annual evapotranspiration rate exceeds the expected total annual rainfall (Figure 4.10). When assessing all 25 towns, only one has a higher total annual rainfall than the total annual evapotranspiration, that being Margate with total annual evapotranspiration of 1285.0 mm and a total annual rainfall of 1294.1 mm. The average evapotranspiration rate for all 160 chosen towns is 1707.94 mm, whilst the average rainfall for these same towns being 648.0 mm, this results in a 40% deficit on rainfall alone for these towns (this does not take effective rainfall into account). This supports statements that evapotranspiration rate is on average higher than rainfall (The Department of Water Affairs, 1986; King, Mitchell and Pienaar, 2011), indicating that evapotranspiration has the potential to negatively impact on plant growth and health. Also (Du Plessis, 2014), for a rain period when evapotranspiration exceeds rainfall the, soil water reserve cannot be built up and plants that rely on rainwater alone could become stressed.

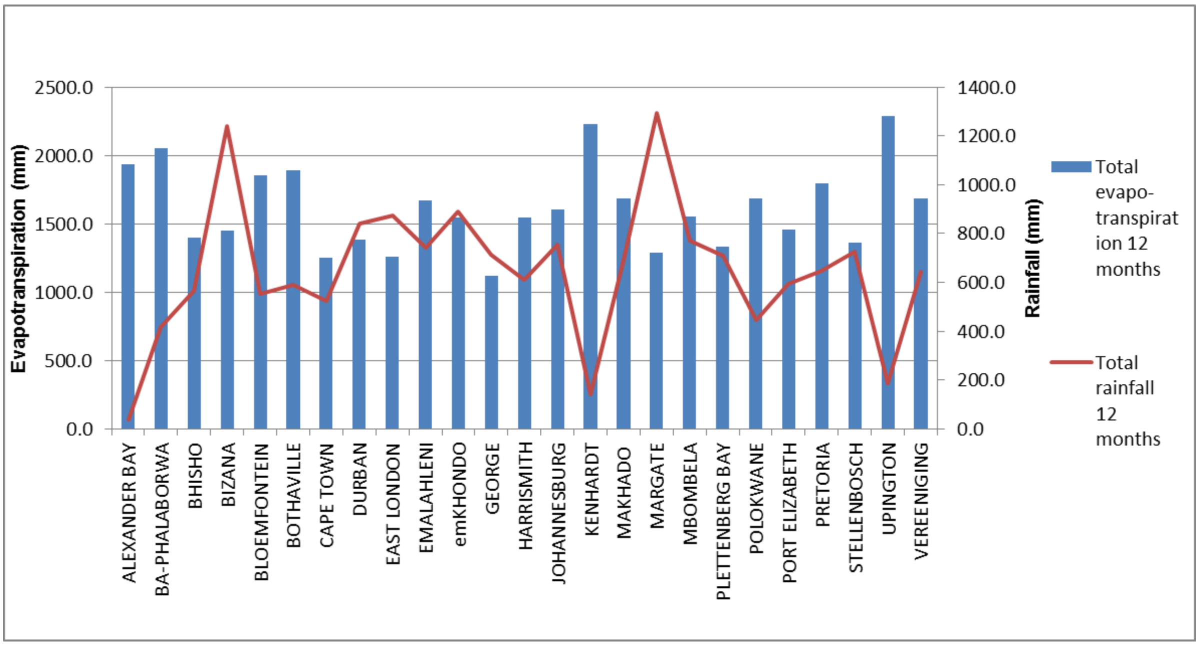

Figure 4.19: Comparison of evapotranspiration with rainfall data of selected towns around South Africa.

Hence evapotranspiration rate reduces the amount of rainfall available for plant root uptake and will influence water availability as observed for the data provided for towns (Table 4.6). Examples of annual average data extrapolated for three major towns in different areas of the country where amenity landscape require supplementary watering, are Johannesburg (Figure 4.20), Cape Town (Figure 4.21) and Durban (Figure 4.22). For these towns, rainfall is noticeably lower than evapotranspiration rate, negatively influencing soil water availability to the detriment of amenity landscapes. Evapotranspiration for the example of a winter rainfall town (Figure 4.21) is lower than the anticipated rainfall during the winter rainfall season, while evapotranspiration for examples of summer rainfall region towns (Figure 4.20 and Figure 4.22) is conversely lower than the expected rainfall during the summer rainfall season. This implies that during the peak rainfall season, when plants in summer or winter rainfall regions are actively growing and receiving rain, the water deficit (in those months at least) is negligible or non-existent. For endemic plants and exotic plants chosen to suit a particular natural climate region of the amenity landscape, the need for water in the dormant period (summer for winter rainfall region and winter for the summer rainfall region), is reduced to the plants being in a dormant phase. Hence, in some cases, more specifically relevant to deciduous plants and bulbous type plants, water use is considerably reduced and excessive evapotranspiration rates in the dryer season may not negatively impact plant growth.

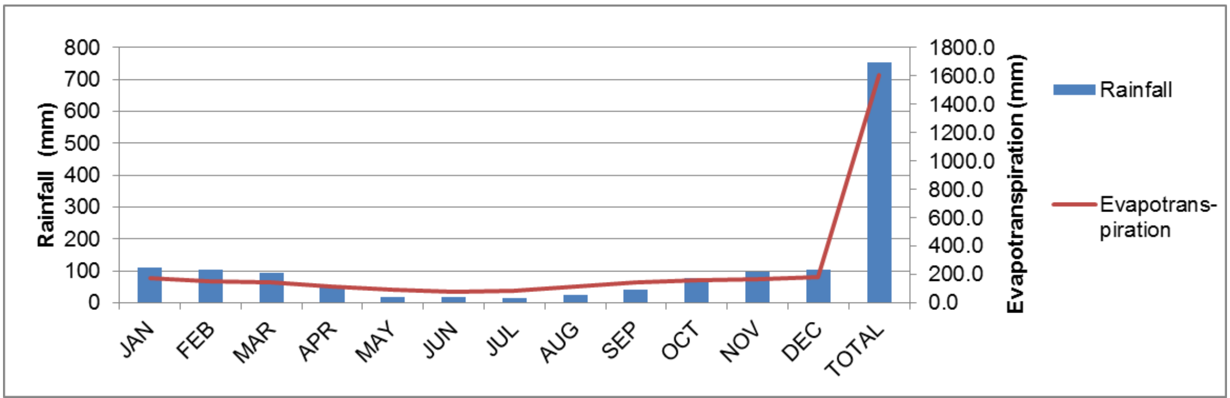

Figure 4.20: Average rainfall and evapotranspiration data for Johannesburg.

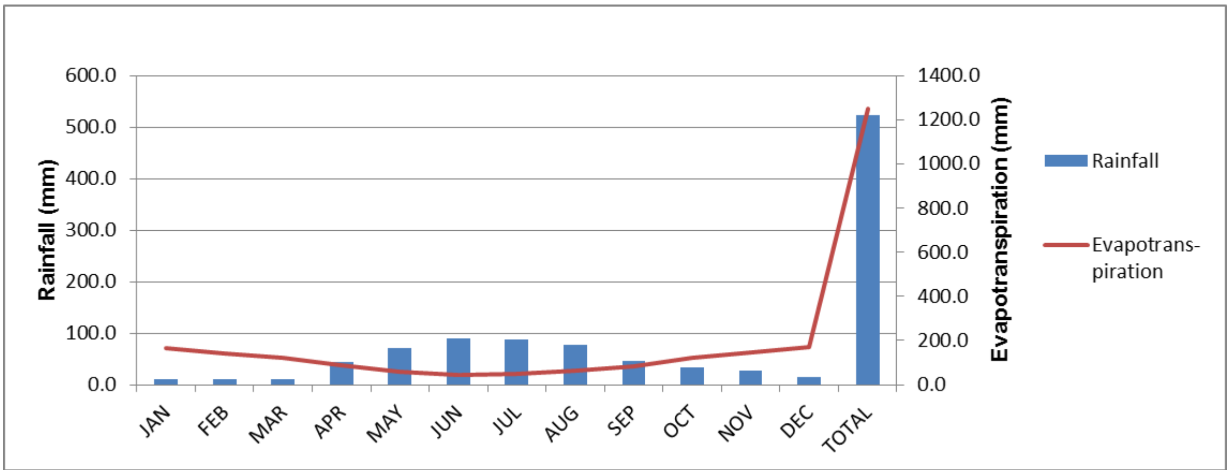

Figure 4.21: Average rainfall and evapotranspiration data for Cape Town.

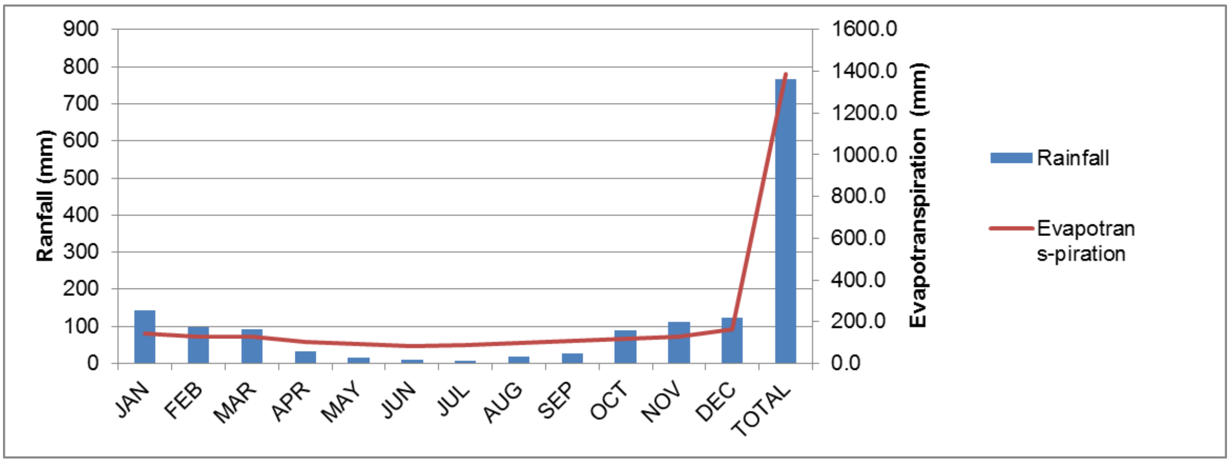

Figure 4.22: Average rainfall and evapotranspiration data for Durban.

4.3. Discussion and conclusion

Data sourced for this study corroborates the standing body of knowledge indicating that for South Africa evapotranspiration outstrips rainfall (Tyson, 1986; CSIR, 2010). For the 160 chosen towns in South Africa for this data base, the average rainfall (574.8 mm/year) is 34% of the average evapotranspiration (1 707.9 mm/year) leaving a shortfall of 66% water required for plant use (this does not consider effective rainfall). For the winter rainfall towns the average rainfall is 347.8 mm per year which ranges 0.6 mm (in December for Alexander Bay) to a high of 124.0 mm (in June for Stellenbosch). While the summer rainfall towns have an average of 598.3 mm per year which ranges from 0.0 mm (in July for Reivilo) to a high of 208.4 mm (in December for Bizana). This compared to the average potential evapotranspiration for the winter rainfall towns of 1587.59 mm/annum and 1720.39 mm/annum for summer rainfall towns.

This all points to the need for appropriate amenity landscape design, hydrozoning and management (Wade, et al., 2007) to ensure that plant choice and sites accommodate for these drastic changes in plant water availability (Stabler and Martin, 2004). It is critical that for any amenity landscape sites in South Africa, these two factors must be considered and incorporated into any water use models to ensure that a sustainable amenity landscape is achieved. Added to this, is the shortfall of water required by plants, which needs to be addressed in the design, environmental factors, edaphic factors, irrigation system and site management of amenity landscapes (Martin, 2001; Wade, et al., 2007).

This database of both potential evapotranspiration (based on the Penman-Montein) methodology and the rainfall for 160 towns around South Africa is the largest combined database currently produced with amenity landscapes in mind.

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CHAPTER 5 – PLANT DATABASE AND HYDROZONES ASSOCIATED TO LANDSCAPE WATER USE MODELS

5.1. Introduction

There is currently no single common database of plants that can be used by amenity landscapers, landscape architects, wholesale nursery growers, horticulturists and nurseries/garden centres in South Africa, linking commonly grown/sold plants to specific hydrozones. Hydrozones can be described as a landscaped area consisting of plants with similar water needs that are served by one irrigation valve or set of valves with the same watering schedule (University of California Cooperative Extension California Department of Water Resources, 2000). The concept of landscaping using hydrozones as described above and linking this to all aspects of an amenity site is also not commonly used across South Africa. These are an important and currently lacking necessity within amenity landscaping and the Green Industry. These aspects form a critical foundation and principle of determining correct water use and application of plants within the amenity landscape. They will also assist in reducing amenity landscape water use if applied correctly which will support the need to save water, as South Africa faces ever more challenges with regards to water availability.

A range of different species of plants are naturally found in diverse biomes and in areas of varying rainfall. Some plants of the same species have adapted to grow in different biomes with different rainfall regimes and climates. Even within biomes, due to site-specific environmental factors, there are plants that require different amounts of water to grow and flourish (e.g. those growing within the riparian habitat, as opposed to those growing slightly further away in a terrestrial habitat). As an example, *Agapanthus praecox* is listed as a plant suitable for a fynbos garden, a thicket garden and a highveld garden (Van Jaarsveld, 2000). Each of these landscapes exhibit different rainfall regimes and climates. Taking this into account, the concept of emulating variations in water availability should be repeated within amenity landscapes in the form of (amongst others) hydrozones. The concept of hydrozones within amenity landscapes has been promoted for several years now. Grouping plants and managing each group of plants as a separate hydrozone is beneficial to the landscape, the plants and the water resource. Most references (See Annexure 11) point to hydrozones that are divided into categories similar to no water, low water, medium water and high water use hydrozones. The terminology and definition of the specific amount of water indicated for use in hydrozones varies from source to source (See Annexure 11). During the data gathering process, definitions and descriptions on a variety of hydrozones from various sources were obtained (Annexure 11). Also plant lists linked to water use (hydrozones) were obtained from a range of internet, literature (Annexure 11) (e.g. Salt Lake City Public Utilities, 2013; Green Building Council of South Africa, 2014; Kwantlen Polytechnic University, 2015 and Arizona Municipal Water Users Association, 2017), as well as industry survey data.

When deciding on plants for a landscape it is necessary to firstly consider the location and to select plants that will suit the location (Kopp, Cerny and Hefelbower, 2002). Secondly, the plants chosen for the location need to be grouped according to their water requirements (Kopp, Cerny and Hefelbower, 2002; Randolph, 2005). The grouping of plants within an amenity landscape can be termed as a hydrozone. A hydrozone is defined as "*a distinct grouping of plants with similar water needs and climatic requirements*" (Thompson and Sorvig, 2000). Amenity landscape water use models typically incorporate plant group selections into "*homogenous water-use categories or hydrozones*" (Randolph, 2005).

To guide amenity landscapers in South Africa, it is necessary to decide upon and use a common description and definition (including water use) for these hydrozones. For this study the definition of hydrozones which are Water Wise's Standard Operating Procedures (SOP) (Rand Water, n.d.; Hoy, et al., 2017.), have been adopted as a basis for this research project (Table 5.5). The sentiment of these zones is supported by University of California Cooperative Extension California Department of Water Resources (2000) and Malakar, Acharyya and Bhargava (2015). As a result, all surveys and data collection during this research project were correlated back to the Water Wise definitions and descriptions. Data was obtained from internet sites (both international and South African), books and printed catalogues (International and South African) and wholesale nurseries (South Africa only) who are members of the South African Nursery Association (SANA) (Annexure 14). All plants in the final database were sold in South Africa. The base list was obtained from wholesaler catalogues from four SANA trade fares (August 2015, March 2016, August 2016 and March 2017) in Gauteng. Data collected from various sources at the trade fares related to plants as listed for sale by the wholesale growers, were collated and used in the final plant database.

An added focus when considering plants for an amenity landscape is the emphasis on using indigenous (local or native) plants. There are some advocates that support using a mixture of both indigenous and exotic plants whilst others promote using predominantly indigenous plants. Reasons for promoting the use of indigenous plants in an amenity landscape range from being water efficient, encouraging biodiversity, it is what nature intended, provision of food sources, require less insecticides to control insects, more suited to the local microclimate and less maintenance work required (Botha and Botha, 1997; Van Jaarsveld, 2000; Johnson, Johnson and Nichols, 2002; Randolph, 2005).

To allow for the hydrozone data to be included into the final model developed it is necessary to allocate a plant factor to each of the four chosen hydrozones. The use of a plant factor (for specific plants or hydrozones) is common practice in other available models such as the Landscape Coefficient Method (University of California Cooperative Extension California Department of Water Resources, 2000), "*Green Star Potable Water calculator Guide*" (Green Building Council of Australia, 2012), the Green Building Council of South Africa's Green Star rating system (Green Building Council of South Africa, 2014) and determining water requirements of residential housing estates (Du Plessis, 2014). The plant factor (Table 5.9) was determined using the landscape coefficient method from California (Pittenger and Shaw, 2004).

5.2. Plant database generation and refinement

A total of 64 different database sources were used (both South African and International) to build the plant data base (Table 5.1). As a comparison (36) sales/availability lists were obtained at four SANA tradeshows, which included those wholesalers who had responded to the plant list definition query as well as those that did not. This allowed for a more complete list of "available" plants.

The total plant list of data gathered from all sources, before numbers were reduced, was initially 5000 plants, split into genus, species, subspecies and cultivars. This was reduced by combining all varieties or hybrids of a species into one name or category. Duplicate plant species were removed. Some references (either those who provided plant list feedback or those whose sales plant lists were used) referred to the same plant species by slightly different names (Table 5.3) or spellings of names (Table 5.4). In certain instances, suppliers of wholesale plants used descriptions that were so generic, that plants could not be identified and were later deleted from the database. Examples of these challenges are listed in Annexure 15. The initial plant database was scrutinised by Coetzer (2018) for corrections. From the initial database, a total of 24 plants were removed that were defined as alien invasive plant species (National Environmental Management: Biodiversity Act, 2004). In some cases plant species were listed as the same species but with different colours or trademark names or variety names, examples being various *Alstroemeria, Viola* and

Camellia species (Table 5.2). In these instances plants were reduced and excess plants were removed. The newly listed plant was then listed using the suffix varieties.

Table 5.1: Summary of plant data hydrozone information sources.

	Internet sites	**Books and similar printed media**	**Wholesale Nurseries that responded to RW definition.**	**Catalogues obtained at Trade shows from Nursery growers (Aug 2015, March 2016 and 8 March 2017).**	**Notes.**
International focus	13	15	N/A	N/A	Only South African wholesale nurseries were approached. Based on method of plant data supply two internet sites were captured as books.
South African focus	3	16	17	36	
TOTAL SOURCES	**16**	**31**	**17**	**36**	

The final database of plants was divided into two groups. The first database group being plants that were rated by sources (e.g. Internet sites, books and wholesale grower nursery feedback) into high/medium/low/no water use, consisting of 2 528 plants. The second database group, being plants that are sold by wholesale nursery growers, but for which no rating was received, consisting of 330 plants. This second database was eliminated.

The plants listed in the database were categorised into 18 different plant type categories (Table 5.5) to assist end users (Landscapers) with plant selection.

Table 5.2: Examples of subspecies lists that were reduced.

Plant name	**Plant category**	**Reduced/joined to in the final list**
Alstroemeria 'Princess Lilies Ariane'	Perennial	*Alstroemeria* 'Princess' varieties
Alstroemeria 'Princess Lilies Elanie'	Perennial	
Alstroemeria 'Princess Lilies Louise'	Perennial	
Alstroemeria 'Princess Lilies Marilene'	Perennial	
Alstroemeria Princess Lilies Princess Ariane var. 'Zapriari'	Perennial	
Alstroemeria Princess Lilies Princess Claire var. 'Zapriclaire'	Perennial	
Alstroemeria Princess Lilies Princess Kate var. 'Zaprikate'	Perennial	
Alstroemeria Princess Lilies Princess Lillian var. 'Zaprillian'	Perennial	
Viola 'Malanseuns Baron Red'	Annual	*Viola* 'Malanseuns' varieties
Viola ' Malanseuns Blue'	Annual	
Viola 'Malanseuns Clear Rose'	Annual	
Viola ' Malanseuns Marina	Annual	
Viola ' Malanseuns Mulberry'	Annual	
Viola ' Malanseuns Purple Orange	Annual	
Camellia sasanqua Bonanza	Shrub & Sub-shrub	*Camellia sasanqua* varieties
Camellia sasanqua Crimson Queen	Shrub & Sub-shrub	
Camellia sasanqua 'Fuji-No-Mine'	Shrub & Sub-shrub	
Camellia sasanqua Henriette	Shrub & Sub-shrub	
Camellia sasanqua 'Jennifer Susan'	Shrub & Sub-shrub	
Camellia sasanqua 'Julie Robinson'	Shrub & Sub-shrub	
Camellia sasanqua 'Kanjiro'	Shrub & Sub-shrub	
Camellia sasanqua mixed	Shrub & Sub-shrub	
Camellia sasanqua 'Narumigata'	Shrub & Sub-shrub	
Camellia sasanqua 'Setsugekka'	Shrub & Sub-shrub	
Camellia sasanqua 'Tama Electra'	Shrub & Sub-shrub	
Camellia sasanqua 'Water Lily'	Shrub & Sub-shrub	

Table 5.3: Examples of references, referred to the same plant species by slightly different names.

Name supplied on plant list	Example of supplier or reference	Final name adopted for the database.
Alstroemeria aurantiaca	Chatto, 1980; Pienaar, 2000.	*Alstroemeria aurea*
Alstroemeria aurea	Keith Kirstens, n.d.; Sittigs Nursery.	
Aloe maculata	eGardens Online Nursery (Pty) Ltd., n.d.; Kazimingi Marketing (Pty) (Ltd).	*Aloe maculata*
Aloe spectabilis	Kazimingi Marketing (Pty) (Ltd).	
Lyssimachia 'green'	Peebles Plants.	*Lysimachia nummularia*
Lysimachia nummularia	Montgomery, n.d.; Malanseuns; Pienaar, 2000.	
Lotus maculatus 'Flash'	Peebles Plants.	*Lotus maculatus* 'Gold Flash'
Lotus maculatus 'Gold Flash'	Ballstraathof.	
Ipomoea Illusion Sweet Caroline	Elands Nursery; eGardens Online Nursery (Pty) Ltd., n.d	*Ipomoea batatas* 'Sweet Caroline' varieties
Ipomoea batatas 'Sweet Caroline' varieties	Keith Kirstens, n.d.; Barnhoorn, 2013.	
Osteospermum jucundum	Hodges, 2008; Allaway, 2013; Green Building Council of South Africa, 2014.	*Dimorphotheca jucunda*
Dimorphotheca jucunda	Pienaar, 1991; Van Jaarsveld, 2000.	
Codiaeum variegatum	Sebenza Nursery; Nedplant Nursery.	*Codiaeum variegatum*
Croton norma	Florex Indoor plant Nursery.	
Thuja orientalis	Zureikat, and Husseini, n.d.; University of California Cooperative Extension California Department of Water Resources, 2000.	*Platycladus orientalis* varieties
Platycladus orientalis varieties	Keith Kirstens, n.d.; Stewart, and Alexander, 2010.	

Table 5.4: Examples of reference referred to the plant species by slightly different spellings of names.

Incorrect spelling or incorrect name	Corrected spelling accepted for database	Reference
Carya illinoensis	*Carya illinoinensis*	Poynton, 1984; Stewart and Alexander, 2010.
Chondropetalum tectorum	*Elegia tectorum*	University of California Cooperative Extension California Department of Water Resources, 2000.
Crassula streyii	*Crassula streyi*	Kazimingi Marketing (Pty) (Ltd).
Eugenia paniculata	*Syzygium paniculatum*	Windy Willows Wholesale Nursery.
Leonotis leonurus 'White'	*Leonotis leonurus* 'Alba'	Ecotray.
Protorhus longofolia	*Protorhus longifolia*	Poynton, 1984.
Rosemary 'Barbeque'	*Rosmarinus officinalis* 'Barbeque'	Elands Nursery.
Syncolestemon densiflorus	*Syncolostemon densiflorus*	Sheat, 1993; Johnson, Johnson and Nichols, 2002.

For this study, determining categories (Table 5.5) for plants meant that a wide range of plants were grouped together. As an example, the category bulbs consists of all bulb type plants such as bulbs, corms, rhizomes, tubers and any form of underground storage mechanism and were bulb like. This rational is consistent with other authors for example Botha, and Botha, 1997, Eslick, 1999a and University of California Cooperative Extension California Department of Water Resources, 2000. For this study the grass like category consists of what are known as grasses, as well as all plants that have a visible grass like growth structure. Some of these may best be suited to the perennials category, however that varies from source to source for example Van Jaarsveld, 2000, Eslick, 1999b, and Allaway, 2013. All plants in the database were categorised as either being indigenous (local or native) 37% (946 plants) or exotic 63% (1582 plants) (Figure 5.1).

Table 5.5: Breakdown of plant categories.

Categories	Total plants in this category	Exotic	Indigenous
Annuals	270	243	27
Bulb like	160	60	100
Conifer trees & shrubs	33	33	0
Cycads	12	3	9
Ferns	19	6	13
Fruit	65	64	1
Grass like	119	66	53
Ground cover	115	49	66
Herbs	36	35	1
Orchids	8	6	2
Palms	33	31	2
Perennials	424	319	105
Shrub-subshrub	668	376	292
Succulents	126	46	80
Trees	289	121	168
Vegetables	35	35	0
Vines/climbers	101	81	20
Water plants	15	8	7
TOTAL	**2 528**	**1 582**	**946**

Moreover, the number of plants per list assessed varies depending on their source, need, area of focus and extent of the database. The number of plants in lists that matched the final database produced fluctuated from 20 to 671 plants. Added to this, only information on plants that linked back to the available plants for sale in South Africa were used in the database. Some plants were only identified to genus level by source lists (e.g. *Strelitzia* Spp (Brandies, 1994.), *Petunia* hybrids (Keane, 1995), *Pentas* Spp. (Elands Nursery), *Liriope* Spp. (Stewart and Alexander, 2010). While other sources broke down information for some plants down to subspecies/variety/cultivar level. Examples being *Agapanthus orientalis* 'Golden Drop' var. Malanseuns), *Alstroemeria* Princess Lilies Princess Ariane var. 'Zapriari' (Malanseuns), *Dianella tasmaniaca* 'variegata'(Elands Nursery) and *Penstemon hartweggii* 'Tubular Bells' (Ballstraathof). Some sources listed plants as species, whilst others listed them as cultivars/varieties for example *Dahlia* hybrids (BallStraathof; Perry, 1982) and

Dahlia species (Spp) (Andy Titterton Wholesale Nursery; Keane, 1995.). These were listed as separate plants on the list as these could essentially consist of two different plants. Data was captured specific to these plants as listed.

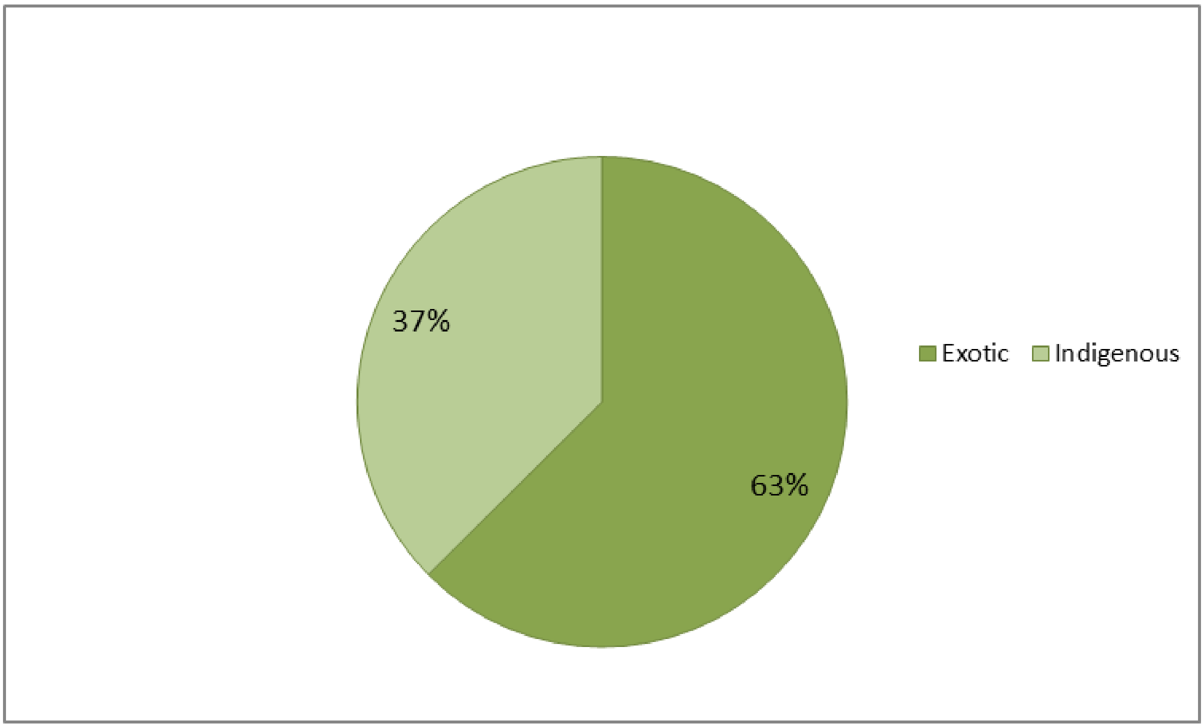

Figure 5.1: Breakdown of indigenous and exotic plants.

The data captured from the various plant lists sourced, provided certain corresponding hydrozone ratings for the same plants (i.e. not all sources placed the same plant in the same hydrozone). As an example, when comparing the captured plant raw data from all sources, for the medium hydrozone, SA wholesale and other growers rated 927 plants in this zone, all SA sources (internet and books) listed 1 418 plants in this zone, and overseas references (Internet and books) listed 731 plants in this zone (Figure 5.2).

An example of the layout of the final plant database produced, that includes full plant names, plant category, genus, species, variety (where applicable), common names (where available), synonyms or changed botanical names, indigenous/exotic and finally plant rating (hydrozone), is listed in Table 5.6. Due to the extent of the full plant database, it is listed as Annexure 13 (Excel document) to this study. Plants that have been left that are listed as category 1b, 2 or 3 for certain areas of South Africa are displayed in orange.

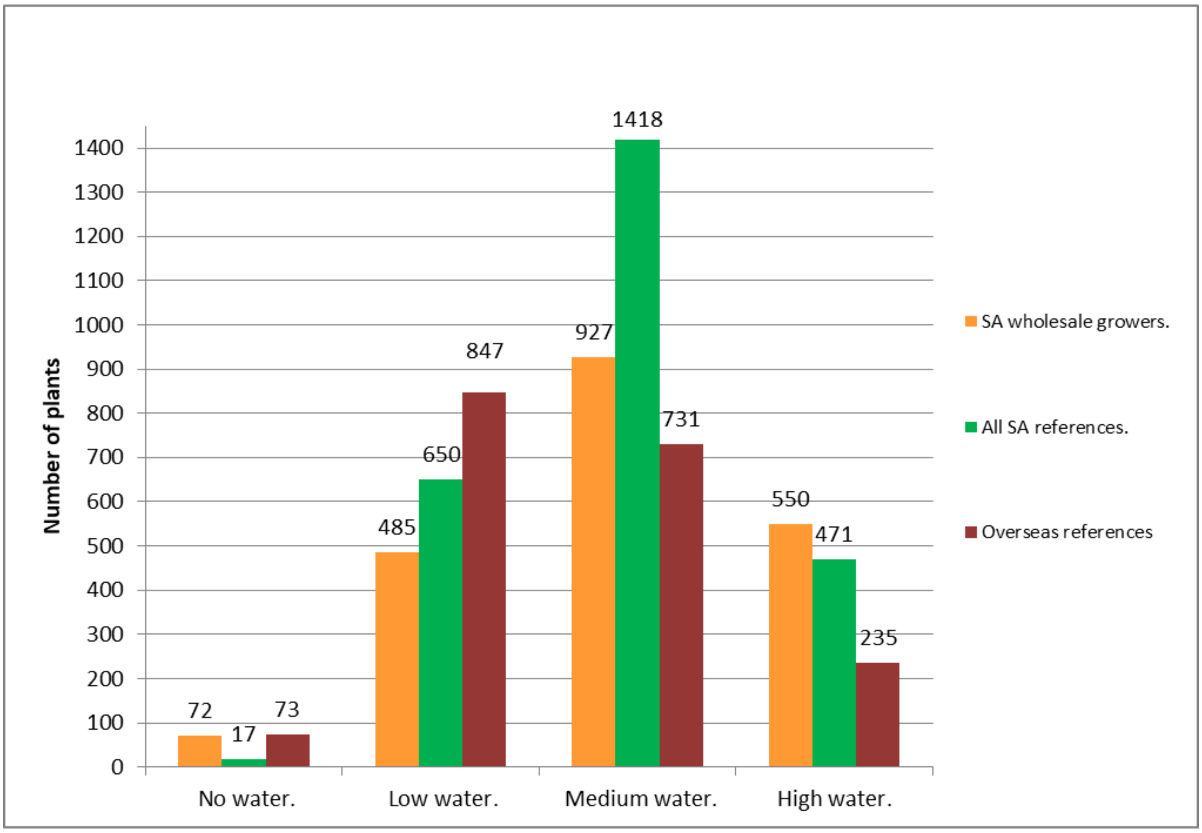

Figure 5.2: Plants rated in each category based on various raw data sources.

Table 5.6: Examples of the Plant database linked to hydrozones.

Genus	**Species**	**Variety/ cultivar/ sub-species**	**Common name**	**Plant category:**	**Indigenous/ Exotic**	**Synonyms or changed botanical names or/& Invader status**	**Hydrozone**
Abelia	*chinensis*		Chinese Abelia	Shrub & Sub-shrub	Exotic		Medium
Abelia	*floribunda*		Mexican Abelia	Shrub & Sub-shrub	Exotic		Medium
Abelia	*grandiflora*		Glossy Abelia, Blinkblaar Abelia	Shrub & Sub-shrub	Exotic		Medium
Abelia	*grandiflora*	varieties	Prostrata Abelia	Shrub & Sub-shrub	Exotic		Medium
Abelia	*schumannii*	'Lutea'		Shrub & Sub-shrub	Exotic		Medium
Abelia	Spp			Shrub & Sub-shrub	Exotic		Low
Abelia	variegata			Shrub & Sub-shrub	Exotic		Low
Abutilon	hybridum		Abutilon	Perennial	Exotic		High
Abutilon	Spp	X hybrids	Chinese Lantern	Shrub & Sub-shrub	Exotic		High
Acacia	*baileyana*		Bailey Acacia	Tree	Exotic	Invader Cat 3	Low
Acacia	*cultriformis*		Knife-Leaved Wattle	Tree	Exotic		Medium
Acacia	*pendula*		Weeping Myall	Tree	Exotic		Low
Acalypha	*hispida*		Chenille Plant	Shrub & Sub-shrub	Exotic		Medium
Acalypha	*wilkesiana*		Fijian Fire Bush, Copper Leaf	Shrub & Sub-shrub	Exotic		Medium

Genus	**Species**	**Variety/ cultivar/ sub-species**	**Common name**	**Plant category:**	**Indigenous/ Exotic**	**Synonyms or changed botanical names or/& Invader status**	**Hydrozone**
Acanthus	*mollis*		Wild Rhubarb	Perennial	Exotic		High
Acanthus	Spp.		Wild Rhubarb	Perennial	Exotic		Medium
Acer	*buergerianum*		Chinese Maple	Tree	Exotic	(=*Acer trifidium*) Invader Cat3	Medium
Acer	*negundo*		Box Elder	Tree	Exotic	Invader Cat 3	Low
Callistemon	*viminalis*		Weeping Bottlebrush	Tree	Exotic	Invader Cat 1b & Cat 3	Low
Callistemon	*viminalis*	varieties	Weeping bottlebrush	Shrub & Sub-shrub	Exotic	*Callistemon. viminalis* -Invader Cat 1b & Cat 3	Low
Callis-tephus	*chinensis*		Aster, China Aster	Annual	Exotic		Medium
Callitris	*calcarata*		Black Callitris	Tree	Exotic		Low
Celosia	*spicata*	'Kosmo'		Annual	Exotic		High
Celosia	Spp			Annual	Exotic		High
Celtis	*africana*		White Stinkwood, Witstinkhout	Tree	Indigenous		Medium
Celtis	*australis*		Hackberry	Tree	Exotic	Invader Cat 3	Medium

Genus	**Species**	**Variety/ cultivar/ sub-species**	**Common name**	**Plant category:**	**Indigenous/ Exotic**	**Synonyms or changed botanical names or/& Invader status**	**Hydrozone**
Felicia	*filifolia*		Fine leaved Felicia daisy	Shrub & Sub-shrub	Indigenous		Medium
Felicia	*heterophylla*		Felicia	Perennial	Indigenous		Low
Felicia	Spp			Perennial	Indigenous		Medium
Ferraria	Spp		Spider lily	Bulb like	Indigenous		Medium
Ilex	*cornuta*	Sp	Chinese Holly	Shrub & Sub-shrub	Exotic		Low
Ilex	*x meserveae*		Cape Holly	Tree	Indigenous	*Ilex mitis*	High
Impatiens	*balsamina*		Balsam	Annual	Exotic		Medium
Impatiens	*balsamina*	Dwarf Tom Thumb	Balsam	Annual	Exotic		High
Impatiens	*'*	Celebrette		Annual	Exotic		High
Kalanchoe	*tomentosa*		Panda plant	Succulent	Exotic		Low
Karomia	*speciosa*		Parasol flower/chinese-hat plant	Shrub & Sub-shrub	Indigenous	(=*Holmskioldia tettensis*)	Medium
Kerria	*japonica*		Jews mallow/ Japanese rose	Shrub & Sub-shrub	Exotic		Low
Khaya	*nyasica*		Red mahogany	Tree	Exotic		Medium

Genus	**Species**	**Variety/ cultivar/ sub-species**	**Common name**	**Plant category:**	**Indigenous/ Exotic**	**Synonyms or changed botanical names or/& Invader status**	**Hydrozone**
Nym-phoides	*indica*		Small yellow water lily/Water snowflake	water plants	indigenous		High
Ochna	*natalitia*		Natal Plane	Shrub & Sub-shrub	Indigenous		Medium
Ochna	*pulchra*		Peeling Plane	Tree	Indigenous		Medium
Ochna	*serrulata*		Mickey Mouse Bush/Small-leaved Plane	Shrub & Sub-shrub	Indigenous		Medium
Ocimum	*americanum*		Basil	Herb	Exotic		Medium
Quercus	*suber*		Cork Oak	Tree	Exotic		Medium
Quisqualis	*indica*		Rangoon creeper	Bulb like	Exotic		Medium
Ranunculus	*asiaticus*		Ranunculus	Bulb like	Exotic		Medium
Scaevola	*aemula*			Perennial	Exotic		Low
Schefflera	*actinophylla*		Umbrella tree/Australia umbrella tree	Shrub & Sub-shrub	Exotic	(=*Brassaia actinophylla*) Invader Cat 1b	Medium
Schefflera	*arboricola*		Dwarf umbrella tree	Shrub & Sub-shrub	Exotic	Invader Cat 3	Medium

Genus	Species	Variety/ cultivar/ sub-species	Common name	Plant category:	Indigenous/ Exotic	Synonyms or changed botanical names or/& Invader status	Hydrozone
Zinnia	*Spp*		Zinnia	Annual	Exotic		Low
Ziziphus	*mucronata*		Buffalo Thorn	Tree	Indigenous		Medium
Ziziphus	*rivularis*		False Buffalo Thorn	Tree	Indigenous		High
Zoysia	*tenuifolia*		Korean grass, Petting grass	Grass like	Exotic		Medium

5.3. Hydrozones

Many sources (e.g. Salt Lake City Public Utilities, 2013; Green Building Council of South Africa, 2014; Kwantlen Polytechnic University, 2015; Arizona Municipal Water Users Association, 2017) vary in their terminology and definition of what water use/hydrozones are termed as and defined. Some sources do not provide definitions for end users but merely provide terminology or graphics (Annexure 11). The range of definitions in the sources used for this study varied from mere pictures (e.g. empty, quarter, half and full watering-can (Joffe, 2003), or one, two and three droplets (Lord, 2010)), to single words (e.g. high, medium and low water use (Talhouk, 2015)), to more complex and specific definitions (Zureikat, and Husseini, n.d.; Poynton, 1984; Keane, 1995). Also, the number of hydrozones from selected sources (books and internet sites) ranged from one to twelve hydrozones. Thirteen percent of sources listed one to two hydrones, 27% listed three to four hydrozones, four pecent listed five to eight hydrozones and three percent listed nine to twelve hydrozones (Annexure 11). Many sources are silent on any comments regarding the plant water use requirements or Hydrozones. For obvious reasons these sources could not be used in the study and were, as a result, excluded from inclusion in the database.

The most commonly quoted data base observed from the USA is the "Water Use Classification of Landscape Species" (WUCOLS), (University of California Cooperative Extension California Department of Water Resources, 2000). The WUCOLS guide consists of 1900 species used in California amenity landscapes. It was produced based on field observations and field experience of 41 landscape horticulturists. Plants were assigned (by consensus) to categories for each of the six California regions. The assessments on all plant species was undertaken based on the fact that plants would be established (generally 2-3 years old). This guide is aimed at;

- professionals in selecting plants for water efficient landscapes,
- allowing landscape maintenance managers to assess water needs of existing plantings thereby developing irrigation schedules that match species needs,
- allowing landscape managers to establish hydrozones, i.e., to alter composition of species thus reducing different water needs within plantings, and
- allow for the estimation of plant water needs for new landscapes (University of California Cooperative Extension California Department of Water Resources, 2000).

All plant species in the WUCOLS database were evaluated based on the concept that the correct plants would be planted in shade, semi shade or sun depending on plant requirements. The same thinking was applied to plants that require either predominantly summer or winter watering (University of California Cooperative Extension California Department of Water Resources, 2000).

The statement “well watered” amenity landscape implies and caters for the fact that the chosen plant(s) are watered in such a manner that should ensure full rigorous productive growth. Any amount of water above this amount, no matter how small, is over watering. It stands to reason that some plants can receive between 20% to 50% of ETo and still grow well (Pittenger et al., 2004). Pittenger and Shaw (2004), state that many different plants can be irrigated at 18% to 80% of ETo, and that plants with unknown water requirements should be watered at 50% of ETo. Hence, plants could “safely” receive less water than required by ETo and still grow well resulting in aesthetically pleasing landscapes.

Water use of plants ultimately defines the hydrozone in which a plant is to be placed (Randolph, 2005). Annexure 11 provides more detail on how the various definitions of sources were interpreted and aligned to the definitions used in this study.

The hydrozone categories and definitions used for this research project were based on the hydrozones which are Water Wise’s Standard Operating Procedures (RW-SoP) (Rand Water, n.d.; Hoy, et al., 2017.) and promoted by the Water Wise brand. They were adopted as a basis for this research project. The concept of these hydrozones is supported by Poynton (1984), University of California Cooperative Extension California Department of Water Resources (2000), Van Jaarsveld (2000), and Malakar, Acharyya and Bhargava (2015) (Table 5.7). These were the hydrozone definitions provided to the wholesale nursery growers and other growers as a reference when providing plant data feedback. It provides annual as well as seasonal variation in water application for summer rainfall regions (the opposite is applied to winter rainfall regions).

Some sources of data had more (Keane, 1995; Eslick, 1999a.) and some had less than four categories (Hodges, 2008; Allaway, 2013) of hydrozones (Annexure 11). As a result, based on the RW-SoP definitions, these were grouped/matched into the hydrozones as used in this study.

Table 5.7: Rand Water hydrozones indicating annual rainfall amounts (Rand Water, n.d.; Hoy, et al., 2017).

Hydro-zone	Definition			
	Annual	**Summer**	**Spring/ Autumn**	**Winter**
No water	Receives less than 300 mm rainfall per annum. Water only in severe cases.	No watering required unless in extreme cases		
Low	Receives annual rainfall of between 300-500 mm. Water every 6-8 weeks.	12 mm(50%)/ week	7 mm (25%)/ week	12 mm every second week (including lawns but not if dormant)
Medium	Receives between 500-750 mm rainfall a year. If plants show signs of distress in dry times, water. Water once a month in winter.	15 mm(60%)/ week	12 mm(50%)/ week	7 mm (25%)/ week
High	Receives over 900 mm of annual rainfall. Water once a week in general and twice or three times a week during very hot dry spells.	25 mm(100%) / week	15 mm(60%)/ week	12 mm (50%)/week

Due to the nature of data gathering from a range of sources, each with its own basis of data, due to their specific reference point for hydrozones, the allocated to plants is not assured. Sources did not agree with ratings e.g. *Asparagus falcatus* was given ratings of no water (Brandies, 1994), low water (ECO Balance Landscapers), medium water (Wildflower Nursery) and high water (Johnson, Johnson and Nichols, 2002) hydrozones. After applying the excel formula *Asparagus falcatus* was finally awarded a category of high water (Table 5.8). Of the final plants in the database, there were some that had ratings of equal weighting in two or more hydrozones (Table 5.8). This meant that certain plants were initially not allocated an overall hydrozone category. By means of an excel formula, all plants that were equal in a specific hydrozone category in more than two hydrozone categories, were then awarded the higher hydrozone rating. As an example, with *Abelia grandiflora* four references indicated that it should be in the low hydrozone category and four indicated the medium hydrozone category. It was eventually allocated to the medium hydrozone category. Similarly, four references indicated that *Acanthus mollis* should be allocated to the low hydrozone, four indicated it should be the medium hydrozone and seven indicated the High hydrozone. As a result *Acanthus mollis* was placed into the high hydrozone category. (Examples of how hydrozone categories were determined see Table 5.8). This is consistent with the concept used in California (Costello and Jones, 2014), except that this study process was formula based versus consensus based as per Costello and Jones, (2014). This resulted in the number of plants in each hydrozone category being rectified. Examples being that the number of plants in the medium hydrozone increased from 1217 plants to 1433 plants (Figure 5.3) after the excel formula was applied (awarding the highest hydrozone rating when two or more zones had equal value).

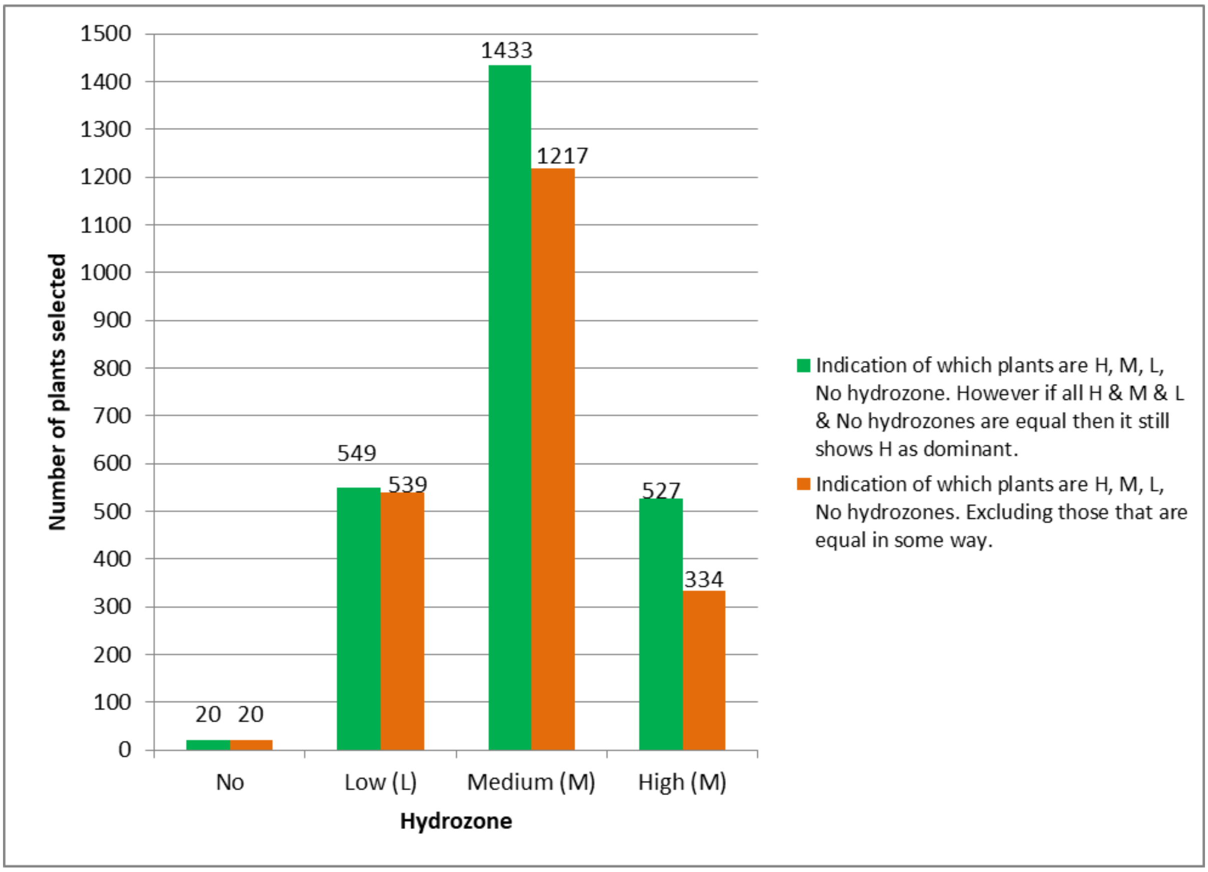

Figure 5.3: Comparison of preliminary database compared to final database.

T**able 5.8**: Examples of how plant hydrozone categories were determined.

Scientific name	**Plant category**	**No Water hydro zone**	**Low water hydro zone**	**Med water hydro zone**	**High water hydro zone**	**Final category awarded**
Abelia grandiflora	Shrub & Sub-shrub	0	4	**4**	0	**Medium**
Acanthus mollis	Perennial	0	4	4	**7**	**High**
Apodytes dimidiata	Tree	0	1	2	**2**	**High**
Asparagus falcatus	Vine/Climber	1	1	1	**2**	**High**
Bauhinia natalensis	Shrub & Sub-shrub	0	**3**	2	2	**Low**
Bougainvillea glabra varieties	Vine/Climber	**1**	0	0	0	**No**
Bulbine latifolia	Bulb like	1	1	**1**	0	**Medium**
Cassinopsis ilicifolia	Shrub & Sub-shrub	0	**4**	3	3	**Low**
Echeveria varieties	Succulent	2	**2**	0	0	**Low**
Hebe varieties	Shrub & Sub-shrub	0	2	2	1	**Medium**
Jasminum nudiflorum	Shrub & Sub-shrub	0	2	**4**	1	**Medium**
Kalanchoe blossfeldiana	Succulent	0	4	**5**	0	**Medium**
Kalanchoe Spp.	Succulent	1	**4**	3	0	**Low**
Lampranthus Spp	Ground Cover	0	**8**	1	1	**Low**
Phormium varieties	Grass like	0	3	**3**	1	**Medium**
Photinia x fraseri 'Red Robin'	Shrub & Sub-shrub	0	3	**4**	1	**Medium**
Phygelius capensis	Perennial	0	2	**4**	3	**Medium**
Protea caffra	Tree	0	1	**1**	0	**Medium**
Punica granatum	Fruit	1	7	**7**	0	**Medium**
Salvia x superba	Perennial	0	1	1	**1**	**High**

The final database of plants includes some exotic plants that are listed alien invasive species that can legally still be allowed to be grown in selected parts of the country. Listed alien invasive plants (LAIP) in category 1a, and 1b (that are not allowed to be grown anywhere in SA) were removed. This accounted for 24 LIAP's from the final database. A total of 44 LIAP's that are listed as either Category 1b, 2 or 3 but that are allowed in certain parts of the country were left in the final plant database (National Environmental Management: Biodiversity Act, 2004).

When comparing the data from South Africa with that of all overseas sources, for the no water hydrozone there was a match of only one plant (0.11%); for the low hydrozone there was a match of 282 plants (30.92%); for the medium hydrozone 524 plants (57.46%); and for the high hydrozone 105 plants (11.51%) (Figure 5.4). Only for the medium hydrozone plants was the match above 50% (Figure 5.4).

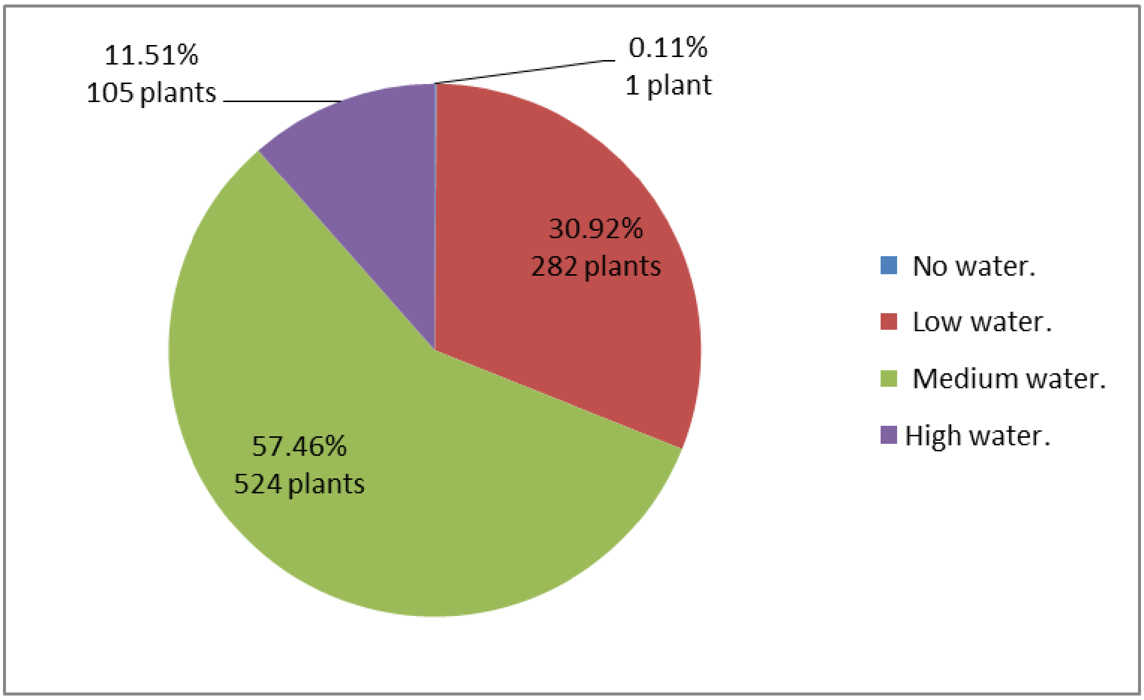

Figure 5.4: Agreement in average rating for hydrozones between SA sources and overseas sources of data.

When comparing data from SA literature and internet sources to those of the answers supplied by the wholesale nursery growers and other growers, the hydrozone data for specific plants in the database that matched each other, indicates that the total number of plant names that match, being 4 plants (0.15%) for no water hydrozone, 134 plants (5.29%) for the low water hydrozone, 489 plants (19.33%) for the medium water hydrozone and only 44 plants(174%), for the high water hydrozone (Table 5.9).

Table 5.9: Association of data between various SA data.

For the same plant is there a link (match) in data for a hydrozone between any SA book & Internet data to any SA nursery wholesalers' data?				
	No water.	Low water.	Medium water.	High water.
Total matches	4	134	489	44
Total non-matches	2 525	2 395	2 040	2 485
Percentage match	0.15%	5.29%	19.33%	1.74%

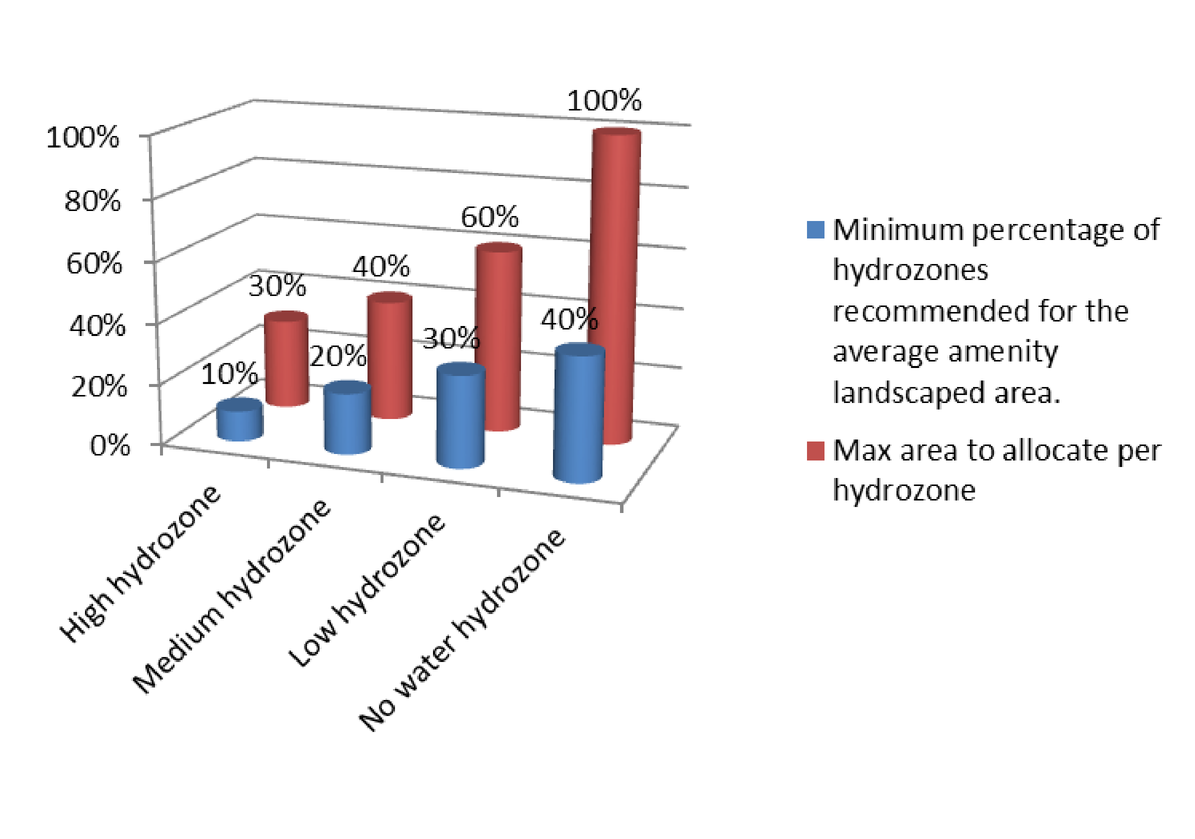

Figure 5.5: Percentage of the total amenity landscape site allocated per hydrozone.

To reduce water required in the amenity landscape, it is important that each hydrozone, of the four hydrozones adopted for this research project, only constitute a set percentage of the total amenity landscape site as stated by RW-SoP (Rand Water, n.d.; Hoy, et al., 2017.). As an example, the high water zones should constitute 10% to 30% of an amenity landscape, medium water zones 20% to 40%, low water zones 30% to 60% and no water zones should make up large portions of amenity landscapes (40 % and more) (Water Wise, n.d.; Hoy, et al., 2017). The concept of allocating less area to high water use hydrozones and a greater area medium, to low and no water use area is supported by Randolph (2005) however Randolph does not go as far as allocating percentages of area to each amenity hydrozone (Figure 5.5).

5.4. Allocation of factors to hydrozones (e.g. Crop, species and plant factors)

Hydrozones allocated for the amenity landscape water use model (ALWUMSA) are no water, low water, medium water and high water. For the zones to be applicable for use in ALWUMSA, it was necessary that plant/species factors be allocated for plants for each zone.

Species/plant factor as used in the Landscape coefficient method (used to determine water requirements for any given landscape) consists of a range of values for each category (University of California Cooperative Extension California Department of Water Resources, 2000). It is one of several factors used to generate a landscape coefficient, and adjusts the landscape coefficient to account for water loss from a hydrozone due to the plant species composition. "*The assigning of the value in each category* (hydrozone) *of either lower or mid or high range value can be determined by the knowledge of the assessor as to the actual water use of the plant species. However, if the assessor is unsure of the plants water use, a mid-range value should be allocated"* (University of California Cooperative Extension California Department of Water Resources, 2000). WUCOLs defines plants in four categories (hydrozones) expressed as a percentage of reference evapotranspiration (ETo), (University of California Cooperative Extension California Department of Water Resources, 2000).

Using this type rating could be viewed as partially subjective, however the method used to determine each plants hydrozone in this study removes some of this subjectivity. This subjectivity is reduced by categorising plants into a hydrozone, nevertheless further sub categorisation within each hydrozone is determined by the assessors' professional experience (Costello and Jones, 2014) and localised conditions. Several sources (Annexure 11) quote a range of factors for different plant categories for different hydrozones. Some quote factors per month for specific plant categories (Pittenger and Shaw, 2004; McCabe, 2005; Pittenger, 2014), while other references such as University of California Cooperative Extension California Department of Water Resources, (2000) and Costello and Jones (2014), provide basically the same generic factors (average for the year) in a range for each of four hydrozones (high, medium, low and very low) for all plants (Table 5.10). These generic factors were used in ALWUMSA. For this study very low hydrozone was replaced with the term no water hydrozone. The determination of a plant factor is inversely proportionate to the percentage of water required as a percentage of ETo. Examples being an amount of 60% of ETo will equate to a plant factor of 0.6, whilst 90% of ETo equates to 0.9 (University of California Cooperative Extension California Department of Water Resources, 2000; Pittenger and Shaw, 2004, Costello and Jones, 2014). Plant coefficients/factors are dimensionless numbers usually ranging from 0.1 to 1.2 (Pittenger and Shaw, 2004).

Table 5.10: Hydrozone factors selected for use in ALWUMSA (University of California Cooperative Extension California Department of Water Resources, 2000; Pittenger and Shaw, 2004; Costello and Jones, 2014).

Plant Category	**High water**	**Medium water**	**Low water**	**Very Low**	**Notes:** (Percentage of ETo to allow plants to be maintained in good condition in the region of interest.)
General plant factor	0,7 – 0,9	0,4 – 0,6	0,1 – 0,3	< 0,1	High - need between 70% and 90% of ETo Medium - need between 40% and 60% of ETo Low - need between 10% and 30% of ETo Very Low - need less than 10% of ETo

5.5. Discussion

No comprehensive data base is available in South Africa linking commercially grown/sold plants to plant factors and to specific hydrozones. As has been pointed out already that to provide a laboratory tested crop factor for all plants commercially available in South Arica would take an enormous amount of time and resources that are currently not available. Hence the methodology of taking data from a range of sources (Internet sites, books, published information and Industry sourced feedback) is seen as the most economical at this stage and that could be accommodated within as short a time constraint as possible. The method undertaken in this study is the most complete known study to date in South Africa involving as wide a field as it has. This has resulted in a comprehensive list of plants linked to four defined hydrozones as well as defined plant factors that can be used in a model (ALWUMSA).

A potential shortcoming and weakness of the data gathered from the industry could be experienced when using the Delphi technique as highlighted by Hsu and Sandford (2007) for this part of the study. This being that, many wholesale grower nurseries simply failed to supply information promised. The fact that only a 22% response rate was received could be a viewed as a limitation. However this was only one source of the data used and therefore counteracted this potential deficiency.

The concept that certain plants require more water than others to grow in selected amenity landscape environments is undisputed. The exact amount of water required by plants for survival, to look aesthetically pleasing, or to grow at optimal conditions is however, debateable and results in different opinions (as has been indicated in the data collected from different sources where in some cases the same species was given different ratings for water use). The determination of plant water use is by no means an exact science and depending on the specialist sources, their understanding (possibly even their localised knowledge context) and ultimately their reference point, could have influenced the hydrozone they recommend for the plant. With additional time and funding the plant water use information could be improved however these are currently limited, thus placing some constraints and limitations on the research. Considering the large number of plants included in the database, the method as used in this study for determining plant water use is currently the most efficient, economical and reliable method available at present in South Africa.

To address the current inconsistencies it would be pertinent for the amenity horticultural and landscaping professionals and community to adopt a common definition for each hydrozone and for allocation of plants to hydrozones to be standardised. This database produced for South Africa attempts to do just this. As a result of this study the definition, of the four hydrozones, that is proposed to be used in South Africa for all regions with amenity landscapes, being (Table 5.11) should be adopted for use by all roles players.

Table 5.11: Hydrozone and associated effective watering definition for South Africa.

Hydro zone	Summer Rainfall region.		Winter rainfall region	
	Detailed definition	**Annualised definition**	**Detailed definition**	**Annualised definition**
No water	No watering required unless in extreme cases.	Receives less than 300 mm effective watering per annum.	No watering required unless in extreme cases.	Receives less than 300 mm effective watering per annum.
Low	• Summer – 12 mm (50%)/week. • Spring/Autumn - 7 mm(25%)/ week • Winter - 12 mm every second week (including lawns but not if dormant).	Receives annual effective watering of between 300-500 mm.	• Winter - 12 mm (50%)/ week. • Spring/Autumn – 7 mm (25%)/ week. • Summer - 12 mm every second week (including lawns but not if dormant).	Receives annual effective watering of between 300-500 mm.
Medium	• Summer – 15 mm (60%)/ week. • Spring/Autumn – 12 mm (50%)/ week. • Winter – 7 mm (25%)/ week.	Receives between 500 - 750 mm effective watering a year.	• Winter – 15 mm (60%)/ week. • Spring/Autumn – 12 mm (50%)/ week. • Summer – 7 mm (25%)/week.	Receives between 500 - 750 mm effective watering a year.
High	• Summer – 25 mm (100%)/ week. • Spring/Autumn – 15 mm (60%)/ week. • Winter – 12 mm (50%)/week.	Receives over 900 mm of annual effective watering.	• Winter – 25 mm (100%)/week. • Spring/Autumn – 15 mm (60%)/ week. • Winter – 12 mm (50%)/week.	Receives over 900 mm of annual effective watering.

* Note these amounts are to be applied only after the settling in period for plants ranging from 12 to 24 months (SAGIC, 2018).

The database produced 2 529 plants for which hydrozone data is determined and would be extremely valuable should it be used for;

- Informing all end users what are the correct plants to place in each hydrozone category in the amenity landscape,
- Wholesale nursery growers, nurseries and garden centres to use as control to ensure plants are sold using the correct information on plant labels, plant lists and sales lists,
- All landscapers, horticulturists, home gardeners and landscape architects should use the plant list as a tool to ensure correct plants are placed in the correct hydrozone when designing either new or revamping existing landscapes, and
- Assist in ensuring that plants placed in the correct hydrozone and watered accordingly will be able to maintain acceptable health, appearance, and growth, modelling of plant water requirements.

The database produced with this study should be seen as a first attempt at creating baseline data and should not be seen as complete. Similarly, the hydrozones allocated to the various plants could be disputed and improved upon in the future. This would provide an ideal opportunity for the Green Industry to determine a more correct method of allocating hydrozones to plants and agreeing on these. Landscapers must also consider other pertinent aspects that affect plant growth such as frost sensitivity, sun/shade placement, acid/alkaline soils etc. for inclusion in an amenity landscape design.

The debate of using indigenous versus exotic plants within amenity landscapes is on-going and ultimately depends on the end users requirements or rules for the environment in which the amenity landscape is placed. Unfortunately, too few indigenous species are used and promoted for use within amenity landscapes in South Africa. Even with the localised natural environment there will be different hydrozones, highlighting that rather than focussing on whether the plant is indigenous or exotic, the emphasis should be on placing it in the correct hydrozone within the amenity landscape. Applying these basic natural principles ensures that future amenity landscapes will be more resilient, requiring less water and still being aesthetically pleasing.

Using the plant database generated in this chapter for ALWUMSA will ensure more efficient water use, careful plant selection and correct placement within the correct hydrozone.

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CHAPTER 6 – AMENITY LANDSCAPE WATER USE MODEL SOUTH AFRICA

6.1. Introduction

Amenity landscape water use models exist in several forms globally as indicated in Chapter 2.6 and Chapter 6. Each model attempts to determine the optimal water use for a unique amenity landscape.

Most water used within urban amenity landscapes emanates from a water source outside of the urban edge. In the case of South Africa, many large storage dams are required to ensure adequate supply of water to urban areas (King and Pienaar, 2011). Hence any saving made within the water use process, such as the amenity landscape, will contribute to reducing pressure on the requirement for additional storage, purification and associated reticulation facilities, let alone reduced water use. Improving water efficiency to delay the need for extensive and large capital investments into additional water supply has obvious benefits in terms of addressing the fundamental issue of water scarcity. Sustainability of water use is important so that consumption does not outstrip the ability of rainfall and ecosystems to replenish water resources (NWRS2, 2013). Added to this, the continual increasing demand for water from all sectors of society drives the need for increased water efficiency in these sectors (NWRS2, 2013). While improving efficiency is important to maximise resource use and minimise wastage, it is reducing water consumption within amenity landscapes that provides the ultimate solution to the sustainability challenge (Armitage, et al., 2014). Amenity landscapes are the first to be impacted by any form of reduced water availability (drought, water shortages or any form of water restrictions) (Hoy, 2009), and hence a South African based model and associated factors is critical to improve the sustainability of all amenity landscapes.

Passive measures aimed at influencing consumer behaviour include amongst others, a wide range of education and communication methods and interventions, demonstration gardens and exhibitions. Active measures such as water restrictions, amenity landscape site functional requirements (legislated and non-legislated), and other mechanisms (Hoy, 2009) are often not well defined and not "tested" before implementation. As a result, amenity landscapes sometimes suffer unduly and water users do not necessarily "buy into" these measures for full compliance. According to Carrow, Duncan and Waltz (2005), there are three methods to address environmental issues, including water-use efficiency/conservation. These being, indifference/inaction (unacceptable), and/or rigid regulations, and/or best management practices. The use of amenity landscape water use models assist with ensuring that best practice is always applied.

Outdoor water demand focuses mainly on garden water use. Garden sizes irrigated often quote ranges from 0 m^2 to 37 000 m^2. Water use varies considerably and according to factors such as garden size, vegetation type, climate, evapotranspiration, geographic location as well as either over or under irrigating. In general the CSIR as well as the engineering council of South Africa use stand size as a guide for residential water demand (CSIR, 2005). However, it is indicated by Jacobs, Geustyn and Loubser (2006), that the CSIR model overestimates water demand. The use of water end-use models is crucial to better understand residential water conservation and water demand. Small scale end use modelling results are able to provide a reasonable correlation when compared to actual metered users (Jacobs, 2007). Water demand management is based on effective water information management (WIM). Due to the fact that end use models have many parameters, making this an extensive and arduous task while many water demand guidelines remain experimental (Jacobs, 2008).

To assist landscapers and gardeners with their overall water usage in amenity landscapes there are many simple “water use” or “water footprint” calculators available on the internet. In their simplest form they take into account factors such as size of the garden and the location against which a volume of water is estimated for the specific site. Some examples of different models (simple and more complex) being Water corporation (n.d.), City of Cape Town, (n.d.), Hunter Water (2011), United utilities (2017), Smart water gardening (2017), Landscape Coefficient Method and WUCOLS, (University of California Cooperative Extension California Department of Water Resources, 2000.) and Green Star Potable Water Calculator Guide (Green Building Council of Australia, 2012). Landscape coefficient models/Amenity landscape water use models are sometimes also known as a water budget. In USA water budgets are most commonly used to set targets for water use within the amenity landscape and provide guidance on the amount or water required by the plants for healthy growth and appearance (Ash, 1998). In California through the implementation of the water budget system, stepped billing, programs and practices have resulted in a 43% increase in landscape water use efficiency between 1990 and 1997 (Ash, 1998).

There are two known South African examples of water use calculators that have been developed and that currently address the potential water use situation of a given site/amenity landscape, namely, the Green Building Council of South Africa’s Green Star rating system (Green Building Council of South Africa (GBCSA), 2014) and the Outdoor Water Demand

Model (SA Outdoor Water Model) developed by Du Plessis (2014). The SA Green Star rating system consists of 5 basic parameters, the size of the area to be calculated, irrigation type, microclimate, irrigation system controls, rainfall, rain days and location. The SA Outdoor Water Model considers size, evapotranspiration, crop coefficient, precipitation, irrigation efficiency including swimming pool size.

The SA Green Star rating system includes a list of approximately 50 most commonly used amenity landscape plants indicating their Hydrozones(Green Building Council of South Africa, 2014), while the SA Outdoor Water Demand Model lists 6 different generic plant categories each allocated a coefficient (Du Plessis, 2014).

The development of ALWUMSA has considered water use efficiency and not the source of the water. As a result, at no stage is grey or recycled water used as an offset to water use, but rather focus has been on the sustainable use of the available water and measures to reduce water use in the amenity landscape.

This chapter addresses the actual model (ALWUMSA) as well as all aspects, elements and factors that are included in the model. The construction, assembly, comparison of data of the ALWUMSA will be discussed. Selected other available models from South Africa, USA and Australia will be also addressed. On site testing as well as modelling of scenarios will be presented and analysed to demonstrate suitability of the model for use in the field as well as on plan. The scenarios tested will entail (in some cases) changing only one variable for each site and in other cases changing several variables. The aim is to test if the model is able to demonstrate clear changes in water requirements for the same site whether the element changed is a design, management, pedology, watering, plant, location (town) related or even a combination of elements.

6.2. Modelling plant water use for amenity landscapes

Water use efficiency in urban amenity landscapes is accomplished through limiting supply to only the specific amount of water that plants will require to maintain a healthy and aesthetic appearance. The water required by urban amenity landscapes cannot be compared to that of agricultural crops and turf grasses, as the specific conditions of urban green spaces are different (UCCECDWR, 2000; Nouri, et al., 2013).

When considering amenity or ornamental landscapes it is important from the start to understand that the landscape itself, its location, soil, microclimate, diverse plant selection/composition, as well as the topography, cannot be compared to a monoculture agricultural production system. The inputs into these two different plant growth areas are vastly different. Added to this, amenity horticulture addresses predominantly aesthetics, form and functional aspect of plants and to a lesser extent production as is the case with agricultural systems (Sun, Kopp and Kjelgren, 2012). Many current approaches to estimating amenity landscape irrigation water requirements originate from agriculture, the Penman-Monteith equation for reference ETo being one (Sun, Kopp and Kjelgren, 2012). Several systems exist in South Africa that are focussed on determining water use and/or water requirements of agricultural crops. Some of these being SAPWAT3 and CLIMWAT (Van Heerden, et al., 2009) and more recently SAPWAT4 (WRC, 2016). However due to the nature of agricultural production these cannot be used effectively in amenity horticultural settings and hence the need to develop specific models for the amenity horticulture industry in South Africa.

According to Devi (2009) in Australia, tools have been developed to analyse and determine detailed indoor water use, however no such tool exists that is able to determine the volume of water that can potentially be saved through implementing a demand management program for urban outdoor water use (urban irrigation). The lack of these tools results in insufficient investment into programs that target a reduction in urban irrigation demand (Devi, 2009). However the Green Star Potable Water calculator Guide for Australia has been implemented (Green Building Council of Australia, 2012).

Urban amenity landscapes consist of a mixed planting of many different types of plants each with species that have different water requirements and demands (Nouri, et al., 2013). As a result, it is more difficult to analyse the irrigation demands of gardens and public open spaces than for indoor water demands. This is primarily because, unlike indoor demand, urban irrigation demand depends on a complex set of factors. Other than being dependent on the technical efficiency of irrigation/watering devices, and on human behavioural factors, amenity landscape irrigation demand is a function of aspects such as water–atmosphere–soil–plant interactions (biophysical factors). These are in turn influenced by climatic factors (e.g. rainfall, evaporation, wind speed, humidity and radiation) as well as the varying characteristics of both soils and plants (UCCECDWR, 2000). Efforts to clarify urban irrigation demand should incorporate these and other aspects. By incorporating these aspects science would be included into the analysis, eliminating uncertainty. This would contribute towards the micro-management of irrigation which entails managing the frequency and amount of irrigation of individual sites, on a specific time basis (e.g. hourly and/or daily) (Devi, 2009).

For amenity landscapes the complex mix of elements such as plants, environmental, edaphic, climatic and management/design elements, makes it difficult to determine a single algorithm that produces an accurate irrigation demand estimate for all possible situations. Simple equations are usually very quick and easy to input data, however results are often inaccurate. Conversely more complex models incorporating multiple factors often take much longer to compute but their accuracy is improved (Pittenger, 2014).

For South Africa there is a lack of researched and available data on all aspects of outdoor water use (excluding swimming pools and car washing) within the field of amenity horticulture. This data would assist and guide users, policy makers and professionals water on decisions of sustainable water use. The starting point being that the majority of properties do not have separate water meters dedicated to measuring outdoor water use. Most have one municipal meter that measures all water that is used both indoors and outdoors. This hampers knowledge of actual amenity landscape water use as well as monitoring this water use.

6.2.1. Models

Of the many models available worldwide only two from outside South Africa will be assessed and compared, the Landscape coefficient method (UCCECDWR, 2000) and the Australia Green Star Potable Water Calculator Guide (Green Building Council of Australia, 2012). Available South African models that will be assessed and compared are 1) Green Star SA – Existing Building Performance PILOT, Potable Water Calculator Guide, produced by the GBCSA (2014) and 2) the SA Outdoor Water Model developed by Du Plessis (2014). Each of these systems is localised and specific to the country of origin.

6.2.2. Landscape coefficient method (California – USA)

The Landscape Coefficient Method (LCM) (UCCECDWR, 2000) is extensively quoted in literature as a guide for professionals that focuses on estimating the irrigation needs of amenity landscape plantings in California. Many variations of this model are available. The model is based on both research and field experience/observation. It provides estimates of water needs that may have to be adjusted to suit quantities of water used for irrigation. The method requires three different calculations to determine the amount of water used on a site, namely determining the landscape coefficient, the landscape evapotranspiration and finally the total water applied. In the implementation of this model it makes use of the Water Use Classification of Landscape Species (plant list) – WUCOLS. The LCM and WUCOLS are used jointly to determine amenity landscape water requirements. The LCM calculates the amount of water that is needed for health, appearance and growth of an amenity landscape and not the maximum amount that can be lost via evapotranspiration. Positive aspects associated with WUCOLS are that it uses a large plant species data base and categorises plants by climate and zone (Pittenger, Kjelgren and Shaw, 2012). This model was developed using a large network of professionals in the field whose experience is seen as valuable. Some negative aspects stated, are that it is not science based, that data is not reliable, it provides a false sense of provision, and is complex and perplexing to use. The LCM is also more specifically orientated towards California (USA) which limits its application (Pittenger, Kjelgren and Shaw, 2012; Pittenger, 2014). In addition according to Pittenger and Shaw (2013) research in amenity landscape plant water needs indicates that using Landscape coefficient (KL) to adjust ETo does not result in greater accuracy in estimating the amount of water an amenity landscape requires.

6.2.3. Green Star - Australia

The Green Building Council of Australia (GBCA) (2012), is similar to the South African Green Star rating system. The GBCA developed a potable water calculator used in the Green Star rating system to estimate potable water consumption in buildings and amenity landscapes. Water usage is calculated monthly as well as annually, taking into account seasonal variation. This forms part of a larger system where amongst others, points are awarded for total water and energy use, eventually awarding a star grading to the facility/site. It also determines the performance of a “standard practice benchmark building” in the same location as a comparison of water use. The model also considers use of reclaimed water. The amenity landscape portion of the model considers three main aspects of water use, plant water demand, effective rainfall and application efficiency of the irrigation system (Green Building Council of Australia, 2012; Green Building Council of Australia, 2015).

6.2.4. Green Star – South Africa

The GBCSA’s Green Star rating system (2014) is not a stand-alone calculator, but rather part of a broader calculator (model) aimed at determining water and energy use for an entire site (inclusive of buildings). Its essence is similar to the Australian Green Star Model (Green Building Council of Australia, 2012) and has a number of system commonalities. The determination of potable water is evaluated by comparing the total estimated water and energy consumption of a project, for the actual building as compared to a standard practice reference building (notional building). Based on results of percentage demand, points are awarded linked to green star ratings. For the amenity landscape portion of the evaluation, it rewards landscape design water use efficiency. It considers appropriate plant choices (linked to five specific hydrozones), irrigation types and systems (including controls/seasonal use and day/night time use), microclimate (exposed, normal or protected), as well as the area (m^2) for that specific zone (Figure 6.1). Seasonal and monthly rainfall patterns are also included. Where no controls exist, the irrigation amount is simply the monthly plant water demand (as calculated). Where seasonal adjustments exist, the default seasonal schedule based on SANS 204 climatic regions is applied. The model provides the end user with a valuable assessment of the quantities of water required for the amenity landscape for each month based on the input parameters.

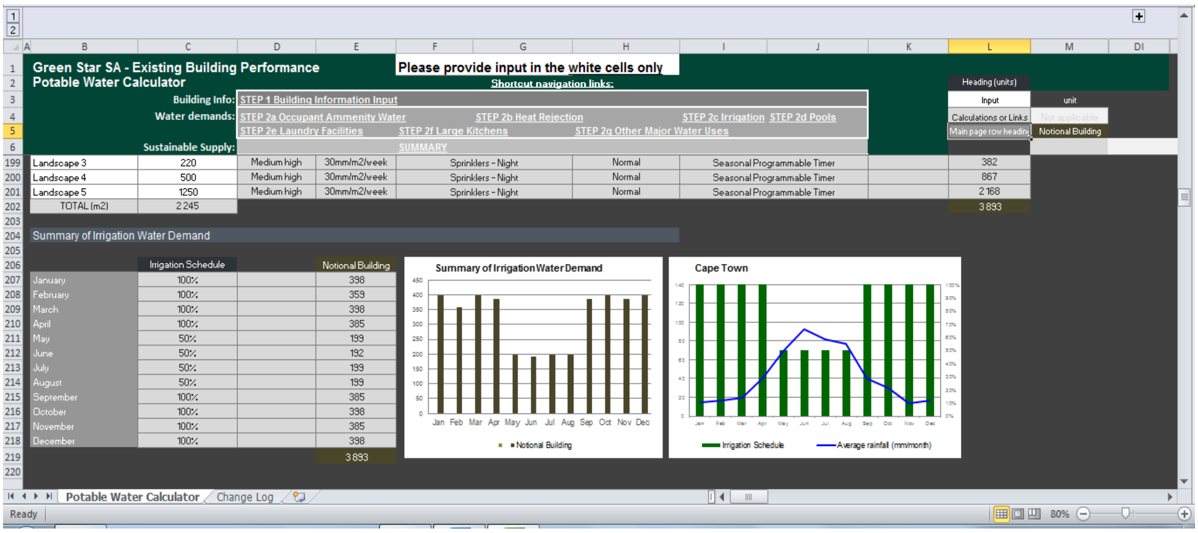

Figure 6.1: Print screen extract of Green Star SA, Existing Building Performance Potable Water Calculator (Green Building Council of South Africa, 2014).

The plants allocated in the model are regarded as the most commonly used plants in landscaping and requires the total area of each landscape area. The irrigation schedules are pre-set within the system and assumes that watering is reduced during the rainy season. There are 10 watering options namely: sprinkler days, sprinkler nights, spray days, spray nights, microspray days, microspray nights, drip bare soil, drip under mulch, subsurface drip and hand watering, each allocated a percentage water efficiency. The microclimate offers only three options namely: exposed no shade during the day, normal and protected full shade no direct sun. It requires information on the irrigation system controls such as no controls, seasonal programmable controls and rainwater sensing (Green Building Council of South Africa, 2014).

6.2.5. Estimating domestic outdoor water demand (SA Outdoor Water Model) for residential estates

The SA Outdoor Water Model (which is not given a specific name/title) focuses on calculating total average outdoor water demand, such as irrigation (types/method), swimming pools, car washing and water features. To determine outdoor use, the indoor water consumption is subtracted from overall monthly water consumption. This outdoor use is then compared to the simulated outdoor use based on the model developed by Du Plessis (2014). The model aims at assisting with determining the Average Annual Daily Demand (AADD) based on property size for residential estates. This model focuses on five basic vegetation types to determine a crop factor and a 75% rainfall efficiency together with a standard irrigation efficiency of 65% (an alternate more complex method of determining irrigation efficiency was also recommended). The model of outdoor water demand yielded results that are comparable with actual outdoor water consumption data and could be modelled internationally (Du Plessis, 2014; Du Plessis and Jacobs, 2015).

6.3. Amenity Landscape Water Use Model South Africa (ALWUMSA)

This section will discuss the elements/aspects and categories that make up the model and some of the factors allocated to selected elements that make the model. As a result of the obvious gaps in existing amenity landscape water use models (insufficient consideration of design, management and site related factors), as well as the urgent need to use water more efficiently and sustainably within amenity landscapes a more comprehensive, specific and accurate model is required for use in South Africa. For the model (inclusive of the plant list discussed in Chapter 5) to be effective, it not only requires scientific vigour and study but needs to involve the concerns and ideas from end users such as Green Industry role players.

A total of 73 industry members attended 8 workshops that contributed towards the development of the final model (Table 3.3). The final model (ALWUMSA) contains a total of 30 elements (questions) that require input data/answers (Table 6.1). This as opposed to the Landscape Coefficient Method and WUCOLS which requires five (5) elements, the Green Star Potable Water calculator Guide - Australia which requires six (6) elements, SA Green Star rating system with seven (7) elements, the SA Outdoor Water Model which requires five (5) elements of data for input and the Water Wise basic hydrozone model which requires only one (1) input element.

6.3.1. ALWUMSA categories, elements and factors (coefficients)

As outlined in Chapter 3 the aspects that needed to be included into the model were determined after extensive consultation with the Green Industry role players. The final elements that were included into the ALWUMSA for consideration consisted of 7 main element categories which was further broken down into 30 elements some with more than one question or possible answer (Table 6.1). One question requires that the closest town (out of a list of 160 towns, as discussed in Chapter 4) be selected. This selection automatically results in the Rainfall and ETo for that town being included into the model calculation. Most elements require either a yes/no/not applicable answer or a yes/no/partial answer (Table 3.5). Each possible answer including partial or not applicable are allocated a factor (as indicated in Chapter 3). Some questions such as orientation require a specific answer such as north, west, east, south or not applicable answer, or for soil types require the choice of sand, clay, loam rocky/stony or not applicable (Table 3.6). Each required answer is linked to a factor (coefficient) which ranges from 0.01 to 1.80 (Table 3.5 and Table 3.6). The excel model produced requires the user to select and input data for each hydrozone separately. The square meters for each hydrozone must also be determined. Some data may be similar for all hydrozones but in many cases will be unique to that hydrozone.

The 30 different elements (excluding rainfall, evapotranspiration, effective rainfall and size of Hydrozones) together with the range of coefficients provided results in a potential of 96 different combinations of data to be multiplied to achieve the end result.

6.4. ALWUMSA formula

Taking into account what other models have considered and how they have structured their formula the construction of the ALWUMSA model followed similar rational (also explained in Chapter 3.4). The summary of the main elements (Table 6.1) are incorporated into an equation through a series of steps (Detailed information see Annexure 23 and 24). The 30 elements have between them a total of 64 questions/options that require choices from the user.

Table 6.1: Categorisation of elements and questions included into ALWUMSA.

Main element category	**Number of main elements / questions**	Total number of sub-questions for all main element questions. (for each hydrozone)
Amenity Landscape design and maintenance aspects	9	19
Pedology aspects	4	11
Plant factors	5	16
Irrigation factor	9	15
Rainfall (effective rainfall)	1	1
ETo (Evapotranspiration)	1	1
Size	1	1

Elements as referred to (Table 6.1) and described in Annexure 23 and 24 were formulated into the mathematical equation steps as outlined below;

Step 1:

Multiply all the Landscape and Management elements (Automatically calculated for user).

Landscape and management factor (LMf)= Professional design(Pd) x Rain screen(Rs) x Build temperature(Bt) x Heat Radiation(Hr) x Building canopy(Bc) x Landscape type(Lt) x Orientation(Or) x Traffic(tr) x Wind(Wi) x Maintenance(Ma)

Step 2:

Multiply all the Pedology elements. (Automatically calculated for user).

Pedology factor (Pef) = Gradient (slope)(Gr) x Soil type(St) x Modified soil(Ms) x Granules(Gra)

Step 3:

Multiply all the Plant elements. (Automatically calculated for user).

Plant factors (Paf) = (Mulch organic(Mo) x Mulch rock(Mr)) x (Landscape age(La) x Plant density(Pld) x Canopy cover(Cc)) + Zone(Z)

Step 4:

Multiply all the Irrigation elements. (Automatically calculated for user).

Irrigation factor (If) = Water time(Wt) x (Rain Sensor(Rs) + Automated(At) + Soil moisture(Sm) + Controller(Co)) x Seasonal change(Sc) x Spacing(Sp) x Irrigation type (efficiency)(IE)

Step 5:

Select closest town to position of amenity landscape (User to input data). Automatically rainfall and ETO is determined.

Step 6:

Determine landscape plant coefficient (Automatically calculated for user).

Landscape plant coefficient (Lc)= Landscape design and management factor (LMf)x Pedology factor (Pef) x Plant factor(Paf) x Evapotranspiration (Eto)

Step 7:

Determine effective rainfall (Automatically calculated for user).

Effective rainfall (ER) = Total average monthly rainfall(Tamr)l x rainfall efficiency(50%)

***Step 8*:**

Determine irrigation (Automatically calculated for user).

Water or Irrigation requirement (WIR) per m^2 = $\frac{\text{Landscape plant coefficient (Lc) – Effective rainfall (ER)}}{\text{Irrigation factor (If)}}$

***Step 9*:**

Landscape water requirements(LspWr) (mm) per zone(m^2*) = Size (*m^2*) x Water or Irrigation requirement (WIR).*

The entire model:

The model can also be displayed in another form as one single formula including all elements as outlined below

$$LspWr = Size \times \left[\frac{(Pd \times Rs \times Bt \times Hr \times Bc \times Lt \times Or \times Tr \times W \times M) \times (Gr \times St \times Ms \times Gra) \times \left((Mo \times Mr) \times (La \times Pld \times Cc) + Z\right) \times Eto - (Tamr \times 50\%)}{(Wt \times (Rs + At + Sm + Co) \times Sc \times Sp \times IE)}\right]$$

Landscape water requirements - LspWr

Automated - At

Build temperature - Bt

Building canopy - Bc

Canopy cover – Cc

Controller - Co

Gradient (slope) - Gr

Granules - Gra

Heat Radiation - Hr

Irrigation efficiency – IE

Landscape age - La

Landscape type - Lt

Maintenance - Ma

Modified soil - Ms

Mulch organic - Mo

Mulch rock - Mr

OrientationOr

Plant density Pld

Professional design - Pd

Rain screen - Rs

Rain Sensor - Rs

Seasonal change - Sc

Soil moisture - Sm

Soil type - St

Spacing - Sp

Traffic -Tr

Water time - Wt

Wind - Wi

Zone - Z

6.5. Baseline testing of ALWUMSA to the actual site

The information obtained from the various site visits, the site water use data, (as described in Chapter 3) the evapotranspiration and rainfall data (as described in Chapter 4) and the plant hydrozone data (as described in Chapter 5) was fed into the model (ALWUMSA) for the three specific Blocks (A, B and C). The detailed site information as required for the model for each zone is listed in Annexure 16 for Block A, Annexure 17 for Block B and Annexure 18 for Block C. All three sites were no more than two years old. All data for the sites was divided into 12 month intervals.

<u>Block A:</u>

The results for Block A range from November 2015 through to October 2017 (Table 6.2) providing thirteen (13), 12 month interval data sets. Comparing the actual site water use for Block A to the results from ALWUMSA indicate that water predicted by ALWUMSA taking into account all appropriate site elements, that the water use ranged from over application of 512.27 L/m^2/yr (50%) to an under application of 472.21 L/m^2/yr (46%). Note that level 2 water restrictions were introduced in October 2016. The actual on-site 12 month staggered intervals for water use on Block A points to a gradual decline in water use from 1543.08 L/m^2/yr down to 558.59 L/m^2/yr (Table 6.2).

Table 6.2: Block A comparison of actual site water use to ALWUMSA modelled water use from November 2015 to October 2017.

Block A (Litres/m^2/yr)				
Twelve (12) month interval data sets	**Actual on site Litres/m^2/yr**	**ALWUMSA (No compensation for restrictions) Annexure 24 Litres/m^2/yr**	**Comparing ALWUMSA to Actual on site Litres/m^2/yr**	**Percentage difference**
Nov 2015 - Oct 2016	1543,08	1030,81	-512,27	-50%
Dec 2015 - Nov 2016	1434,34	1030,81	-403,53	-39%
Jan 2016 - Dec 2016	1278,19	1030,81	-247,38	-24%
Feb 2016 - Jan 2017	1,32	1030,81	1029,49	-28%
March 2016 - Feb 2017	1067,85	1030,81	-37,04	-4%
April 2016 - March 2017	1105,78	1030,81	-74,97	-7%
May 2016 - April 2017	968,25	1030,81	62,56	6%
June 2016 - May 2017	766,91	1030,81	263,90	26%
July 2016 - June 2017	596,07	1030,81	434,74	42%
Aug 2016 - July 2017	558,59	1030,81	472,21	46%
Sept 2016 - Aug 2017	560,02	1030,81	470,79	46%
Oct 2016 - Sept 2017	600,60	1030,81	430,21	42%
Nov 2016 - Oct 2017	594,92	1030,81	435,89	42%

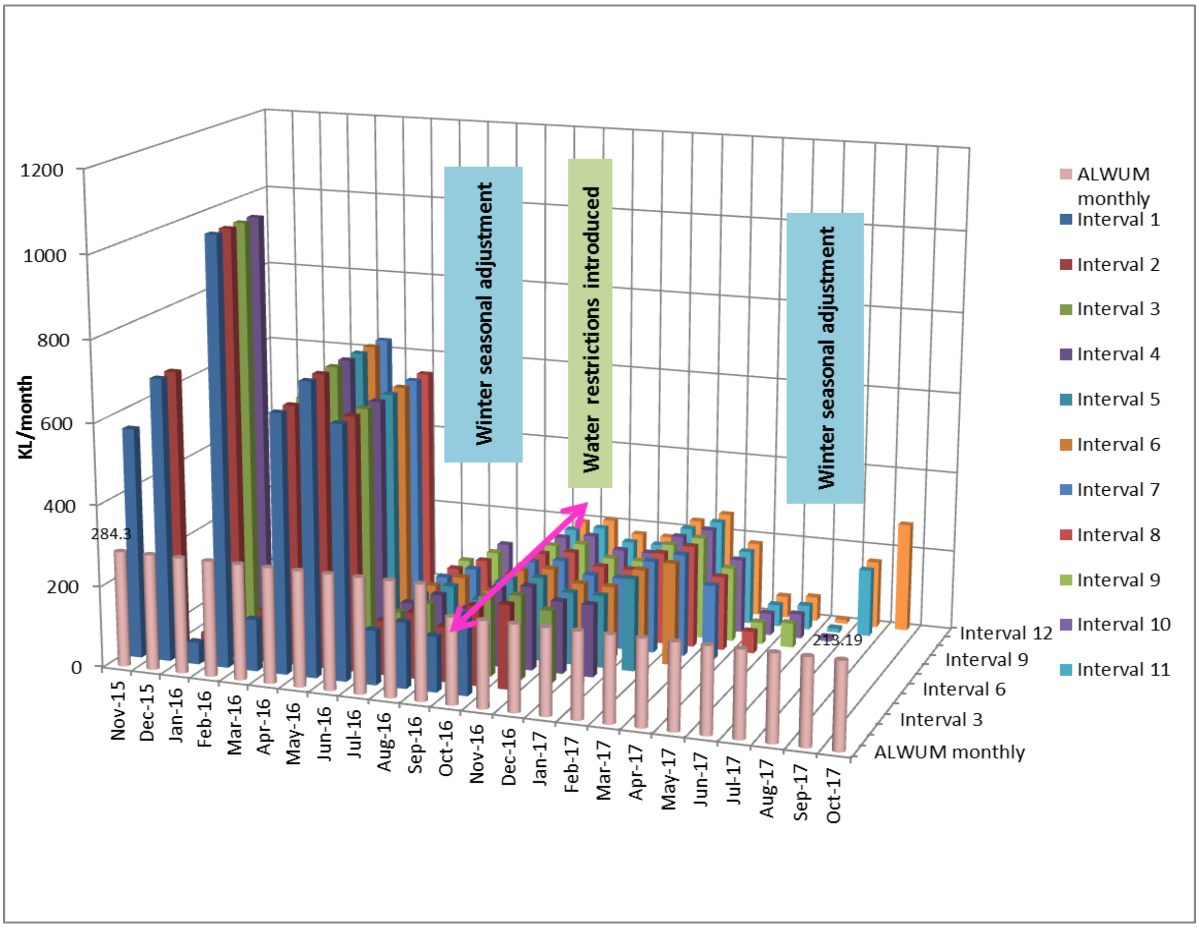

Figure 6.2: Block A water use November 2015 to October 2017 demonstrating actual 12 month interval data compared to ALWUMSA (Pre and including water restrictions).

The detailed water application based on 12 month intervals for Block A as listed in Annexure 19 and Figure 6.2 indicate that actual monthly water use for the site ranged from 1048.4 KL/month (0.32 KL/m^2/month) down to 10 KL/month (0.00 KL/m^2/month).

Block B:

The results for Block B range from February 2016 through to October 2017 (Table 6.3) providing ten (10), 12 month interval data sets. Comparing the actual site water use for Block B to the results from ALWUMSA indicate that water use predicted by ALWUMSA (taking into account all appropriate elements) ranged from over application of 147.89 L/m^2/yr (13%) to an under application of 173.92 L/m^2/yr (16%). Level 2 water restrictions were introduced in October 2016. The actual on-site 12 month interval data for water use on Block B points to a decline in water use from 1268.30 L/m^2/yr down to 946.96 L/m^2/yr (Table 6.3).

Table 6.3: Block B comparison of actual site water use to ALWUMSA modelled water use from February 2016 through to October 2017.

Block B (Litres/m²/yr)				
Twelve (12) month interval data sets	**Actual on site Litres/m²/yr**	**ALWUMSA (<u>No compensation for restrictions</u>) Annexure 24 Litres/m²/yr**	**Comparing ALWUMSA to Actual on site Litres/m²/yr**	**Percentage difference**
Feb 2016 - Jan 2017	1268.30	1120.41	-147.89	-13%
March 2016 - Feb 2017	1207.47	1120.41	-87.06	-8%
April 2016 - March 2017	1075.68	1120.41	44.74	4%
May 2016 - April 2017	993.96	1120.41	126.46	11%
June 2016 - May 2017	946.49	1120.41	173.92	16%
July 2016 - June 2017	976.36	1120.41	144.05	13%
Aug 2016 - July 2017	962.13	1120.41	158.28	14%
Sept 2016 - Aug 2017	995.01	1120.41	125.40	11%
Oct 2016 - Sept 2017	1077.89	1120.41	42.52	4%
Nov 2016 - Oct 2017	1040.79	1120.41	79.63	7%

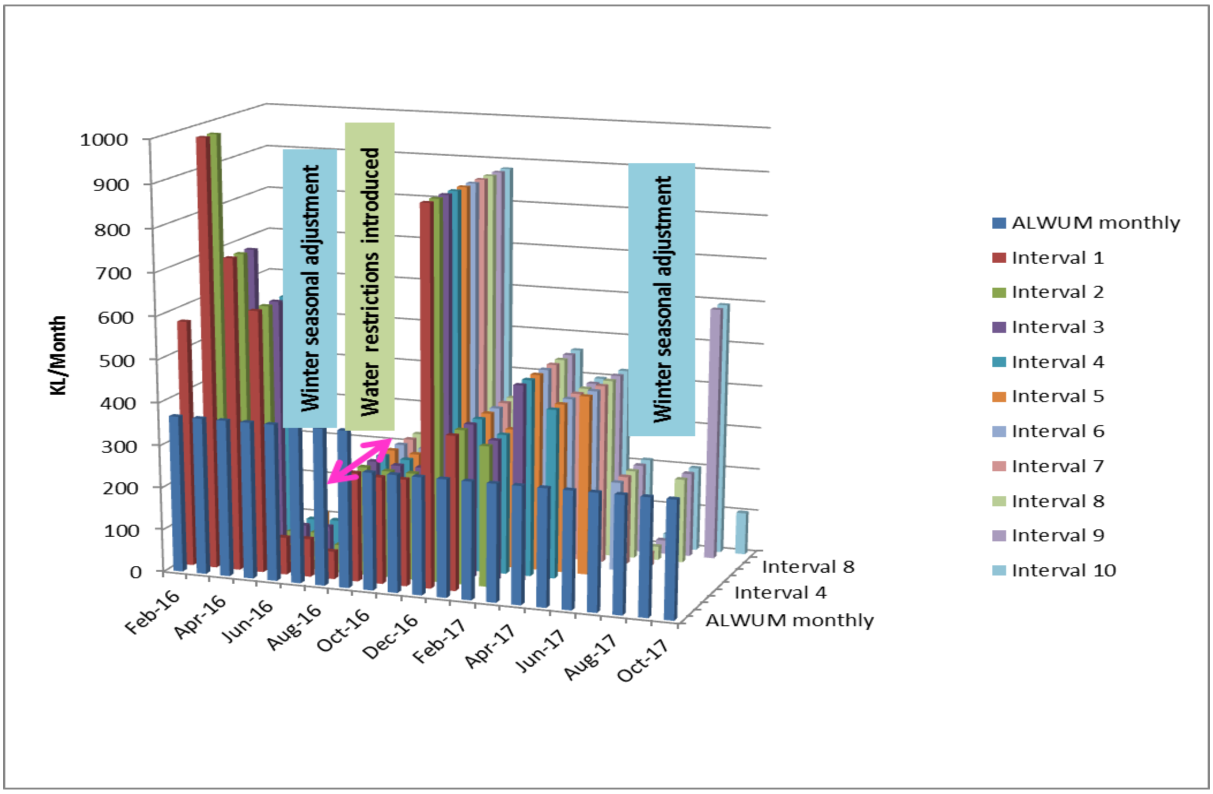

Figure 6.3: Block B water use February 2016 to October 2017 demonstrating actual 12 month interval data compared to ALWUMSA (Pre and including water restrictions).

The detailed water application based on 12 month intervals for Block B as listed in Annexure 20 and Figure 6.3 indicates that actual monthly water use for the site ranged from a high of 998.0 KL/month (0.25 KL/m^2/month) down to 31.9 KL/month (0.01 KL/m^2/month).

<u>Block C</u>

Analyses of information for Block C ranged from June 2016 through to October 2017 (Table 6.4) providing six (6), 12 month interval data sets. Comparing the actual site water use for Block C to the results from ALWUMSA indicate that water requirements predicted by ALWUMSA taking into account all appropriate elements, that the water use ranged from over application of 104.63 L/m^2/yr (10%) to an under application of 651.35 L/m^2/yr (61%). In October 2016, Level 2 water restrictions were introduced. For Block C, the actual on-site for the 12 month staggered intervals for water use points to a sharp increase in water use from 464.28 Litres/m^2/yr down to 1179.59 Litres/m^2/yr (Table 6.4).

Table 6.4: Block C comparison of actual site water use to ALWUMSA modelled water use from June 2016 through to October 2017.

Block C Litres/m^2/yr				
Twelve (12) month interval data sets	**Actual on site Litres/m^2/yr**	**ALWUMSA (No compensation for restrictions) Annexure 24 Litres/m^2/yr**	**Comparing ALWUMSA to Actual on site Litres/m^2/yr**	**Percentage difference**
June 2016 - May 2017	464.28	1074.96	610.68	57%
July 2016 - June 2017	423.61	1074.96	651.35	61%
Aug 2016 - July 2017	1134.87	1074.96	-59.92	-6%
Sept 2016 - Aug 2017	1056.42	1074.96	18.54	2%
Oct 2016 - Sept 2017	1079.64	1074.96	-4.69	0%
Nov 2016 - Oct 2017	1179.59	1074.96	-104.63	-10%

The detailed water application based on 12 month intervals for Block C is listed in Annexure 21 and Figure 6.4 indicate that actual monthly water use ranged from a high of 3086.8 KL/month (1.02 KL/m^2/month) down to 55.6 KL/month (0.02 KL/m^2/month).

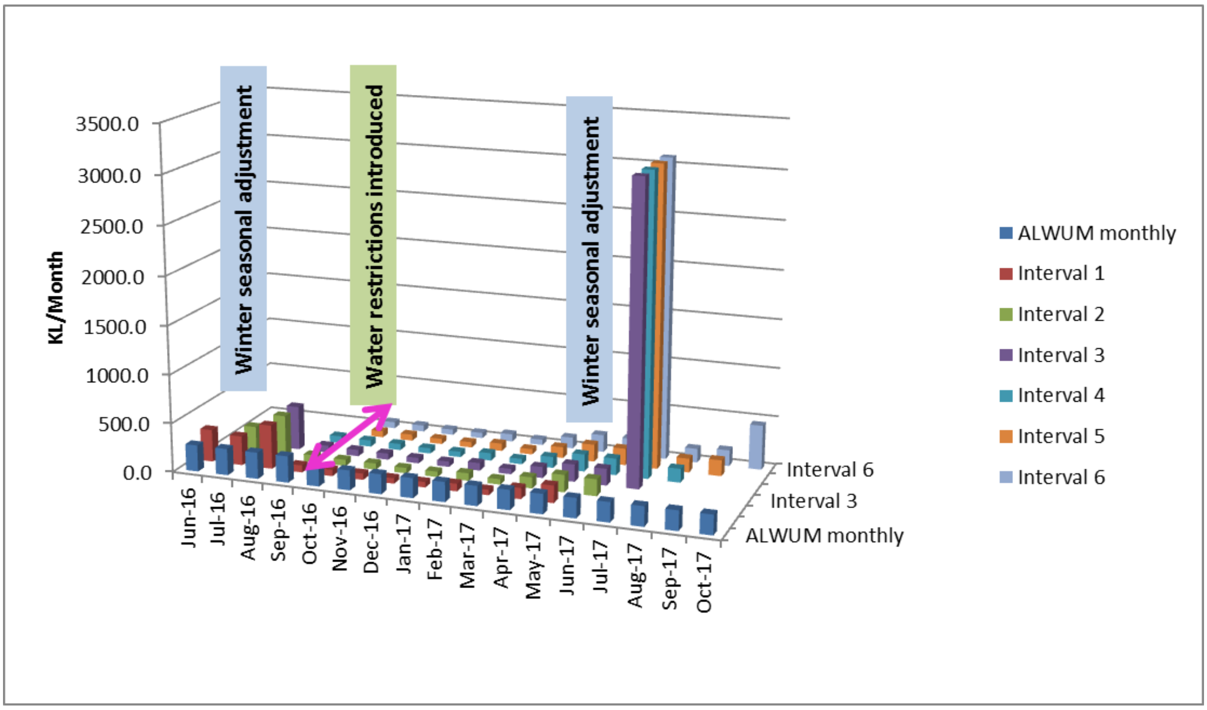

Figure 6.4: Block C water use June 2016 to October 2017 demonstrating actual 12 month interval data compared to ALWUMSA (Pre and including water restrictions).

6.6. Testing of ALWUMSA to other selected models

To assess the performance of ALWUMSA it is necessary to assess its water use against that of other existing water use models. ALMUM was compared to four (4) other models, one from USA, one from Australia, and two from South Africa. The South African models have previously either been tested or used. The comparison of the two Green Star models also included comparison of water predicted for Standard practice/Notional building requirements.

Block A:

The results for all models were again tested against the 12 month interval water use data for the actual site (Table 6.5 and Annexure 19). The results of water requirements from ALWUMSA were lower than those of Australian Green Star, Landscape Coefficient Model, South African Green Star, South African Green Star Notional Building and SA-Outdoor Water Model (Du Plessis, 2014). The water use was over estimated by these other existing models when compared to ALWUMSA, and ranged from 24% (SA-Outdoor Water Model) to 66% (South African Green Star) (Table 6.6). Only the Australian Green Star Standard practice building model produced water requirement figures (920.33 L/m^2/yr or 12%) that were lower than the calculated figure for Block A by ALWUMSA (1030.81 L/m^2/yr). For the 12 month interval periods from May 2016 – June 2017 through to November 2016 – October

2017 the actual water onsite use was lower than the results produced by ALWUMSA (Table 6.5).

Table 6.5: Block A comparison of actual onsite water use against ALWUMSA and four other models.

Block A Litres/m2/yr								
	Actual on site	ALWUMSA	Aus Green Star (AGS)	AGS Standard practice build	USA - Landscape Coefficient	SA Green Star (SAGS)	SAGS Notional building	SA-Outdoor Water Model
Nov 2015 - Oct 2016	1 543.08	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Dec 2015 - Nov 2017	1 434.34	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Jan 2016 - Dec 2017	1 278.19	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Feb 2016 - Jan 2017	1 315.82	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
March 2016 - Feb 2017	1 067.85	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
April 2016 - March 2017	1 105.78	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
May 2016 - April 2017	968.25	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
June 2016 - May 2017	766.91	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
July 2016 - June 2017	596.07	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Aug 2016 - July 2017	558.59	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Sept 2016 - Aug 2017	560.02	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Oct 2016 - Sept 2017	600.60	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04
Nov 2016 - Oct 2017	594.92	1 030.81	1 433.77	920.65	1 815.80	2 993.19	1 565.64	1 352.04

Table 6.6: Block A percentage difference between ALWUMSA and four other existing models tested.

Block A percentage difference of other tested models when compared to ALWUMSA					
Australian Green Star (AGS)	**AGS Standard practice build**	**USA - Landscape Coefficient**	**SA Green Star (SAGS)**	**SAGS Notional building**	**SA-Outdoor Water Model**
-39%	12%	-43%	-66%	-34%	-24%

Block B:

The comparison of all models was again tested against the 12 month interval water use data for the actual site (Table 6.7 and Annexure 20). For the 12 month interval periods ranging from February 2016 – March 2017 through to November 2016 – December 2017 the actual water use was lower than the results produced by ALWUMSA (Table 6.7). From visual onsite inspections during data collection and site information gathering sessions, the reduced watering had not impacted the plant quality negatively. The results of water requirements from ALWUMSA were lower than those of Australian Green Star, Landscape Coefficient Model, South African Green Star, South African Green Star Notional Building and SA-Outdoor Water Model (Du Plessis, 2014). The overestimation of water use by models when compared to ALWUMSA ranges from 166% (South African Green Star) to 27% (SA-Outdoor Water Model) to (Table 6.8). Only the Australian Green Star Standard practice building model produced water requirement figures (920.65 L/m^2/yr or 18%) that were lower than the calculated figure for block B by ALWUMSA (1120.41 L/m^2/yr). The average water use on site was only higher than ALWUMSA for the first two intervals namely February 2016 - March 2017 and March 2016 – April 2017 (Table 6.7). This could be influenced by the following; the landscape was newly planted, water restrictions where only imposed in October 2016 and possibly an over application of water had occurred due to incorrect practices.

Table 6.7: Block B comparison of actual onsite water use against ALWUMSA and four other models.

Block B Litres/m^2/yr								
Actual on site		ALWUMSA	Aus Green Star (AGS)	AGS Standard practice build	USA - Landscape Coefficient	SA Green Star (SAGS)	SAGS Notional building	SA-Outdoor Water Model
Feb 2016 - Jan 2017	1 268.30	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
March 2016 - Feb 2017	1 207.47	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
April 2016 - March 2017	1 075.68	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
May 2016 - April 2017	993.96	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
June 2016 - May 2017	946.49	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
July 2016 - June 2017	976.36	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
Aug 2016 - July 2017	962.13	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
Sept 2016 - Aug 2017	995.01	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
Oct 2016 - Sept 2017	1 077.89	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88
Nov 2016 - Oct 2017	1 040.79	1 120.41	1 578.53	920.65	1 904.05	2 975.82	1 566.12	1 424.88

Table 6.8: Block B percentage difference between ALWUMSA and four other existing models tested.

Block B percentage difference of other tested models when compared to ALWUMSA					
Australian Green Star (AGS)	**AGS Standard practice build**	**USA - Landscape Coefficient**	**SA Green Star (SAGS)**	**SAGS Notional building**	**SA- Outdoor Water Model**
-41%	18%	-70%	-166%	-40%	-27%

Block C:

For Block C the results for all models were tested against the 12 month interval water use data for the actual site ranging from February 2016 to October 2017 (Table 6.6 and Annexure 21). The results of water requirements from ALWUMSA were lower than those of Australian Green Star, Landscape Coefficient Model, South African Green Star, South

African Green Star Notional Building and SA-Outdoor Water Model (Du Plessis, 2014). The water use was over estimated, when compared to ALWUMSA, ranging from 24% (SA-Outdoor Water Model) to 166% (South African Green Star) (Table 6.10). Only the Australian Green Star Standard practice building (920.65 L/m^2/yr or 17%) model produced water requirement figures that were lower than the calculated figure for Block C by ALWUMSA (1074.96 L/m^2/yr). For the 12 month interval periods June 2016 to June 2017 and September 2016 to August 2017 the actual water use was lower than the results produced by ALWUMSA (Table 6.9). The reason for the lower onsite water use could be due to the reduced winter watering added to that water restrictions were imposed in October 2016.

Table 6.9: Block C comparison of actual onsite water use against ALWUMSA and four other models.

Block C Litres/m^2/yr								
Actual on site Block C		ALWUMSA	Aus Green Star (AGS)	AGS Standard practice build	USA - Landscape Coefficient	SA Green Star	SAGS Notional building	SA - Outdoor Water Model
June 2016 - May 2017	464.28	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32
July 2016 - June 2017	423.61	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32
Aug 2016 - July 2017	1 134.87	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32
Sept 2016 - Aug 2017	1 056.42	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32
Oct 2016 - Sept 2017	1 079.64	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32
Nov 2016 - Oct 2017	1 179.59	1 074.96	1 553.54	920.65	1 334.99	2 863.05	1 565.84	1 331.32

Table 6.10: Block C percentage difference in water use between ALWUMSA and four other existing models tested.

Block C percentage difference of other tested models when compared to ALWUMSA					
Australian Green Star (AGS)	AGS Standard practice build	USA - Landscape Coefficient	SA Green Star (SAGS)	SAGS Notional building	SA- Outdoor Water Model
-45%	17%	-70%	-166%	-46%	-24%

6.7. Testing of ALWUMSA to a range of scenarios based on site information

ALWUMSA was tested on a range of different scenarios. For each scenario, all site assessed elements were left exactly the same except for the elements being tested. Each block was tested separately for the same scenarios against ALWUMSA.

Elements were selected based on the listings in Table 6.1. Elements were randomly chosen from the four broad main element categories to ensure that a range of scenarios with possible different influences could be observed. For the main element categories of amenity landscape and design and irrigation 5 scenarios were selected from each and for pedology and plant factors 4 elements were selected from each (as they have less listed elements). Added to this several additional combinations of scenarios were tested to consider the water use implications. Each combination was selected based on references in literature;

- plant density sparse with no mulch (immature or sparsely planted landscapes will characteristically have less leaf area and thus loose less water (Sun, Kopp and Kjelgren, 2012; Costello and Jones, 2000) and mulching able to reduce water loss from the soils in young plantings of plant (Andrews, 2004)).
- no water hydrozone 30%, low hydrozone 30%, medium hydrozone 30% and high hydrozone 10% (The high water zone should consist of 10% to 30% of a landscape, medium zone 20% to 40%, low water zone 30% to 60% and a no water zone should make up a large area of the landscape (Hoy, et al., 2017))

The best and worst case scenario was determined by considering all those elements of the model and site that could possibly have been changed or influenced via a design or management decision. The best case being the scenario where all possible elements that could reduce water use (due to good management/design decisions) were selected and the worst case being exactly the opposite (where poor management decisions could be made). As a result various elements of the model were changed to represent the best or worst case. The elements changed for both best and worst case scenarios being design by professional, use of mulch, soil type, inclusion of water retention granules, hydrozones, all elements linked to irrigation and maintenance (these aspects were also used exactly the same when considering Block B and C).

The ALWUMSA was also tested on 4 major towns in different provinces to obtain an indication of possible water requirements from this same site if it were placed in any of these other cities (noting that the actual site is with a major town already). The four other towns used for comparison being Durban, Cape Town, Port Elizabeth and Bloemfontein. These towns are dispersed around South Africa and have varying rainfall and potential evapotranspiration and hence should reflect dissimilar water use figures for each.

<u>Block A</u>

For Block A, the testing (Table 6.11) of scenarios for, no mulch, design undertaken by a non-professional, high wind, no seasonal change and no rain sensor installed all produced results that were higher than ALWUMSA. While testing scenarios of improved zone placement (No water hydrozone 30%, Low hydrozone 30%, Medium hydrozone 30% and High hydrozone 10%), landscape age at 15 years, watering at night (18h00 to 06h00) and no specific temperature from surrounding buildings that may increase surrounding temperature all produced results that were lower than ALWUMSA. Only one result that considered whether the entire site had soil that was changed to a pure bark type mix was equal to that of ALWUMSA.

Table 6.11: Block A comparison of ALWUMSA against selected scenarios.

Block A - Litres/m^2/yr												
Actual on site Block A		ALWUMSA	Scenario-Mulch -no	Scenario-Zones - No30%L30%M30%H10%	Scenario-Non-Prof Design	Scenario-High wind	Scenario-Watering no season change	Scenario - Rainsensor-none	Scenario-Lsp Age 15yrs	Scenario-Water time night (6pm-6am)	Scenario - Increase temp surround build_no	Scenario <100% pure bark type mix
Nov 2015 - Oct 2016	1 543.08	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Dec 2015 - Nov 2017	1 434.34	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Jan 2016 - Dec 2017	1 278.19	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Feb 2016 - Jan 2017	1 315.82	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
March 2016 - Feb 2017	1 067.85	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
April 2016 - March 2017	1 105.78	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
May 2016 - April 2017	968.25	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
June 2016 - May 2017	766.91	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
July 2016 - June 2017	596.07	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Aug 2016 - July 2017	558.59	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Sept 2016 - Aug 2017	560.02	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Oct 2016 - Sept 2017	600.60	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81
Nov 2016 - Oct 2017	594.92	1 030.81	1 358.78	717.65	1 174.85	1 089.11	1 374.41	1 202.61	774.13	773.11	696.90	1 030.81

For Block A the testing (Table 6.12) of scenarios such as sandy soil, rocky soil, sprinklers not placed at correct spacing and not running at optimal pressure, site maintenance undertaken only every six months and plant density being sparse with no mulch added produced results that were higher than ALWUMSA. While testing of landscape that is partially natural and partially transformed, addition of water retention granules, plant density sparse and irrigation efficiency with the entire site being converted to drip irrigation, all produced results that were lower than ALWUMSA.

Table 6.12: Block A comparison of ALWUMSA against selected scenarios.

Block A - Litres/m²/yr												
Actual on site Block A		ALWUMSA	Scenario-Lsp design-mix Nat &Transform	Scenario-Soil-Sand	Scenario-Soil-Rocky	Scenario-Water rentn granules-yes	Scenario-Plant density Sparse	Scenario-Irrigation efficiency & all drip	Scenario-Sprinkler space & optimum pressure-No	Scenario-Site maint_6 mnthly	Scenario-Density sparse & no mulch
Nov 2015 - Oct 2016	1 543.08	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Dec 2015 - Nov 2017	1 434.34	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Jan 2016 - Dec 2017	1 278.19	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Feb 2016 - Jan 2017	1 315.82	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
March 2016 - Feb 2017	1 067.85	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
April 2016 - March 2017	1 105.78	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
May 2016 - April 2017	968.25	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
June 2016 - May 2017	766.91	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
July 2016 - June 2017	596.07	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Aug 2016 - July 2017	558.59	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Sept 2016 - Aug 2017	560.02	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Oct 2016 - Sept 2017	600.60	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48
Nov 2016 - Oct 2017	594.92	1 030.81	871.12	1 506.93	1 438.92	808.21	970.61	890.47	1 325.33	2 255.13	1 268.48

The results from ALWUMSA were also tested against what could be termed a best case and a worst case scenario. For the best case scenario various aspects of the site that could be changed through either design or maintenance aspects were assessed. The results for these two scenarios are that the best case is predictably lower than the results for the worst case scenario and ALWUMSA produced results between these two scenarios (Table 6.13).

Table 6.13: Block A comparison of ALWUMSA against best and worst case scenarios.

Block A - Litres/m²/yr				
Actual on site Block A		ALWUMSA	Scenario-Best case scenario	Scenario-Worst case scenario
Nov 2015 - Oct 2016	1 543.08	1 030.81	200.85	1 739.17
Dec 2015 - Nov 2017	1 434.34	1 030.81	200.85	1 739.17
Jan 2016 - Dec 2017	1 278.19	1 030.81	200.85	1 739.17
Feb 2016 - Jan 2017	1 315.82	1 030.81	200.85	1 739.17
March 2016 - Feb 2017	1 067.85	1 030.81	200.85	1 739.17
April 2016 - March 2017	1 105.78	1 030.81	200.85	1 739.17
May 2016 - April 2017	968.25	1 030.81	200.85	1 739.17
June 2016 - May 2017	766.91	1 030.81	200.85	1 739.17
July 2016 - June 2017	596.07	1 030.81	200.85	1 739.17
Aug 2016 - July 2017	558.59	1 030.81	200.85	1 739.17
Sept 2016 - Aug 2017	560.02	1 030.81	200.85	1 739.17
Oct 2016 - Sept 2017	600.60	1 030.81	200.85	1 739.17
Nov 2016 - Oct 2017	594.92	1 030.81	200.85	1 739.17

To assess the potential water requirements for the same landscape in different towns around South Africa, four scenarios were run. The results for Block A being; Durban and Cape Town having similar water use requirements with Bloemfontein requiring the most (the actual site tested using ALWUMSA is based in Pretoria).

Table 6.14: Block A comparison of ALWUMSA against selected towns.

Block A - Litres/m²/yr							
Actual on site Block A		ALWUMSA (Tshwane)	Scenario -change town Durban	Scenario-change town Cape Town	Scenario-change town Port Elizabeth	Scenario-change town Bloemfontein
Nov 2015 - Oct 2016	1 543.08	1 030.81	692.40	695.19	814.64	1 097.38
Dec 2015 - Nov 2017	1 434.34	1 030.81	692.40	695.19	814.64	1 097.38
Jan 2016 - Dec 2017	1 278.19	1 030.81	692.40	695.19	814.64	1 097.38
Feb 2016 - Jan 2017	1 315.82	1 030.81	692.40	695.19	814.64	1 097.38
March 2016 - Feb 2017	1 067.85	1 030.81	692.40	695.19	814.64	1 097.38
April 2016 - March 2017	1 105.78	1 030.81	692.40	695.19	814.64	1 097.38
May 2016 - April 2017	968.25	1 030.81	692.40	695.19	814.64	1 097.38
June 2016 - May 2017	766.91	1 030.81	692.40	695.19	814.64	1 097.38
July 2016 - June 2017	596.07	1 030.81	692.40	695.19	814.64	1 097.38
Aug 2016 - July 2017	558.59	1 030.81	692.40	695.19	814.64	1 097.38
Sept 2016 - Aug 2017	560.02	1 030.81	692.40	695.19	814.64	1 097.38
Oct 2016 - Sept 2017	600.60	1 030.81	692.40	695.19	814.64	1 097.38
Nov 2016 - Oct 2017	594.92	1 030.81	692.40	695.19	814.64	1 097.38

Block B

For Block B the testing (Table 6.15) of several scenarios produced results higher than ALWUMSA, namely; no mulch, design undertaken by a non-professional, high wind, no seasonal adjustment and no rain sensor installed. While testing of improved zone placement (No water hydrozone 30%, Low hydrozone 30%, Medium hydrozone 30% and High hydrozone 10%), landscape age at 15 years or more, watering at night (18h00 to 06h00) and no specific temperature from surrounding buildings that may increase surrounding temperature, all produced results that were lower than ALWUMSA. Only one result namely, considering if the entire site had soil that was changed to a pure bark type mix was equal to that of ALWUMSA.

Table 6.15: Block B comparison of ALWUMSA against selected scenarios.

Block B- Litres/m²/yr													
Actual Block B		ALWUMSA	Scenario-Mulch - no	Scenario-Zones - No30%L 30%M30 %H10%	Scenario-Non-Prof Design	Scenario-High wind	Scenario-Watering no season change	Scenario - Rainsensor-none	Scenario-Lsp Age 15yrs	Scenario-Water time night (6pm-6am)	Scenario - Increase temp suround build_no	Scenario-<100% pure bark type mix
Feb 2016 - March 2017	1268.30	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
March 2016 - April 2017	1207.47	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
April 2016 - May 2017	1075.68	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
May 2016 - June 2017	993.96	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
June 2016 - July 2017	946.49	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
July 2016 - Aug 2017	976.36	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
Aug 2016 - Sept 2017	962.13	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
Sept 2016 - Oct 2017	995.01	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
Oct 2016 - Nov 2017	1077.89	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41
Nov 2016 - Dec 2017	1040.79	1 120.41	1 423.64	719.22	1 276.06	1 183.41	1 493.88	1 307.15	883.10	840.31	759.60	1 120.41

For Block B (Table 6.16) the following scenarios produced results that were higher than ALWUMSA namely; sandy soil, rocky soil, sprinklers not placed at correct spacing and not running at optimal pressure, site maintenance undertaken only every six months, and plant density being sparse with no mulch added. While testing of landscape that is partially natural and partially transformed, addition of water retention granules, plant density sparse and irrigation efficiency with the entire site being converted to drip irrigation produced results that were lower than ALWUMSA.

Table 6.16: Block B comparison of ALWUMSA against selected scenarios.

Block B - Litres/m²/yr											
Actual Block B		ALWUMSA	Scenario-Lsp design-mix Nat &Transform	Scenario-Soil-Sand	Scenario-Soil-Rocky	Scenario-Water rentn granules-yes	Scenario-Plant density Sparse	Scenario-Irrigation efficiency & all drip	Scenario-Sprinkler space & optimum pressure-No	Scenario-Site maint_6monthly	Scenario-Density sparse & no mulch
Feb 2016 - March 2017	1 268.30	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
March 2016 - April 2017	1 207.47	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
April 2016 - May 2017	1 075.68	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
May 2016 - June 2017	993.96	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
June 2016 - July 2017	946.49	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
July 2016 - Aug 2017	976.36	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
Aug 2016 - Sept 2017	962.13	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
Sept 2016 - Oct 2017	995.01	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
Oct 2016 - Nov 2017	1 077.89	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67
Nov 2016 - Dec 2017	1 040.79	1 120.41	947.85	1 634.90	1 561.40	879.87	1 059.76	925.82	1 440.53	2 443.39	1 332.67

The results for these two scenarios (Table 6.17) namely best case is, and the worst case scenario produced lower and higher water requirements respectively that ALWUMSA.

Table 6.17: Block B comparison of ALWUMSA against best and worst case scenarios.

Block B- Litres/m²/yr				
Actual Block B		ALWUMSA	Scenario-Best case scenario	Scenario-Worst case scenario
Feb 2016 - March 2017	1 268.30	1 120.41	271.22	4 280.36
March 2016 - April 2017	1 207.47	1 120.41	271.22	4 280.36
April 2016 - May 2017	1 075.68	1 120.41	271.22	4 280.36
May 2016 - June 2017	993.96	1 120.41	271.22	4 280.36
June 2016 - July 2017	946.49	1 120.41	271.22	4 280.36
July 2016 - Aug 2017	976.36	1 120.41	271.22	4 280.36
Aug 2016 - Sept 2017	962.13	1 120.41	271.22	4 280.36
Sept 2016 - Oct 2017	995.01	1 120.41	271.22	4 280.36
Oct 2016 - Nov 2017	1 077.89	1 120.41	271.22	4 280.36
Nov 2016 - Dec 2017	1 040.79	1 120.41	271.22	4 280.36

To assess the potential water requirements for the same landscape (Block B) in different towns, four scenarios were run namely Durban, Cape Town, Port Elizabeth, Bloemfontein and ALWUMSA (undertaken in Pretoria) (Table 6.18).

Table 6.18: Block B comparison of ALWUMSA against selected towns.

Block B- Litres/m²/yr							
			Scenario-change town				
Actual Block B		ALWUMSA (Tshwane)	Durban	Cape Town	Port Elizabeth	Bloemfontein
Feb 2016 - March 2017	1 268.30	1 120.41	756.68	756.49	886.31	1 191.38
March 2016 - April 2017	1 207.47	1 120.41	756.68	756.49	886.31	1 191.38
April 2016 - May 2017	1 075.68	1 120.41	756.68	756.49	886.31	1 191.38
May 2016 - June 2017	993.96	1 120.41	756.68	756.49	886.31	1 191.38
June 2016 - July 2017	946.49	1 120.41	756.68	756.49	886.31	1 191.38
July 2016 - Aug 2017	976.36	1 120.41	756.68	756.49	886.31	1 191.38
Aug 2016 - Sept 2017	962.13	1 120.41	756.68	756.49	886.31	1 191.38
Sept 2016 - Oct 2017	995.01	1 120.41	756.68	756.49	886.31	1 191.38
Oct 2016 - Nov 2017	1 077.89	1 120.41	756.68	756.49	886.31	1 191.38
Nov 2016 - Dec 2017	1 040.79	1 120.41	756.68	756.49	886.31	1 191.38

<u>Block C</u>

For Block C tested the same (Table 6.19) scenarios as Block A and B. Element scenarios with results higher than ALWUMSA, are no mulch, design undertaken by a non-professional, high wind, no seasonal adjustment and no rain sensor installed. While testing of ALWUMSA for improved zone placement (No water hydrozone 30%, Low hydrozone 30%, Medium hydrozone 30% and High hydrozone 10%), landscape age at 15 years or more, watering at night (18h00 to 06h00) and no specific temperature from surrounding buildings that may increase surrounding temperature, all produced results that were lower than ALWUMSA. Only one result namely, considering if the entire site had soil that was changed to a pure bark type mix was nearly equal to that of ALWUMSA.

Table 6.19: Block C comparison of ALWUMSA against selected scenarios.

Block C- Litres/m²/yr													
Actual on site Block C		ALWUMSA	Scenario-Mulch - no	Scenario-Zones - No30%L 30%M30 %H10%	Scenario-Non-Prof Design	Scenario-High wind	Scenario-Watering no season change	Scenario - Rainsensor-none	Scenario-Lsp Age 15yrs	Scenario-Water time night (6pm-6am)	Scenario - Increase temp suround build_no	Scenario <100% pure bark type mix
June 2016 - May 2017	464.28	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96
July 2016 - June 2017	423.61	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96
Aug 2016 - July 2017	1134.87	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96
Sept 2016 - Aug 2017	1056.42	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96
Oct 2016 - Sept 2017	1079.64	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96
Nov 2016 - Oct 2017	1179.59	1 074.96	1 373.12	662.97	1 225.12	1 135.74	1 433.27	1 254.12	841.61	806.22	726.85	1 074.96

The testing of other scenarios for Block C (Table 6.20) on scenarios of sandy soil, rocky soil, sprinklers not placed at correct spacing and not running at optimal pressure, site maintenance undertaken only every six months, and plant density being sparse with no mulch added displayed results that were higher than ALWUMSA. Results of the testing of landscape that is partially natural and partially transformed, addition of water retention granules, plant density sparse and irrigation efficiency with the entire site being converted to drip irrigation produced results that were lower than ALWUMSA.

Table 6.20: Block C comparison of ALWUMSA against selected scenarios.

Block C - Litres/m²/yr												
Actual on site Block C		ALWUMSA	Scenario-Lsp design-mix Nat &Transform	Scenario-Soil-Sand	Scenario-Soil-Rocky	Scenario-Water rentn granules-yes	Scenario-Plant density Sparse	Scenario-Irrigation efficiency & all drip	Scenario-Sprinkler space & optimum pressure-No	Scenario-Site maint_6 mnthly	Scenario Density sparse & no mulch
June 2016 - May 2017	464.28	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39
July 2016 - June 2017	423.61	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39
Aug 2016 - July 2017	1 134.87	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39
Sept 2016 - Aug 2017	1 056.42	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39
Oct 2016 - Sept 2017	1 079.64	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39
Nov 2016 - Oct 2017	1 179.59	1 074.96	908.47	1 571.33	1 500.42	842.89	1 017.80	892.29	1 382.09	2 351.34	1 287.39

The results for Block C for the best case indicate lower water use than ALWUMSA and the worst case scenario indicated higher water use (Table 6.21).

Table 6.21: Block C comparison of ALWUMSA against best and worst case scenarios.

Block C - Litres/m²/yr				
Actual on site Block C		ALWUMSA	Scenario- Best case scenario	Scenario- Worst case scenario
June 2016 - July 2017	464.28	1 074.96	239.93	3 685.08
July 2016 - Aug 2017	423.61	1 074.96	239.93	3 685.08
Aug 2016 - Sept 2017	1 134.87	1 074.96	239.93	3 685.08
Sept 2016 - Oct 2017	1 056.42	1 074.96	239.93	3 685.08
Oct 2016 - Nov 2017	1 079.64	1 074.96	239.93	3 685.08
Nov 2016 - Dec 2017	1 179.59	1 074.96	239.93	3 685.08

Assessing the potential water requirements for the same landscape in four different towns (Table 6.22) indicates that Bloemfontein has the highest site water requirement.

Table 6.22: Block C comparison of ALWUMSA against selected towns.

Block C - Litres/m²/yr							
Actual on site Block C		ALWUMS (Tshwane)	Scenario-change town Durban	Scenario-change town Cape Town	Scenario-change town Port Elizabeth	Scenario-change town Bloemfontein
June 2016 - July 2017	464.28	1 074.96	722.25	725.00	849.57	1 144.31
July 2016 - Aug 2017	423.61	1 074.96	722.25	725.00	849.57	1 144.31
Aug 2016 - Sept 2017	1 134.87	1 074.96	722.25	725.00	849.57	1 144.31
Sept 2016 - Oct 2017	1 056.42	1 074.96	722.25	725.00	849.57	1 144.31
Oct 2016 - Nov 2017	1 079.64	1 074.96	722.25	725.00	849.57	1 144.31
Nov 2016 - Dec 2017	1 179.59	1 074.96	722.25	725.00	849.57	1 144.31

Summary comparison of scenarios

To allow for an additional scenario comparison across all three test sites the percentage change for each site was determined against that of ALWUMSA. This allowed for an assessment of each scenario element(s) against each test site and to observe trends in water use requirements (Table 6.23, 6.24 and 6.25).

Table 6.23: Comparison summary of all scenarios for all Blocks against ALWUMSA water figures for each.

Description/ Scenario	Block A (L/m^2/yr)	Percentage increase or decrease from ALWUMSA	Block B (L/m2/yr)	Percentage increase or decrease from ALWUMSA	Block C (L/m2/yr)	Percentage increase or decrease from ALWUMSA	Expected increase or decrease	Actual increase or decrease
ALWUMSA	1 030.81		1 120.41		1 074.96		N/A	N/A
Scenario-Mulch -no	1 358.78	32%	1 423.64	27%	1 373.12	28%	Increase	Yes
Scenario-Zones - No30%L30%M30%H10%	717.65	-30%	719.22	-36%	662.97	-38%	Decrease	Yes
Scenario-Non-Proffessional Design	1 174.85	14%	1 276.06	14%	1 225.12	14%	Increase	Yes
Scenario-High wind	1 089.11	6%	1 183.41	6%	1 135.74	6%	Increase	Yes
Scenario - Watering no season change	1 374.41	33%	1 493.88	33%	1 433.27	33%	Increase	Yes
Scenario - Rain sensor-none	1 202.61	17%	1 307.15	17%	1 254.12	17%	Increase	Yes
Scenario - Landscape Age 15yrs	774.13	-25%	883.10	-21%	841.61	-22%	Decrease	Yes
Scenario - Water time night (6pm-6am)	773.11	-25%	840.31	-25%	806.22	-25%	Decrease	Yes
Scenario - Increase temp surround build, no increase.	696.90	-32%	759.60	-32%	726.85	-32%	Decrease	Yes
Scenario - <100% pure bark type mix	1 030.81	0%	1 120.41	0%	1 074.96	0%	Increase	Yes (Negligable)
Scenario-Lsp design-mix Nat &Transform	871.12	-15%	947.85	-15%	908.47	-15%	Decrease	Yes
Scenario - Soil type Sand	1 506.93	46%	1 634.90	46%	1 571.33	46%	Increase	Yes
Scenario - Soil type Rocky	1 438.92	40%	1 561.40	39%	1 500.42	40%	Increase	Yes
Scenario-Water retention granules-yes	808.21	-22%	879.87	-21%	842.89	-22%	Decrease	Yes
Scenario-Plant density Sparse	970.61	-6%	1 059.76	-5%	1 017.80	-5%	Decrease	Yes
Scenario-Irrigation efficiency & all irrigation drip	890.47	-14%	925.82	-17%	892.29	-17%	Decrease	Yes
Scenario-Sprinkler space & optimum pressure-No	1 325.33	29%	1 440.53	29%	1 382.09	29%	Increase	Yes
Scenario-Site maint, 6 monthly	2 255.13	119%	2 443.39	118%	2 351.34	119%	Increase	Yes
Scenario - Density sparse & no mulch	1 268.48	23%	1 332.67	19%	1 287.39	20%	Increase	Yes

Table 6.24: Comparison summary of best and worst scenarios for all Blocks against ALWUMSA water figures for each.

Description/ Scenario	Block A (L/m2/yr)	Percentage increase or decrease from ALWUMSA	Block B (L/m2/yr)	Percentage increase or decrease from ALWUMSA	Block C (L/m2/yr)	Percentage increase or decrease from ALWUMSA	Expected increase or decrease	Actual increase or decrease
ALWUMSA	1 030.81		1 120.41		1 074.96		N/A	N/A
Scenario - Best case scenario	200.85	-81%	271.22	-76%	239.93	-78%	Decrease	Yes
Scenario - Worst case scenario	1 739.17	69%	4 280.36	282%	3 685.08	243%	Increase	Yes

Table 6.25: Comparison of scenario – Changing towns including their rainfall and Evapotranspiration.

	Block A ($L/m^2/yr$)	Block B ($L/m^2/yr$)	Block C ($L/m^2/yr$)	Rainfall/ Annual Average	Potential Evapotranspiration
ALWUMSA (Pretoria)	1 030.81	1 120.41	1 074.96	647.20	1 797.97
Scenario-change town Durban	692.40	756.68	722.25	840.00	1 385.66
Scenario-change town Cape Town	695.19	756.49	725.00	522.70	1 250.43
Scenario-change town Port Elizabeth	814.64	886.31	849.57	595.80	1 457.95
Scenario-change town Bloemfontein	1 097.38	1 191.38	1 144.31	551.70	1 853.79

6.8. Comparison of ALWUMSA to on-site water use before and after water restrictions imposed

Table 6.26: Pre and post water restrictions, water use on site, compared to ALWUMSA.

	Pre water restrictions (average water use) ($L/m^2/month$)		Post water implementation of restrictions (average water use) ($L/m^2/month$)		Percentage reduction water use (pre versus post restrictions)	Percentage reduction water use (pre versus post restrictions)
	On-site	**ALWUMSA**	**On-site**	**ALWUMSA**	**On-site**	**ALWUMSA**
Block A	134.88	85.90	50.32	64.40	63%	25%
Block B	108.45	93.40	87.64	70.00	19%	25%
Block C	212.84	89.60	119.28	67.00	44%	25%

Water restrictions were introduced in October 2016 (City of Tshwane, 2016). To model the same requirements as set out for the water restrictions as imposed by Tshwane municipality, the scenario was run for all three sites changing the watering time to water at night only. The on-site water use for each Block as well as the modelled water use with ALWUMSA was compared for the period before water restrictions as well as after water restrictions were imposed (Table 6.26). For this scenario the average actual monthly water use for all Blocks reduced by 25% (Table 6.26).

6.9. Discussion

The main aim of this study was to develop a model (ALWUMSA) that could be used to determine water requirements of amenity landscapes taking into account a range of elements that would either influence water use positively or negatively. The discussion below outlines the results that consistently have demonstrated that through the application of ALWUMSA on-site water requirements are reduced resulting in water being saved and thus making amenity landscapes more sustainable. This is consistent for testing against on-site water use, other existing models and a range of scenarios.

Model factors and categories

The model factors and categories developed for ALWUMSA are industry based, grounded on available scientific and other printed information (as discussed in the Chapters 2, 3 and 6).

ALWUMSA formula

Each of the 30 elements in ALWUMSA has been allocated a factor. This concept is similar to the models compared to in this study. Similarly the multiplication and division of certain elements as well as the inclusion of location, effective rainfall, area (size) and evapotranspiration is supported in several models. However none of the other models consider these aspects like ALWUMSA does, or in the same manner as does ALWUMSA.

The landscape plant coefficient is common across Australian Green Star, Landscape Coefficient Model, South African Green Star and SA-Outdoor Water Model, however not in the same format or considering all the same elements. Effective rainfall is common across Australian Green Star, and the SA-Outdoor Water Model. The water or irrigation requirement is similar in concept to Australian Green Star, and SA-Outdoor Water Model. ALWUMSA has included several additional irrigation/watering related elements while the landscape water requirement is considered in all models.

Thus, although there are large differences across the models and when compared to what has been developed for ALWUMSA, there are at the same time some elements, coefficients, factors and formulae that correlate.

Comparison of ALWUMSA to Test Site (Blocks A, B and C) water use.

ALWUMSA calculation was determined taking into account all relevant site, environmental, edaphic and management related elements including that seasonal adjustment of water application which was implemented. The existing sites (Blocks A, B and C) were all newly landscaped sites in the process of being established which may have influenced water use. The results of the average actual on site water use versus modelled water use, using ALWUMSA indicate that for Blocks A, B and C (Table 6.26) under normal operating conditions, water use was higher than calculated using ALWUMSA.

For Block A water use reduced during the winter period 2016 and 2017 (Figure 6.1 and Annexure 19) as expected due to seasonal changes in water application as per the statement by site management that water use is adjusted seasonally. Similarly water restrictions were introduced in October 2016 (City of Tshwane, 2016). Based on average annual monthly calculations ALWUMSA indicates that 85.90 L/m^2/month be applied during non-restriction times. Water requirements taking into account a change in watering times determines that the water requirements reduce to 50.32 L/m^2/month (Figure 6.2 in KL/month and Table 6.23 in L/m^2/month). This compared to the average water use (November 2015 to September 2016) for Block A before restrictions being 134.88 L/m^2/month whilst after restrictions were announced, the average water use (October 2016 to December 2017) was 50.32 L/m^2/month (Table 6.23).

Water use on Block B for the 12 month intervals reduced during the winter period 2016 and 2017 (Figure 6.3 and Annexure 20), as expected, due to the statement by site management that water use is adjusted seasonally. Correspondingly in October 2016 water restrictions were introduced (City of Tshwane, 2016). Based on average annual monthly calculations ALWUMSA indicates that 93.40 L/m^2/month be applied during non-restriction times and with a change in watering times for water restrictions demand be reduced to 70.00 L/m^2/month. (Figure 6.3 in KL/month and Table 6.23 in L/m^2/month). This compared to the average water use (February 2016 to September 2016) for Block B before restrictions being 108.45 L/m^2/month, whilst after restrictions were announced the average water use (October 2016 to October 2017) was 87.64 L/m^2/month (representing an average of 19.18 % monthly saving) (Figure 6.3 and Table 6.23).

Water use on Block C, did not reduce during the winter period 2016 or 2017 (Figure 6.4 and Annexure 21). Based on average annual monthly calculations ALWUMSA indicates that 89.60 L/m^2/month be applied during non-restriction times, whilst the watering requirements during this restriction period indicate that 67.00 L/m^2/month is required (Table 6.23

L/m^2/month and Figure 6.4 in KL/month). This compared to the average water use (June 2016 to September 2016) for Block C before restrictions being 212.84 L/m^2/month whilst after restrictions were imposed, the average is water use (October 2016 to October 2017) was 119.28 L/m^2/month (representing a 44% reduction).

The gradual decline in actual on-site water use for the 12 month intervals for Block A from 1543.08 L/m^2/yr down to 594.92 L/m^2/yr and for Block B from 1268.30 L/m^2/yr down to 1040.79 L/m^2/yr, could in part be ascribed to the water restrictions imposed in October 2016, as well as the plant root system developing and maturing over time. This contrasts strongly with the increased water use for Block C for the 12 month intervals from 464.28 L/m^2/yr to 1179.59 L/m^2/yr. For this modelling for the 12 month intervals, ALWUMSA calculations were not changed to reflect water restrictions except where reference is made to Table 6.26. The anomaly amounts (volumes) of water use, that either spike or decline cannot be explained as the measurements were based on automatic meter reader results. Examples of these spikes/decline in water volumes being: Block A 1 048 000 L (1 048 KL) February 2016, Block B 881 000 L (881 KL) December 2016 and Block C 3 086 800 L (3 086.8 KL) July 2017) or drop (e.g. Block A 54 200 L (54.2 KL) January 2016 and Block B 31 900 L (31.9 KL) July 2017. These results were however all included to contribute towards the average 12 month figures (Annexure 19, 20 and 21, Figure 6.1, 6.2 and 6.3).

In September 2016 water restrictions were imposed to commence in October 2016 (City of Tshwane, 2016). The restrictions required a minimum of 15% water saving from users as well as limiting watering to evenings (18h00 to 06h00) which should have contributed to considerable savings. This did impact water use in Block A (Figure 6.1 and Table 6.26), down by 62% and Block B (Figure 6.2 and Table 6.23), down by 19%. For Block C the water use actually increased (Table 6.26), by 24%. This would have impacted the water use in the 12 month intervals measured for all Blocks.

Comparison of ALWUMSA to existing models

Of the existing models compared to ALWUMSA namely Australian Green Star, South African Green Star rating system (SAGS), SA Outdoor Water Model and the Landscape Coefficient Method, none match the application rates as determined by ALWUMSA. None of the existing models available cater for as many site, environmental, edaphic and management aspects as are included in ALWUMSA. The existing models have limited input parameters and in many cases aspects are either omitted completely (e.g. edaphic related factors, management and design– all models), insufficiently described (e.g. irrigation system controls

- SA Green Star Model) (Figure 6.1) or allow for a limited number of categories (e.g. the range of input elements for irrigation – all models).

It is important that a balance between actual input data, time spent inserting the data into the model and the value of the output data, be achieved. The four models compared to ALWUMSA in the study each have little input data which means that crucial site specific influences of water required could be lost. The models available do not sufficiently cater for or consider the complexity of amenity landscape sites thus limiting the integrity of the total input data as well as the results achieved. Because the number of input elements is reduced in existing models they do not cater for a broader range of site specific situation elements which may change from site to site, as compared to ALWUMSA (Table 6.1). These will ultimately impact on water use required for the site (positively or negatively) (e.g. Table 6.5 and 6.6). The other models input elements are at times defined too broad and without considering certain changes that may influence water use. For site A, B and C neither the Australian Green Star, Landscape Coefficient Method, South African Green Star rating system, SA Outdoor Water Model or the South African Green Star rating system Notional Building achieved results of amenity landscape water required that were lower than ALWUMSA. Only Australian Green Star Standard Practice Building (ranging from 12% - 18%) achieved rates that were lower than ALWUMSA (Tables 6.6, 6.8 and 6.10).

The challenge with all models assessed is that they fail to consider and evaluate sufficient detailed site aspects such as soils, slope, mulch, use of water retention granules, irrigation management tools, hard surface related elements and amenity landscape maintenance.

Testing of ALWUMSA against a range of scenarios based on site information

As expected with ALWUMSA when tested the actual on-site parameters for each Block (A, B and C), the model was able to consistently predict an increase or a decrease in water use based on the element that was changed (Table 6.23). Table 6.23 summarises the results as set out in Tables 6.11, 6.12, 6.15, 6.16, 6.19 and 6.20.

Literature sources quote savings for mulch that range between 50% and 70% (Buckle, et al., 2003; Waskom and Neibauer, 2014; Ranjan, et al., 2017) (Annexure 22). The anticipated increase in water use with no mulch (as the site was mulched) did in fact result in an increase in water use that ranged from 27% to 32% (Table 6.23). This is below the rates of literature sources quoted above. The use of Rain sensors (Rain shutoff) can produce savings of between 15% and 30% (Connellan, 2002; Carrow, Duncan and Waltz, 2005; St. Hilaire, et al., 2008; Riverside County Transportation and Land Management Agency, 2009;

City of Kelowna, 2010; Cabrera, et al., 2013; Team Watersmart - Regional District of Nanaimo, 2018) (Annexure 22). The site makes use of rain sensors and hence the scenario was to test with no rain sensors. This resulted in an increase in 17% for all three sites (Table 6.23), which is close to the bottom range of saving as quoted by literature cited above. Other scenario elements such as sandy soils, drip irrigation, watering hours at night, high wind, no seasonal change to the watering times of irrigation systems, water retention granules and incorrect irrigation sprinkler spacing showed similar positive water use trends when tested against ALWUMSA (Annexure 22).

The sites had amongst others different sized zones, different areas of lawn versus plantings, different hydrozone sizes, areas of different orientation, sloped and level areas and different irrigation systems. These did not negatively change the anticipated results of the model when various scenarios were considered. The scenarios that were predicted to impact equally across all three sites such as professional design, change of wind, change of watering season, increase in temperature from surrounding buildings and changing sprinkler spacing and working pressures, did in provide a consistent percentage change in water requirements for all three Blocks (Table 6.23). In some cases the increase varied by 1% for example inclusion of water retention granules (Block A 22%, Block B 21% and Block C 22%) and soil type rocky (Block A 40%, Block B 39% and Block C 40%). For the scenario where all irrigation was changed to drip irrigation (shrub areas and lawn), Block A had the least increase as there were three hydrozones in this block that were already designated as drip irrigation, no other Blocks had drip irrigation as a specific hydrozone (Table 6.23). The decrease in water requirement (when considering drip irrigation) for the three Blocks being Block A 14%, Block B 17% and Block C being 17%. In some scenarios it was anticipated that the percentage water required would differ between Blocks, this did occur, e.g. changing the percentage area covered by each zone type to match a more ideal situation (No Water hydrozone 30%, Low water hydrozone 30%, Medium water hydrozone 30% and High water hydrozone 10%) of the site (Hoy, et al., 2017). The following decrease in water use was obtained, Block A 30%, Block B 36% and Block C 38% (Table 6.23).

Considering the best case (due to best management/design decisions for that site as described in Chapters 3.5.3 and 6.7), as well as the worst case scenario (where poor management decisions could be made for that site as described in Chapters 3.5.3 and 6.7) for each of the Blocks, due to each site's specific elements that were already pre-existing on site, the change in water use for each scenario was different (Table 6.24). Table 6.24 summarises the results of Tables 6.13, 6.17 and 6.21. The variation in water requirement from ALWUMSA for the best case scenario was a decrease of water required for Block A 81%, Block B 76% and Block C 78% (Table 6.24).

The scenario (Chapter 6.7) that considered placing the existing Blocks (amenity landscapes) in different major towns around South Africa (explained in Chapters 3.5.3 and 6.1) demonstrates the impact of evapotranspiration in the ALWUMSA. As an example, the difference in average annual rainfall between Cape Town and Bloemfontein is merely 29 mm (more in Bloemfontein), however the evapotranspiration difference is 603.36 mm higher in Bloemfontein. This has translated to an increase in water requirements for Block A, for the same amenity landscape site for Bloemfontein of 402.2 $L/m^2/yr$ more than for Cape Town (Table 6.25). For Block A, B and C Durban required the least amount of water, followed by Cape Town, Port Elizabeth, Tshwane and finally Bloemfontein. While for Block B and C Cape Town requires marginally less water than Durban, followed by Port Elizabeth, Tshwane and finally Bloemfontein with increased water requirements.

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CHAPTER 7 – CONCLUSION AND RECOMMENDATIONS

Through the development of ALWUMSA it is possible to more accurately predict the amount of water that should be used on any amenity landscape, when compared to other existing models. This is supported by visual observations on site indicating that the site could still be aesthetically pleasing with reduced actual on-site water use. The development of ALWUMSA resulted in the formulation of 30 different elements used and for each it was required that a coefficient value, an area value or a quantity value (rainfall and evapotranspiration) be determined and allocated.

The study set out to develop a comprehensive water-use model for South Africa that can be applied in various amenity landscapes to ensure sustainable water use. To derive a model a large number of plant databases were analysed to produce a plant database for South Africa that is linked to hydrozones and plant factors. The data obtained for evapotranspiration was based on 49 years' worth of data. It was spatially joined using ArcMap to level 1 and 2 towns providing a list of 160 towns each with linked evapotranspiration data. The rainfall data from SAWS (based on 29 years of data) and other sources was also matched to these 160 towns.

For model development SAGIC industry members were engaged to establish a wide range of elements for inclusion in the model. Through repetitive workshops with Green Industry representatives in various locations around the country combined with the Delphi process, a basis for the models' requirements was determined. By prioritising elements for inclusion in the model and comparing these to existing models 30 different elements were selected for inclusion into the model. These elements were divided into categories based on design and maintenance, pedology, plant characteristics, irrigation, evapotranspiration, rainfall, location and area size. A model (ALWUMSA) formula was generated to determine a landscape and management factor, a pedology factor, an irrigation factor, a landscape plant coefficient, effective rainfall, a water or irrigation requirement and finally the landscape water requirements.

ALWUMSA as a model incorporates various aspects common to the Australian Green Star, South African Green Star rating system (SAGS), SA Outdoor Water Model, Landscape Coefficient Method and Water Wise Hydrozones. It includes principles of existing model formula but is represented differently (for example the plant list is a national list and not a regional list as is the WUCOLS list, the plant factor for ALWUMSA includes more than plant density, for the plant factor portion of the calculator than does any other model). The process of developing ALWUMSA as well as the 30 elements that constitute the model means that it is only applicable to South Africa and South African amenity landscapes.

The generated plant database is extensive and does not compare to any other existing plant database for South Africa. Characteristics making the database unique include a list of plants most commonly grown and sold in South Africa with a link to one of four specific hydrozones (high, medium, low and no water) with water requirements that are in turn linked to a specific plant factor (PF) range, each with three levels of PF application.

Potential evapotranspiration and rainfall data will be used to assist with the application of the plant database in amenity landscape planning and management.

The ALWUMSA is unique to South Africa with regards to the specific elements that are required to determine site amenity landscape water use. ALWUMSA was tested against on-site actual water use for 3 test sites (prior to local government imposed water restrictions). Results indicate that actual water use was higher than modelled required water use. The average water use as calculated by ALWUMSA under normal operating conditions was lower than the actual water use on the three test sites.

The testing of ALWUMSA on all three test sites against the Australian Green Star, Landscape Coefficient Method, South African Green Star rating system, SA Outdoor Water Model or the South African Green Star rating system Notional Building all produced consistent results indicating that ALWUMSA is more efficient in terms of water use after considering all onsite elements. Only the Australian Green Star Standard Practice Building produced rates that were lower than ALWUMSA. The Australian Green Star Standard Practice Building model considers what the water use should be based on the ideal site and other best practice sites and not necessarily on the actual on-site conditions experienced. However, based on completeness of assessing a wide range of influencing factors ALWUMSA is more inclusive and accurate.

With the testing of ALWUMSA for the same three sites (Block A, B and C) against a range of 21 different scenarios (against a range of actual on-site parameters i.e. for each scenario one element was changed while leaving all others the same), inclusive of a best case and a worst case scenario in all but one scenario (Converting entire site to less than 100% pure bark type mix) the results were as expected. For all the scenarios tested where management decisions could be made to minimise water requirements of the amenity landscape the results demonstrate reduced water required for the site. Similarly for all scenarios tested where poor management decisions may lead to a potential increase in water required for the amenity landscape the results did show an increase in water required for the site. The scenario test results consistently produced either increased or decreased volumes of water required for the amenity landscape, as anticipated. This will encourage water conservation for amenity landscapes resulting in a more sustainable landscape and also influence the sustainability of the Green Industry. Further to other comparisons ALWUMSA (test site Pretoria) was tested against four different towns (Cape Town, Port Elizabeth, Bloemfontein and Durban) around South Africa. The results indicate that increased evapotranspiration (which is known to influence water stress within amenity landscapes, Chapter 4.2.1) as is the case in Bloemfontein, when compared to Cape Town with only marginal difference in rainfall (29 mm) results in an increased water requirement for the site.

Pittenger (2014) indicates that more complex equations take longer to run and involve more effort that may only improve accuracy of results slightly. It may be argued that in order to improve water use efficiency of amenity landscapes additional time and effort is required. In mitigation of a more complex model when tested, ALWUMSA consistently demonstrated average water requirements (L/m^2/month)for the sites that were lower than all other models, despite the sites being placed under level 2 water restrictions due to drought (Table 6.26).

ALWUMSA results were lower when compared to the actual onsite water use pre introduction of water restrictions. The actual onsite water use for the three test sites post the introduction of water restrictions reduced, was lower than ALWUMSA calculation (except for 1 twelve month interval for site C). This consistently lower water use (post water restrictions) did not reduce the observed visual quality or health of the amenity landscapes (when visited by the researcher to obtain on-site data). Thus the ALWUMSA results that require less water than the actual onsite water applied, should not contribute towards death of trees and shrubs as occurred in the Royal Botanical Gardens Melbourne Australia in 2007 (Symes, et al., 2008) where Landscape coefficient rates used in their model were set too low.

Keanne, (1995), Pauker, (2001), Symes, et al., (2008), Thompson and Sorvig, (2008), Rutland and Dukes, (2012), Sun, Kopp and Kjelgren, (2012), Ghebru, Du Toit and Steyn, (2013), Costello and Jones, (2014), Hartin, Oki, Fujino and Faber, (2015), Pannkuk and Wolfskill, (2015) and Rico, Navarro and Gōmez, (2016) refer to a range of methods that reduce water use (Annexure 22). Many of these were tested in this project using ALWUMSA and demonstrated water savings. The tested scenarios of ALWUMSA against actual onsite data, produced results that were consistent.

The scenario that a site may have all soil changed to have bark type mix, was included in the testing to accommodate roof type gardens where an artificial soil mix is required. Results produced the same water use figures required as did ALWUMSA for the actual sites. The reason for this could be that the water holding capacity of bark type soil mixes increases with increased pore space (Masaka, et al., 2016), therefore the < 100% pure bark type mix could most likely have a reduced pore space and therefore hold less water.

ALWUMSA in combination with the plant database provides a novel approach to determining anticipated and actual water use for amenity landscapes. It allows for a combination of site managed aspects that should encourage amenity landscape designers, landlords, property management companies and owners to consider implementing water conservation measures that will reduce water use and costs. Through application of these water conserving aspects such as xeriscaping which encompass the entire amenity landscape from design, through implementation to maintenance, it should be possible to demonstrate cost and manpower savings in the landscape as supported by Medina and Gumper, 2004 and Mayer, Lander and Glenn; 2015.

ALWUMSA together with the plant database would be suitable for use by organisations that focus on sustainable landscapes (e.g. Green Building Council of South Africa (GBCSA) and Leadership in Energy and Environmental Design - LEED) to assist with determining water use of sites.

Institutions of higher learning that focus on amenity landscapes and plant production, could include the plant database as well as ALWUMSA into their training as a methodology for determining appropriate water use and amenity landscaping best practice for site design, construction, management and maintenance.

The results of ALWUMSA calculations could be used when amenity landscape sites of SALI and LIA members are being assessed in competitions. This would encourage improved water efficiencies.

The plant database could be used by SANA growers to group plants for correct watering. It should also be used by retail nurseries and amenity landscape media to advice customers and journalists on correct hydrozone placement. An element of the plant database could be included into the SANA Garden Centre Association competition to allow for members to demonstrate a practical commitment to water conservation in garden centres.

SAGIC and all its associated members could adopt this version of ALWUMSA as well as the plant database for implementation in all their spheres of operation.

ALWUMSA and the plant database could also be considered for implementation by government and organs of state to improve water use efficiency on their sites and as a preventative drought management tool. It can also be used to determine amenity landscape water use requirements during drought (when restrictions are imposed) by altering the necessary model parameters.

A supplementary booklet that explains all elements of ALWUMSA as well as how evaluations should proceed still needs to be produced. It is possible that training sessions may need to be included to help ensure an improved understanding of actual on-site implemenation is achieved.

Project constraints include time, funds and additional resources. This may have allowed for additional site monitoring and additional engagement and refinement to improve the plant database. Another constraint is the quality of information in the sources of information used for plant the data base. A variety of sources such as internet sites, books (and other printed literature) and feedback from wholesale nurseries in South Africa. Obtaining data for the plant data base was based on the premise that data was correct and verified. However a number of unexpected challenges where experienced such as plant names that were incorrectly spelt, old botanical names were used and incomplete plant used names.

The attendance of workshops was voluntary and hence the range and number of attendees was based on their availability and willingness to attend. The variety of participants and their range of experience could have been both a positive and a negative aspect. As an example, some participants were specialists in irrigation, others in landscaping and others were landscape architects. From a negative aspect their input into all diverse aspects (elements) could have been limited, however from a positive aspect their speciality could have contributed to the holistic data and information gathered. Due to the nature of the workshops, the researcher was unable to intervene and “fill” in gaps. The importance of remaining impartial was crucial.

Several potential shortcomings as highlighted by Hsu and Sandford (2007) that could be experienced by using the Delphi technique were experienced in the workshops.

Initially an open letter of invitation was sent out to members of SALI, LIA and ILASA as these organisations are known to work on amenity landscape sites where landscape water is often metered, no responses were received. As a result the researcher embarked on convenience sampling and engaged with SAGIC member contacts and companies for assistance with sites to be used to test the model. Of the many potential test sites visited, unfortunately only the three test sites that were used had available water readings that could be used as a comparison.

Regional climatic limitations that may be specific to some locations in South Africa have not been included in the model except for the average annual rainfall and potential evapotranspiration figures. The plant database is also generic and aimed for use throughout the country and is not regionally specific.

The key problem that this study addressed was that, there is currently no comprehensive water use model linked to an extensive plant database associated with hydrozones that can be applied across a broad range of amenity landscapes in South Africa. The resultant plant database, climatic maps and model addresses this void.

- Recommendations for future studies include;
- Determining the hydrozone data for the plants not included in the current plant database and incorporating them into the database.
- The development of a user manual or explanatory document for using the ALWUMSA needs to be developed to assist with correct implementation of the model.
- The model could also be turned into a standalone software package or APP.
- ALWUMSA could be tested over a longer period of time and on other sites.
- Additional specific water restriction parameters could be included in the model to allow for adaptation.

The reality for South Africa is that available water per person is reducing; extreme water shortages are anticipated in six of the nineteen water management areas, with moderate shortages in nine areas. Evapotranspiration outstrips rainfall in most areas of the country and water use is increasing at a rate that will result in water shortages. Added to these dilemmas, climate change will reduce rainfall in many areas and water restrictions are becoming the norm in many towns all around South Africa with amenity landscapes being impacted first in these situations.

Water is integral and important in every landscape no matter what the climatic region. The need for amenity landscapes to become more sustainable, to conserve water and be resilient is critical if SAGIC industry members are to continue to make a valuable contribution to society. The basis for using and implementing the plant database is to implement hydrozoning in all landscapes. The premise should be that all amenity landscape sites should be divided into a range of hydrozones (high, medium, low and no water as defined in this project), with high hydrozone being allocated the smallest area in the landscape. Where a single hydrozone consists of a mixture of plants from different hydrozones this unfortunately mitigates all attempts to conserve water.

ALWUMSA has been developed after consultation with industry and after research into the existing models. All main element categories (Amenity landscape design aspects, pedology aspects, plant factors, irrigation factors, rainfall (effective rainfall), ETo (Evapotranspiration) and area size) and the elements as listed in the ALWUMSA together with the equations are aimed at conserving water within all types of amenity landscapes in South Africa. As a result upfront incorporation of the elements into new designs or gradual implementation into existing landscapes over time will result in both long-term financial savings and water savings for the amenity landscape.

Ultimately both the plant database and ALWUMSA has been developed specifically for South Africa to suite our plants and environmental conditions with assistance from a range of SAGIC members. The model specifically caters for a broad range of possible site scenarios to allow for each site to be uniquely assessed. Examples of the range of elements considered being, design elements, microclimate elements, soils and slopes (pedology), orientation, irrigation and associated water conservation mechanisms, watering times, a range of plant related elements, mulching, hydrozones, maintenance, potential evapotranspiration, rainfall and hydrozone size.

The results of water use for the sites assessed demonstrated consistently less water use for ALWUMSA compared to other models. Evidence suggests that other models over estimate water requirements. Comparisons of the ALWUMSA calculations for onsite with a range of scenarios presented water use figures that consistently displayed the water requirements according to the input parameters. ALWUMSA should be included for planning of all sites and maintenance of all existing amenity landscape sites to ensure that water conservation is successfully implemented and achieved.

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Annexure 1: Example of external water use by various communities in different locations – globally.

This provides an overall assessment of examples from various locations, of water use in the landscape (referenced in 2.2.5 Amenity landscape water use). The references unfortunately do not distinguish between amenity landscape water use and other external water use such as swimming pools and car washing.

Location	**% of total domestic water used outdoors**	**Note/Location**	**Source**
Australia	23%	Melbourne	(Devi, 2009).
	27%	Sydney	(Devi, 2009).
	49%	Adelaide	(Devi 2009).
	55%	Canberra	(Devi 2009).
	56%	Perth	(Devi, 2009).
	65%	Alice Springs	(Devi, 2009).
Western Australia and Perth	50%	Multi-residential units	(Loh and Coghlan, 2003).
	56%	Single residential units	(Loh and Coghlan, 2003).
Australia	25%	Melbourne	(Willis, et al., 2011)
	8%	Gold Coast (Residents with moderate concern for environment)	(Willis, et al., 2011).
	14%	Gold Coast (Residents with high concern for environment)	(Willis, et al., 2011).
New Zealand	8%	Aukland	(Willis, et al., 2011)
America	7%	Cambridge (Ontario)	(Devi, 2009)
	14%	Waterloo (Ontario)	(Devi, 2009)
	29%	Seattle (Washington)	(Devi, 2009)
	38%	Eugene (Oregon)	(Devi, 2009)
	43%	Lompoc (California)	(Devi, 2009)
	67%	Phoenix (Arizona)	(Devi, 2009)
	69%	Scottsdale (Arizona)	(Devi, 2009)
	72%	Las Virgenes (California)	(Devi, 2009)
	58%	America	(AWWARF, 1999)
	50%- 75%	Arizona	(Water Use it Wisely, 2005)
	58%	USA	(Willis, et al., 2011; IRWD, 2012),
	60%	USA	(Pittenger, et al., 2015).
	40%-70%	USA	(Pittenger and Shaw 2005; St. Hilaire, et al., 2008)

Location	% of total domestic water used outdoors	Note/Location	Source
	46%	Texas	(Cabera, et al., 2013)
	50%	California	(Anon, 2016).
	10%	USA (Cool, wet climates)	(Barta, et al., 2004)
	75%	USA (Hot dry climates)	(Barta, et al., 2004)
	40%-60%	Colorado	(Barta, et, al., 2004)
	30%	USA	(U.S. Environmental Protection Agency, 2013)
	305-50%	USA	(Thompson, and Sorvig, 2008)
South Africa	30%-50%	South Africa	(Landscape Irrigation Association of SA, 2009; Wegelin and Jacobs, 2013.)
	31%-50%	South Africa	(Rand Water, n.d.)
	73%	South Africa (perceived use)	(Jacobs, 2008)

Annexure 2: Examples of the wide range of names and descriptions given to Hydrozones emanating from a range of sources.

Very few sources use the same description or definition when referring to plant water use in the amenity landscape which is ultimately referring to the required hydrozone that the plant should be planted in (referenced in 2.3.3 Plants and Hydrozones). The examples were matched to suit the hydrozones as adopted for this study and hence in some cases two categories were merged into one new category.

Institution or book reference name	**High**	**Medium**		**Low**		**No watering**	**Country of origin of source**
Kwantlen Polytecchnic University	High water/aquatic	Moderate water use.		Low water		Dry/no watering	USA
eGardens Online Nursery (Pty) Ltd	Water needs: Lots	Water needs: medium		Water needs: Low			
Salt Lake City Public Utilities	Four irrigation applications per month (or once per week)	Three irrigation applications per month		One irrigation application per month Two irrigation applications per month			USA
Keith Kirstens (Plantinfo)	High	Medium		Low			South Africa
Arizona Municipal Water Users	High	Moderate		Low		Very low	USA

Institution or book reference name	**High**	**Medium**		**Low**		**No watering**	**Country of origin of source**
Association							
Landscape water efficiency guide	Once a week. Require relatively high amounts of water	Plants that require relatively high amounts of water-high maintained areas, lushest part of the landscape and may require regular watering in the absence of rainfall. Twice a month		Some watering once established- require only occasional watering. Do not require constant watering. Include low-water-use ground covers and shrubs. Once a month		No watering once established- Plants are watered by rainfall. Use drought tolerant native vegetation or imported plants from similar regions. Low water use zone No watering	Jordan
Green Building Council of Australia	High water use	Moderate water use		Low water use		Very low water use	Australia

Institution or book reference name	High	Medium		Low		No watering	Country of origin of source
Annuals for the South African Garden							South Africa
Gardening with Indigenous Plants	Lots of water	Average water		Little water			South Africa
Characteristics and uses of selected Trees and Shrubs cultivated in South Africa	No X-Susceptible; undependable in sub humid regions except on selected sites where supplementary soil moisture is available. Drought hardy (but not frost sensitive) at George, Cedara, Van Reenen and Piet Retief.	X-Somewhat susceptible: unable to survive in the semi-arid regions except in presence of abundant seepage water. Drought hardy (but not frost sensitive) at Humansdorp,	XX-Moderately resistant: suitable for planting in the semi-arid interior regions of the central, N, NE Cape dryland of Natal midlands, W-OFS, etc. Suitable for	XXX-Very resistant: able to survive without watering, once well established, in the arid interior regions, Drought hardy.			South Africa

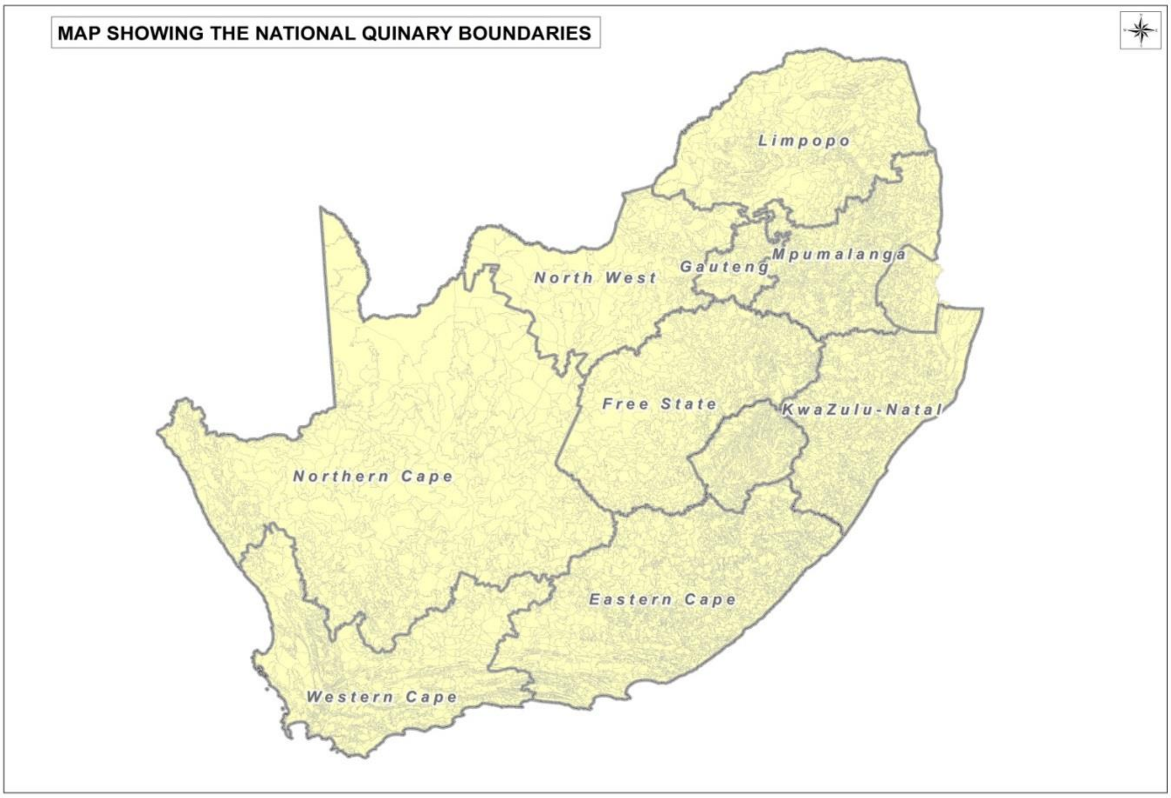
Institution or book reference name	High	Medium		Low		No watering	Country of origin of source
		Ladysmith, Bethlehem and in Pretoria - Witwatersrand area.	drier areas as long as sufficient soil moisture.				
Royal Horticultural Society What Plant Where Encyclopaedia	Full water droplet- Prefers wet soil.	Half full water droplet - Prefers moist soil.		Empty water droplet - Prefers well drained soil.			United Kingdom
Water-wise Landscaping guide for water management planning	Zone 4 plants are shallow rooted or water loving. They need irrigation twice per week.	Zone 3 plants require weekly watering.		Zone 2 plants require irrigation once every 2 weeks. They may also require an additional irrigation during hot spells.	Zone 1 plants will need a monthly irrigation. During extremely hot or windy weather	Zone 0 means that little or no irrigation is required. Plants in this zone will be drought tolerant native or naturalized plants. During extended hot spells they may need some irrigation.	USA

Institution or book reference name	High	Medium		Low		No watering	Country of origin of source
					they may need an additional irrigation.		
Xeriscape Plant Guide	Moist	Moderate/Somewhat dry/ best with occasional deep soaking		Low/Dry			USA
Easy Guide to Indigenous Shrubs	Full watering can- requires lots of water	Half full watering can - Requires moderate water		Quarter full watering can - Requires little water			
Water Wise Watering	Summer- 25 mm(100%)/ week Spring/Autumn- 15 mm(60%)/week	Summer- 15 mm(60%)/ week Spring/Autumn- 12 mm(50%)/		Summer- 12 mm(50%)/ week Spring/Autumn- 7 mm(25%)/w		No watering required unless in extreme cases	South Africa – Rand Water

Institution or book reference name	High	Medium		Low		No watering	Country of origin of source
	Winter-12 mm (50%)/week	week Winter-7 mm (25%)/week		eek Winter-12 mm every second week (including lawns but not at all if dormant)			
South African Landscapers' Institute & Rand Water's Guide to Water Wise Landscaping	Receive over 900 mm of annual rainfall. Water once a week in general, and twice or three times a week during very hot dry spells	Receive between 500-750 mm rainfall a year. If they show signs of distress in dry times water. Water once a month in winter.		Receive annual rainfall of between 300-500 mm rainfall. water every 6-8 weeks		Receive less than 300 mm rainfall per annum. Water on in severe cases.	South Africa – Rand Water & Landscapers' Institute

Annexure 3: Creation of an evapotranspiration map – procedure.

- A Polygon Shape file with all the National Quinary (Sub-Catchment) Boundaries was provided for the purpose of this exercise. This is the Spatial Dataset to which the calculations from the excel spreadsheet will be joined.



- The **Attribute Table** included the **SUB_CAT** *unique code*, this code is also contained in the excel spreadsheet and the two tables will be joined using this field.

Table

Quinaries_Nat_New_Town

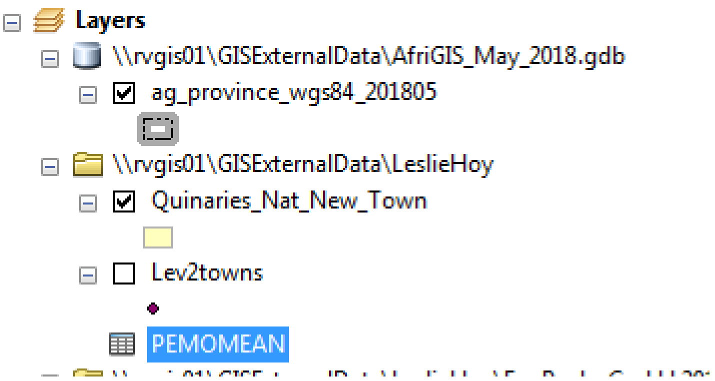
FID	Shape	FID_1	AREA	PERIMETER	PRIMARY	SECONDARY	SUB_CAT	UNIQUE_ID	QUINARY	SUBQUIN	MAP_his	SFRA_E_his	SFRA_E_in	test	OID_	SUB
14	Polygon	1053	0.008	0.943	A	A1	1	1	A10A1	1	0	0	0	217.63	0	[illegible]
12	Polygon	1020	0.022	1.376	A	A1	2	2	A10A2	2	0	0	0	218.99	1	[illegible]
10	Polygon	991	0.02	0.921	A	A1	3	3	A10A3	3	0	0	0	225.05	2	[illegible]
11	Polygon	994	0.001	0.269	A	A1	4	5	A10B1	1	0	0	0	221.89	3	[illegible]
41	Polygon	753	0.006	0.749	A	A1	4	4	A10B1	1	0	0	0	221.89	3	[illegible]
2	Polygon	748	0.015	1.463	A	A1	5	6	A10B2	2	0	0	0	225.76	4	[illegible]
5	Polygon	900	0.019	1.03	A	A1	5	7	A10B2	2	0	0	0	225.76	4	[illegible]
9	Polygon	938	0.005	0.365	A	A1	5	8	A10B2	2	0	0	0	225.76	4	[illegible]
1	Polygon	732	0.044	2.134	A	A1	6	9	A10B3	3	0	0	0	227.3	5	[illegible]
40	Polygon	745	0.006	0.55	A	A1	7	10	A10C1	1	0	0	0	221.47	6	[illegible]
39	Polygon	734	0.006	0.632	A	A1	8	11	A10C2	2	0	0	0	223.22	7	[illegible]
38	Polygon	700	0.012	0.67	A	A1	9	12	A10C3	3	0	0	0	226.62	8	[illegible]
476	Polygon	1471	0.012	1.384	A	A2	10	13	A21A1	1	0	0	0	175.17	9	[illegible]
1611	Polygon	1444	0.018	1.44	A	A2	11	14	A21A2	2	0	0	0	176.95	10	[illegible]
445	Polygon	1398	0.014	0.92	A	A2	12	15	A21A3	3	0	0	0	179.38	11	[illegible]
446	Polygon	1440	0.012	0.983	A	A2	13	16	A21B1	1	0	0	0	176.85	12	[illegible]
444	Polygon	1365	0.021	1.892	A	A2	14	17	A21B2	2	0	0	0	176.73	13	[illegible]
442	Polygon	1361	0.015	1.078	A	A2	15	18	A21B3	3	0	0	0	192.51	14	[illegible]
1755	Polygon	1494	0.021	1.676	A	A2	16	19	A21C1	1	0	0	0	175.97	15	[illegible]
239	Polygon	1442	0.026	2.044	A	A2	17	20	A21C2	2	0	0	0	182.01	16	[illegible]
475	Polygon	1419	0.021	1.096	A	A2	18	21	A21C3	3	0	0	0	184.68	17	[illegible]
1580	Polygon	1528	0.012	0.757	A	A2	19	22	A21D1	1	0	0	0	182.77	18	[illegible]
1579	Polygon	1465	0.012	1.28	A	A2	20	23	A21D2	2	0	0	0	192.82	19	[illegible]
1578	Polygon	1456	0.01	0.764	A	A2	21	24	A21D3	3	0	0	0	199.3	20	[illegible]
241	Polygon	1543	0.005	0.492	A	A2	22	25	A21E1	1	0	0	0	174.4	21	[illegible]
234	Polygon	1434	0.001	0.207	A	A2	23	26	A21E2	2	0	0	0	190.25	22	[illegible]
240	Polygon	1492	0.01	0.793	A	A2	23	27	A21E2	2	0	0	0	190.25	22	[illegible]
238	Polygon	1432	0.01	0.691	A	A2	24	28	A21E3	3	0	0	0	192.25	23	[illegible]

0 (0 out of 7710 Selected)

Quinaries_Nat_New_Town

Excel Spreadsheet

- The excel spreadsheet is added as a table to ArcMap



- Excel Spreadsheet Attribute Table showing the Evapotranspiration Calculations

Table

PEMOMEAN

SUB_CAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MEAN
1	208.5	175.46	172.73	136.2	114.15	93.49	100.22	131.96	166.62	195.82	207.81	217.63	1920.6	160.05
2	209.43	175.9	173.09	137.34	115.21	94.37	101.37	133.71	169.48	197.61	209.67	218.99	1936.18	161.34833
3	216.93	182.02	177.29	140.27	118.79	99.03	106.63	138.56	174.12	203.76	213.05	225.05	1995.51	166.2925
4	215.47	182.32	177.63	140.74	118.69	99.64	106.66	136.63	173.38	201.3	211.61	221.89	1985.96	165.49667
5	217.93	185.06	182.69	143.67	122.81	101.31	109.83	140.03	177.22	203.48	215.16	225.76	2024.95	168.74583
6	220.02	189.06	185.3	145.77	124.56	103.32	111.21	142.08	177.93	204.06	216.13	227.3	2046.74	170.56167
7	218.47	183.88	179.1	140.93	119.32	100.47	107.58	138.89	175.81	204.72	211.8	221.47	2002.43	166.86917
8	218.61	186	183.78	142.93	123.02	102.46	109.26	139.91	177.7	203.67	212.7	223.22	2023.28	168.60667
9	220.97	189.71	185.87	146.33	125.2	104.74	112.43	142.38	180.31	206.12	216.36	226.62	2057.04	171.42
10	177.78	147.8	138.93	107.95	93.27	73.32	81.98	106.55	141.35	160.71	168.14	175.17	1572.94	131.07833
11	179.68	149.84	144.42	114.06	97.42	77.88	87.38	112.07	144.83	167.81	171.03	176.95	1623.38	135.28167
12	181.27	152.11	148.36	116.16	98.55	81.09	88.63	113.53	146.3	168.67	171.8	179.38	1645.84	137.15333
13	177.57	150.2	146.03	116.14	98.09	81.28	87.46	111.81	146.6	166.11	170.02	176.85	1628.16	135.68
14	174.07	151.09	148.27	118.34	98.76	84.07	87.4	113.18	149.05	164.63	169.12	176.73	1634.72	136.22667
15	189.81	161.96	160.31	121.28	103.6	87.72	94.68	123.18	160.87	176.86	180.54	192.51	1753.33	146.11083
16	174.12	146.93	141.68	106.88	92.22	71.99	78.4	106.7	140.88	158.92	166.02	175.97	1560.71	130.05917
17	182.68	152.64	149.94	118.47	100.43	78.37	85.36	111.98	146.63	164.45	175.43	182.01	1648.38	137.365
18	181.71	153.69	151.07	119.52	101.87	83.61	90.73	118.65	153.64	171.1	176.49	184.68	1686.76	140.56333
19	180.07	153.79	148.14	113.62	95.63	79.85	82.56	111.69	147.67	165.77	169.66	182.77	1631.22	135.935
20	188.83	160.98	156.25	118.73	99.9	82.8	87.1	117.87	155.37	175.41	176.29	192.82	1712.33	142.69417
21	197.02	166.85	159.46	121.21	101.3	83.43	87.62	117.96	155.51	177.03	184.67	199.3	1751.36	145.94667
22	174.9	145.54	143.19	114.26	97.63	77.27	83.07	109.85	142.62	158.98	167.11	174.4	1588.83	132.4025
23	189.27	158.24	151.91	118.82	100.22	80.82	86.16	115.05	149.8	171.41	179.4	190.25	1691.34	140.945
24	185.94	158.7	154.64	118.63	102.1	84.04	92.02	119.09	153.68	174	179.35	192.25	1714.44	142.87
25	190.04	162.78	158.94	119.75	100.88	84.31	88.33	118.43	156.15	176.07	176.06	194.13	1725.86	143.82167
26	185.8	160.38	159.2	119.28	102.1	85.61	92.27	121.69	157.91	176.09	172.71	192.07	1725.12	143.76
27	190.34	165.18	163.66	121.35	104.25	87.58	94.89	124.13	161.32	181.02	179.01	198.3	1771.03	147.58583

0 (0 out of 5838 Selected)

PEMOMEAN

- To do the join, open up the National Quinary Attribute Table and the excel spreadsheet table.

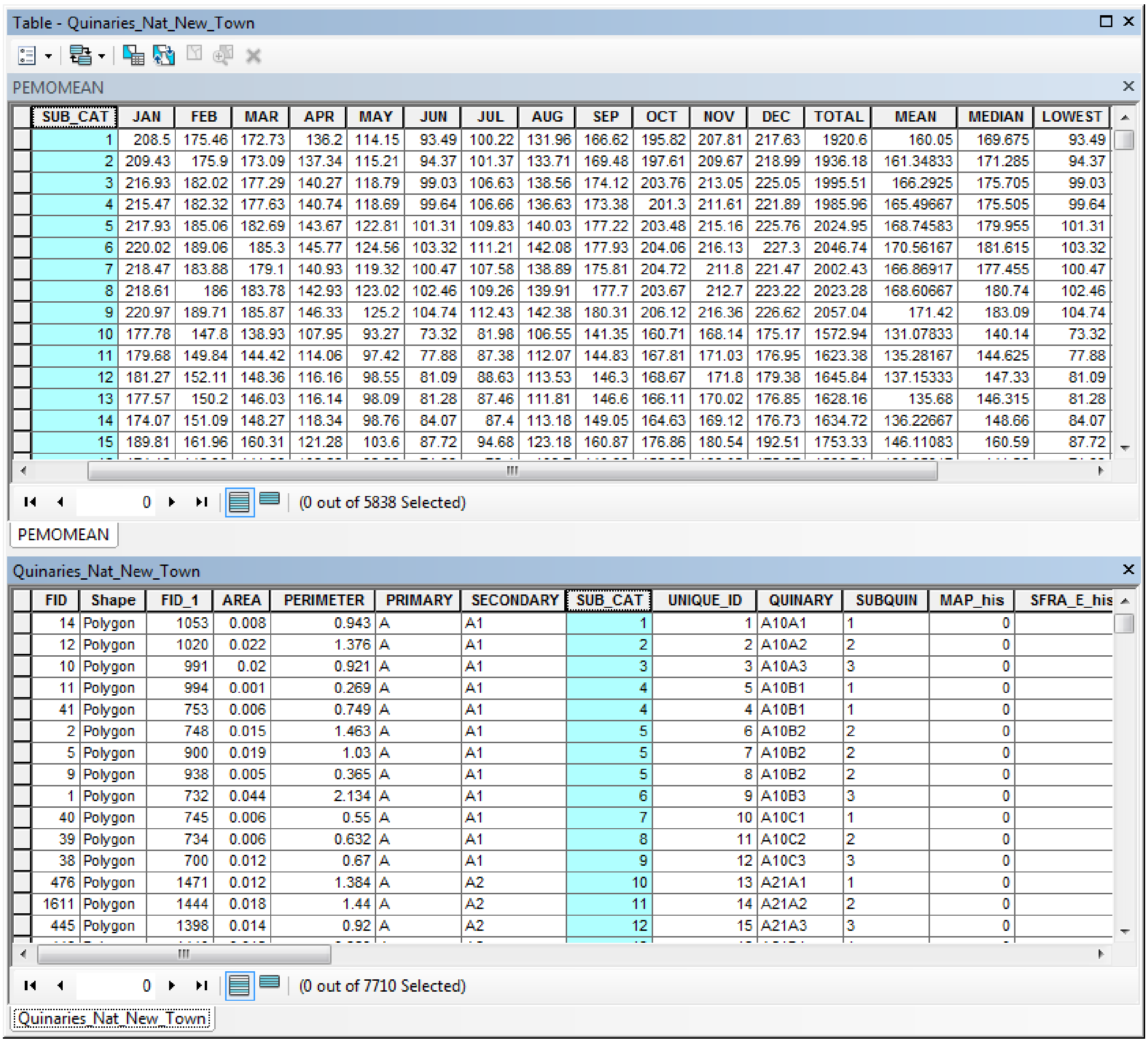


Table - Quinaries_Nat_New_Town

PEMOMEAN

SUB_CAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MEAN	MEDIAN	LOWEST
1	208.5	175.46	172.73	136.2	114.15	93.49	100.22	131.96	166.62	195.82	207.81	217.63	1920.6	160.05	169.675	93.49
2	209.43	175.9	173.09	137.34	115.21	94.37	101.37	133.71	169.48	197.61	209.67	218.99	1936.18	161.34833	171.285	94.37
3	216.93	182.02	177.29	140.27	118.79	99.03	106.63	138.56	174.12	203.76	213.05	225.05	1995.51	166.2925	175.705	99.03
4	215.47	182.32	177.63	140.74	118.69	99.64	106.66	136.63	173.38	201.3	211.61	221.89	1985.96	165.49667	175.505	99.64
5	217.93	185.06	182.69	143.67	122.81	101.31	109.83	140.03	177.22	203.48	215.16	225.76	2024.95	168.74583	179.955	101.31
6	220.02	189.06	185.3	145.77	124.56	103.32	111.21	142.08	177.93	204.06	216.13	227.3	2046.74	170.56167	181.615	103.32
7	218.47	183.88	179.1	140.93	119.32	100.47	107.58	138.89	175.81	204.72	211.8	221.47	2002.43	166.86917	177.455	100.47
8	218.61	186	183.78	142.93	123.02	102.46	109.26	139.91	177.7	203.67	212.7	223.22	2023.28	168.60667	180.74	102.46
9	220.97	189.71	185.87	146.33	125.2	104.74	112.43	142.38	180.31	206.12	216.36	226.62	2057.04	171.42	183.09	104.74
10	177.78	147.8	138.93	107.95	93.27	73.32	81.98	106.55	141.35	160.71	168.14	175.17	1572.94	131.07833	140.14	73.32
11	179.68	149.84	144.42	114.06	97.42	77.88	87.38	112.07	144.83	167.81	171.03	176.95	1623.38	135.28167	144.625	77.88
12	181.27	152.11	148.36	116.16	98.55	81.09	88.63	113.53	146.3	168.67	171.8	179.38	1645.84	137.15333	147.33	81.09
13	177.57	150.2	146.03	116.14	98.09	81.28	87.46	111.81	146.6	166.11	170.02	176.85	1628.16	135.68	146.315	81.28
14	174.07	151.09	148.27	118.34	98.76	84.07	87.4	113.18	149.05	164.63	169.12	176.73	1634.72	136.22667	148.66	84.07
15	189.81	161.96	160.31	121.28	103.6	87.72	94.68	123.18	160.87	176.86	180.54	192.51	1753.33	146.11083	160.59	87.72

0 (0 out of 5838 Selected)

PEMOMEAN

Quinaries_Nat_New_Town

FID	Shape	FID_1	AREA	PERIMETER	PRIMARY	SECONDARY	SUB_CAT	UNIQUE_ID	QUINARY	SUBQUIN	MAP_his	SFRA_E_his
14	Polygon	1053	0.008	0.943	A	A1	1	1	A10A1	1	0	
12	Polygon	1020	0.022	1.376	A	A1	2	2	A10A2	2	0	
10	Polygon	991	0.02	0.921	A	A1	3	3	A10A3	3	0	
11	Polygon	994	0.001	0.269	A	A1	4	5	A10B1	1	0	
41	Polygon	753	0.006	0.749	A	A1	4	4	A10B1	1	0	
2	Polygon	748	0.015	1.463	A	A1	5	6	A10B2	2	0	
5	Polygon	900	0.019	1.03	A	A1	5	7	A10B2	2	0	
9	Polygon	938	0.005	0.365	A	A1	5	8	A10B2	2	0	
1	Polygon	732	0.044	2.134	A	A1	6	9	A10B3	3	0	
40	Polygon	745	0.006	0.55	A	A1	7	10	A10C1	1	0	
39	Polygon	734	0.006	0.632	A	A1	8	11	A10C2	2	0	
38	Polygon	700	0.012	0.67	A	A1	9	12	A10C3	3	0	
476	Polygon	1471	0.012	1.384	A	A2	10	13	A21A1	1	0	
1611	Polygon	1444	0.018	1.44	A	A2	11	14	A21A2	2	0	
445	Polygon	1398	0.014	0.92	A	A2	12	15	A21A3	3	0	

0 (0 out of 7710 Selected)

Quinaries_Nat_New_Town

- Ensure that the table to join to the spreadsheet to is selected, The National Quinaries, in this instance.
- Click on the drop-down button at the top of the tables

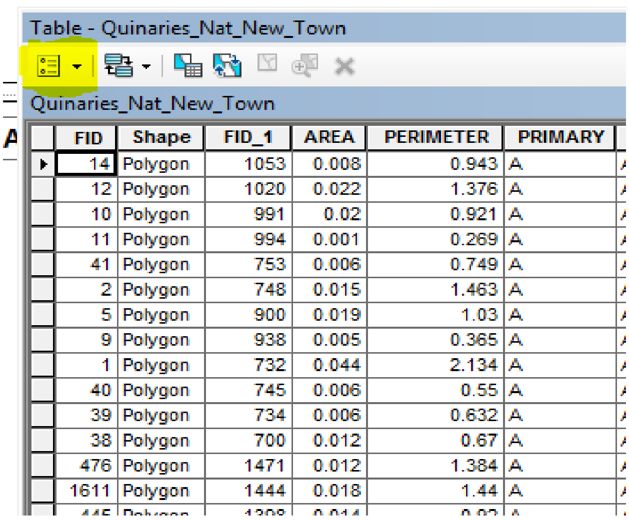
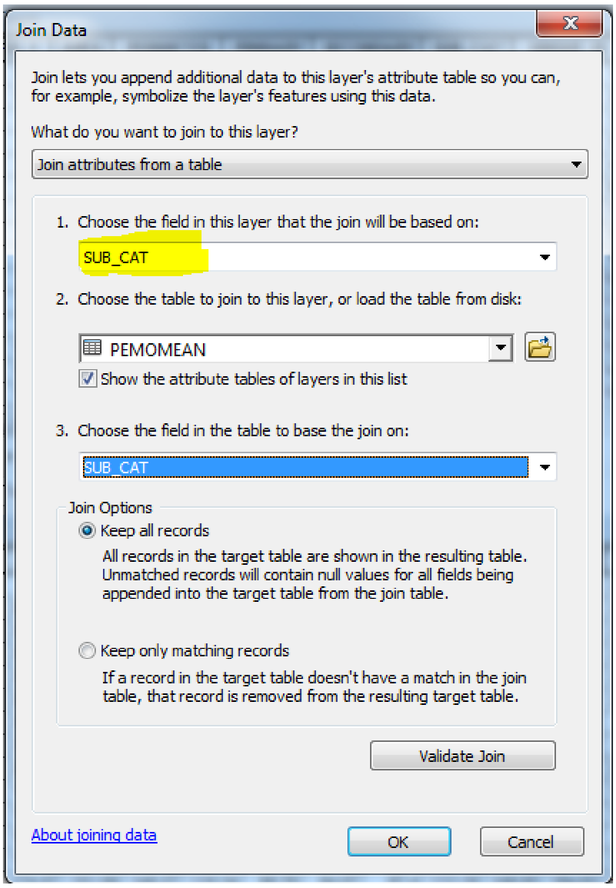


Table - Quinaries_Nat_New_Town

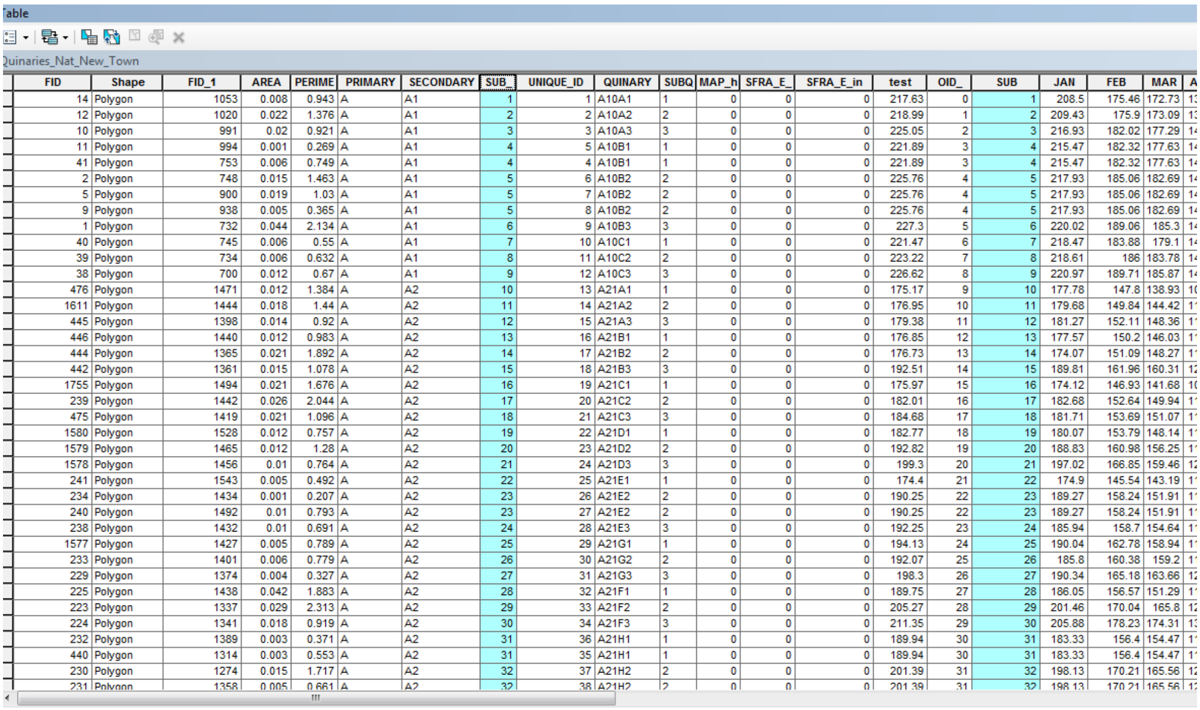
Quinaries_Nat_New_Town

FID	Shape	FID_1	AREA	PERIMETER	PRIMARY
14	Polygon	1053	0.008	0.943	A
12	Polygon	1020	0.022	1.376	A
10	Polygon	991	0.02	0.921	A
11	Polygon	994	0.001	0.269	A
41	Polygon	753	0.006	0.749	A
2	Polygon	748	0.015	1.463	A
5	Polygon	900	0.019	1.03	A
9	Polygon	938	0.005	0.365	A
1	Polygon	732	0.044	2.134	A
40	Polygon	745	0.006	0.55	A
39	Polygon	734	0.006	0.632	A
38	Polygon	700	0.012	0.67	A
476	Polygon	1471	0.012	1.384	A
1611	Polygon	1444	0.018	1.44	A

- Click on ***Join and Relates*** and fill in the details



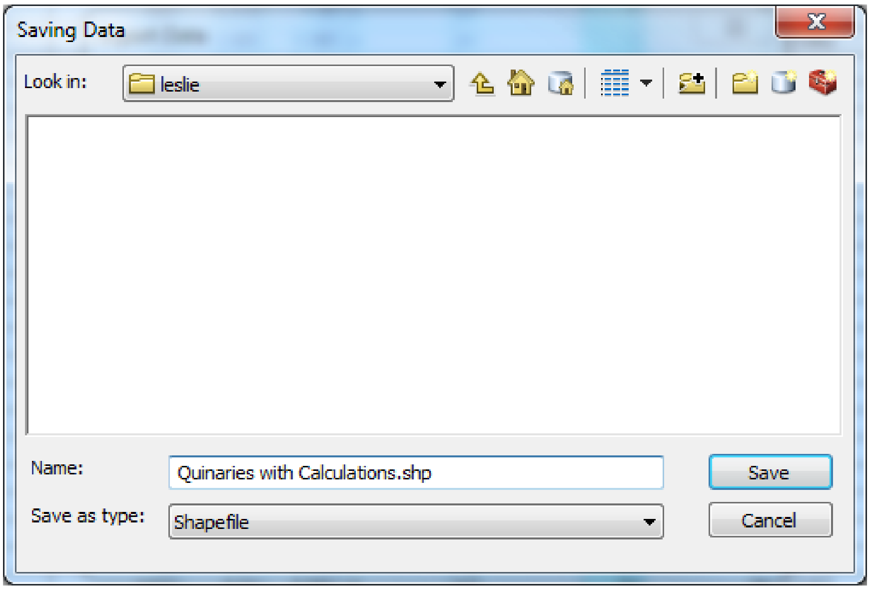
- Once Complete Click "OK" and the excel spreadsheet will be joined to the National Quinaries table showing all the fields in the original file and well as the monthly Evapotranspiration Calculations from the excel spreadsheet.



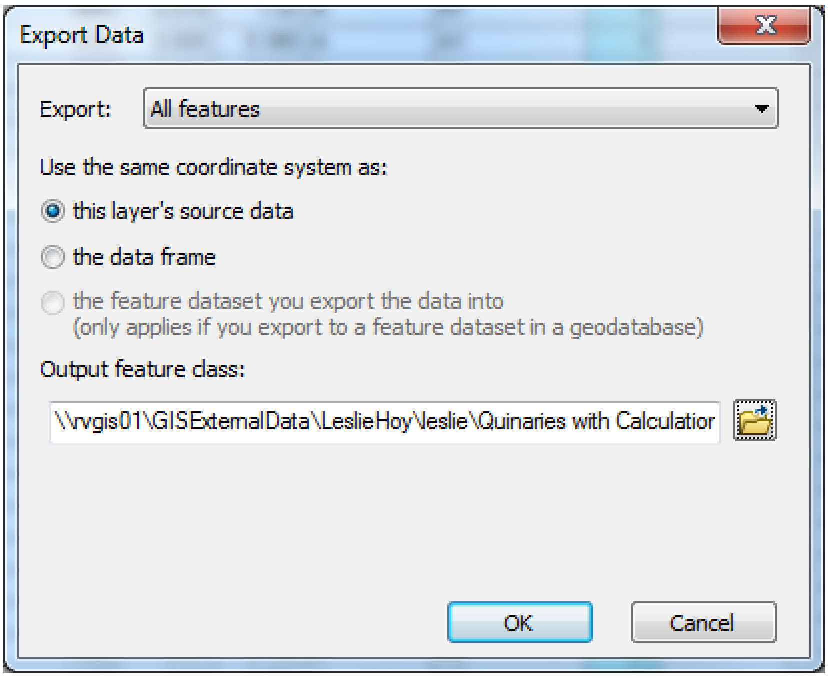
FID	Shape	FID_1	AREA	PERIME	PRIMARY	SECONDARY	SUB_	UNIQUE_ID	QUINARY	SUBQ	MAP_h	SFRA_E_	SFRA_E_in	test	OID_	SUB	JAN	FEB	MAR
14	Polygon	1053	0.008	0.943	A	A1	1	1	A10A1	1	0	0	0	217.63	0	1	208.5	175.46	172.73
12	Polygon	1020	0.022	1.376	A	A1	2	2	A10A2	2	0	0	0	218.99	1	2	209.43	175.9	173.09
10	Polygon	991	0.02	0.921	A	A1	3	3	A10A3	3	0	0	0	225.05	2	3	216.93	182.02	177.29
11	Polygon	994	0.001	0.269	A	A1	4	5	A10B1	1	0	0	0	221.89	3	4	215.47	182.32	177.63
41	Polygon	753	0.006	0.749	A	A1	4	4	A10B1	1	0	0	0	221.89	3	4	215.47	182.32	177.63
2	Polygon	748	0.015	1.463	A	A1	5	6	A10B2	2	0	0	0	225.76	4	5	217.93	185.06	182.69
5	Polygon	900	0.019	1.03	A	A1	5	7	A10B2	2	0	0	0	225.76	4	5	217.93	185.06	182.69
9	Polygon	938	0.005	0.365	A	A1	5	8	A10B2	2	0	0	0	225.76	4	5	217.93	185.06	182.69
1	Polygon	732	0.044	2.134	A	A1	6	9	A10B3	3	0	0	0	227.3	5	6	220.02	189.06	185.3
40	Polygon	745	0.006	0.55	A	A1	7	10	A10C1	1	0	0	0	221.47	6	7	218.47	183.88	179.1
39	Polygon	734	0.006	0.632	A	A1	8	11	A10C2	2	0	0	0	223.22	7	8	218.61	186	183.78
38	Polygon	700	0.012	0.67	A	A1	9	12	A10C3	3	0	0	0	226.62	8	9	220.97	189.71	185.87
476	Polygon	1471	0.012	1.384	A	A2	10	13	A21A1	1	0	0	0	175.17	9	10	177.78	147.8	138.93
1611	Polygon	1444	0.018	1.44	A	A2	11	14	A21A2	2	0	0	0	176.95	10	11	179.68	149.84	144.42
445	Polygon	1398	0.014	0.92	A	A2	12	15	A21A3	3	0	0	0	179.38	11	12	181.27	152.11	148.36
446	Polygon	1440	0.012	0.983	A	A2	13	16	A21B1	1	0	0	0	176.85	12	13	177.57	150.2	146.03
444	Polygon	1365	0.021	1.892	A	A2	14	17	A21B2	2	0	0	0	176.73	13	14	174.07	151.09	148.27
442	Polygon	1361	0.015	1.078	A	A2	15	18	A21B3	3	0	0	0	192.51	14	15	189.81	161.96	160.31
1755	Polygon	1494	0.021	1.676	A	A2	16	19	A21C1	1	0	0	0	175.97	15	16	174.12	146.93	141.68
239	Polygon	1442	0.026	2.044	A	A2	17	20	A21C2	2	0	0	0	182.01	16	17	182.68	152.64	149.94
475	Polygon	1419	0.021	1.096	A	A2	18	21	A21C3	3	0	0	0	184.68	17	18	181.71	153.69	151.07
1580	Polygon	1528	0.012	0.757	A	A2	19	22	A21D1	1	0	0	0	182.77	18	19	180.07	153.79	148.14
1579	Polygon	1465	0.012	1.28	A	A2	20	23	A21D2	2	0	0	0	192.82	19	20	188.83	160.98	156.25
1578	Polygon	1456	0.01	0.764	A	A2	21	24	A21D3	3	0	0	0	199.3	20	21	197.02	166.85	159.46
241	Polygon	1543	0.005	0.492	A	A2	22	25	A21E1	1	0	0	0	174.4	21	22	174.9	145.54	143.19
234	Polygon	1434	0.001	0.207	A	A2	23	26	A21E2	2	0	0	0	190.25	22	23	189.27	158.24	151.91
240	Polygon	1492	0.01	0.793	A	A2	23	27	A21E2	2	0	0	0	190.25	22	23	189.27	158.24	151.91
238	Polygon	1432	0.01	0.691	A	A2	24	28	A21E3	3	0	0	0	192.25	23	24	185.94	158.7	154.64
1577	Polygon	1427	0.005	0.789	A	A2	25	29	A21G1	1	0	0	0	194.13	24	25	190.04	162.78	158.94
233	Polygon	1401	0.006	0.779	A	A2	26	30	A21G2	2	0	0	0	192.07	25	26	185.8	160.38	159.2
229	Polygon	1374	0.004	0.327	A	A2	27	31	A21G3	3	0	0	0	198.3	26	27	190.34	165.18	163.66
225	Polygon	1438	0.042	1.883	A	A2	28	32	A21F1	1	0	0	0	189.75	27	28	186.05	156.57	151.29
223	Polygon	1337	0.029	2.313	A	A2	29	33	A21F2	2	0	0	0	205.27	28	29	201.46	170.04	165.8
224	Polygon	1341	0.018	0.919	A	A2	30	34	A21F3	3	0	0	0	211.35	29	30	205.88	178.23	174.31
232	Polygon	1389	0.003	0.371	A	A2	31	36	A21H1	1	0	0	0	189.94	30	31	183.33	156.4	154.47
440	Polygon	1314	0.003	0.553	A	A2	31	35	A21H1	1	0	0	0	189.94	30	31	183.33	156.4	154.47
230	Polygon	1274	0.015	1.717	A	A2	32	37	A21H2	2	0	0	0	201.39	31	32	198.13	170.21	165.56
231	Polygon	1358	0.005	0.661	A	A2	32	38	A21H2	2	0	0	0	201.39	31	32	198.13	170.21	165.56

- A Join is not permanent, to ensure that the shapefile is permanent, export and save it.

- Right Click on the Quinaries shapefile
- Scroll down to Data
- Select Export Data



- Type in the name and Click “Save”
- Click “OK”



- The file will be saved to the new location

• To add orientation, intelligence and clarity to the map as well as to provide locations to this new table, the Town Shapefile is added to ArcMap. The Town shapefile contained 1685 towns. For this purpose the focus was on the towns classified as Level 1Towns which are Capital Cities in each Province and the Level 2 Towns which are smaller towns that provide goods and services to the surrounding areas. They may also have an airport.

- The classification of the towns was not done by our data provider for the RW ArchMap program.

Table

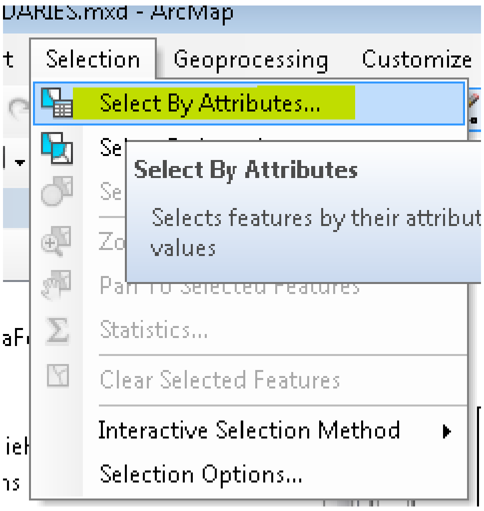
Town_All_wgs29

OBJECTID	AREA	PERIMETER	TOWN_	TOWN_ID	TOWN	AIRPORT	HARBOUR	LEVEL
1596	0	0	707	1098	KOMATIPOORT	YES		2
1597	0	0	708	1099	BARBERTON	YES		2
1598	0	0	747	1138	PONGOLA	YES		2
1599	0	0	768	1159	MKUZE	YES		2
1600	0	0	769	1160	HLUHLUWE	YES		2
1601	0	0	771	1162	KIMBERLEY	YES		2
1602	0	0	778	1169	PETRUSVILLE	YES		2
1603	0	0	780	1171	MIDDELBURG	YES		2
1604	0	0	782	1173	GRAAF-REINET	YES		2
1605	0	0	804	1200	COLESBERG	YES		2
1606	0	0	817	1213	CRADOCK	YES		2
1607	0	0	819	1215	SOMERSET EAST	YES		2
1608	0	0	842	1248	TABA-NCHU	YES		2
1609	0	0	853	1259	ALIWAL NORTH	YES		2
1610	0	0	859	1265	QUEENSTOWN	YES		2
1611	0	0	881	1287	FORT BEAUFORT	YES		2
1612	0	0	902	1313	FICKSBURG	YES		2
1613	0	0	906	1317	LADYBRAND	YES		2
1614	0	0	939	1350	INDWE	YES		2

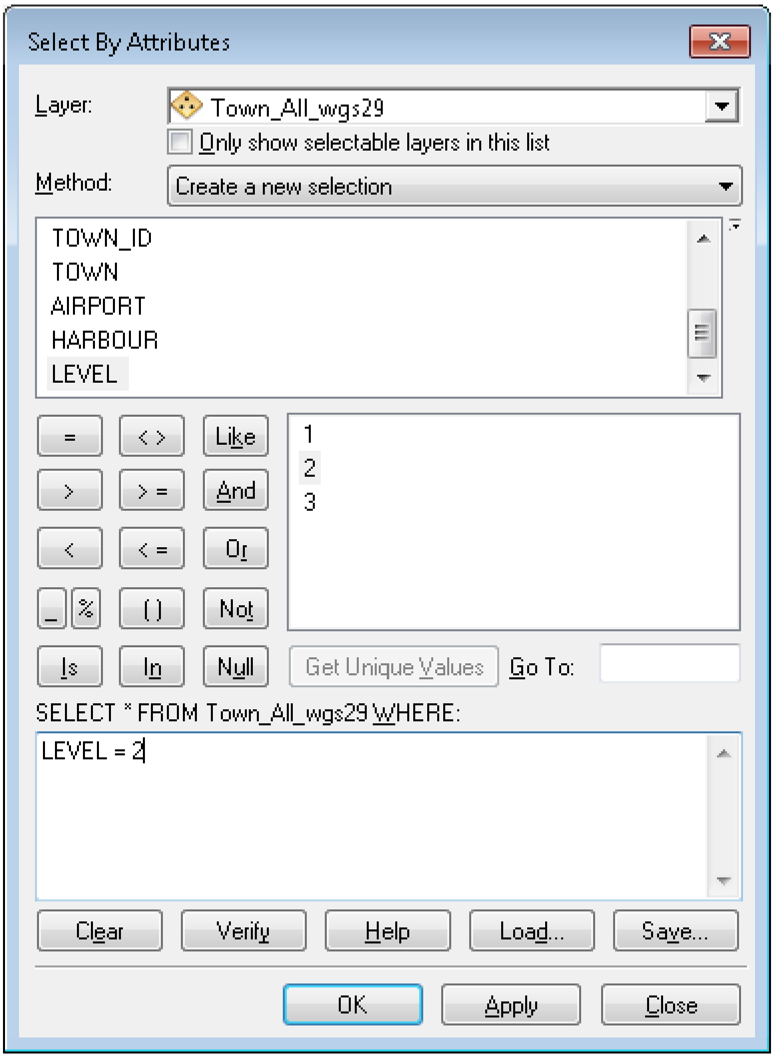
0 (0 out of 1685 Selected)

Quinaries_with_Calculations | Town_All_wgs29

- To select only the level 2 Towns, the **"Select by Attributes"** option was used
- Click on the Selection option on the Main Toolbar and from the drop down menu choose, Select by attributes



- Fill in the fields



- Click OK
- The resulting table contained 151 Towns that were all classified as Level 2 Towns.

Table

TOWNS_LEVEL_2

OBJECTID	AREA	PERIMETER	TOWN_	TOWN_ID	TOWN	AIRPORT	HARBOUR	LEVEL
1655	0	0	1564	382	ABERDEEN	YES		2
1640	0	0	1359	84	ALEXANDER BAY	YES		2
1609	0	0	853	1259	ALIWAL NORTH	YES		2
1568	0	0	467	858	ARNOT	YES		2
1554	0	0	295	685	BAPSFONTEIN	YES		2
1597	0	0	708	1099	BARBERTON	YES		2
1649	0	0	1519	314	BEAUFORT WEST	YES		2
1573	0	0	485	876	BETHAL	YES		2
1561	0	0	336	726	BETHLEHEM	YES		2
1623	0	0	1136	1547	BIZANA	YES		2
1530	0	0	63	452	BLOEMHOF	YES		2
1535	0	0	108	497	BOTHAVILLE	YES		2
1557	0	0	307	697	BRAKPAN	YES		2
1647	0	0	1470	246	BRANDVLEI	YES		2
1672	0	0	1661	267	BREDASDORP	YES		2
1541	0	0	166	556	BRITS	YES		2
1538	0	0	118	507	BULTFONTEIN	YES		2
1658	0	0	1592	194	CALVINIA	YES		2
1661	0	0	1596	311	CARNARVON	YES		2

0 (0 out of 151 Selected)

TOWNS_LEVEL_2

- The same process was repeated to extract only the Level 1 Towns.

Table

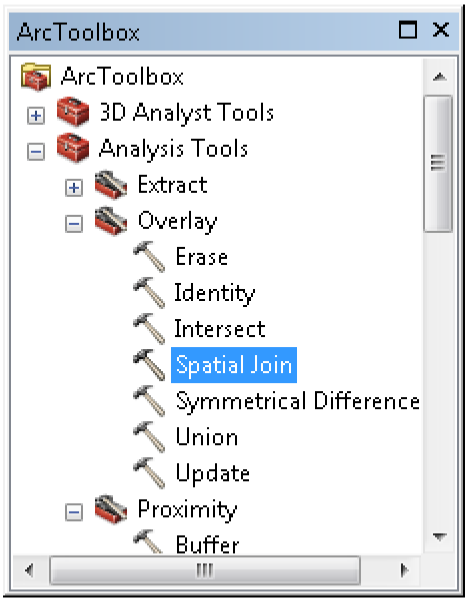
Capital City

AREA	PERIMETER	TOWN_	TOWN_ID	TOWN	AIRPORT	HARBOUR	LEVEL
0	0	26	415	MMABATHO	YES		1
0	0	178	568	JOHANNESBURG			1
0	0	374	765	PIETERSBURG	YES		1
0	0	615	1006	NELSPRUIT	YES		1
0	0	833	1239	BLOEMFONTEIN	YES		1
0	0	993	1404	BISHO	YES		1
0	0	1175	1586	PIETERMARITZBURG	YES		1
0	0	1288	13	UPINGTON	YES		1
0	0	1413	165	CAPE TOWN	YES	YES	1

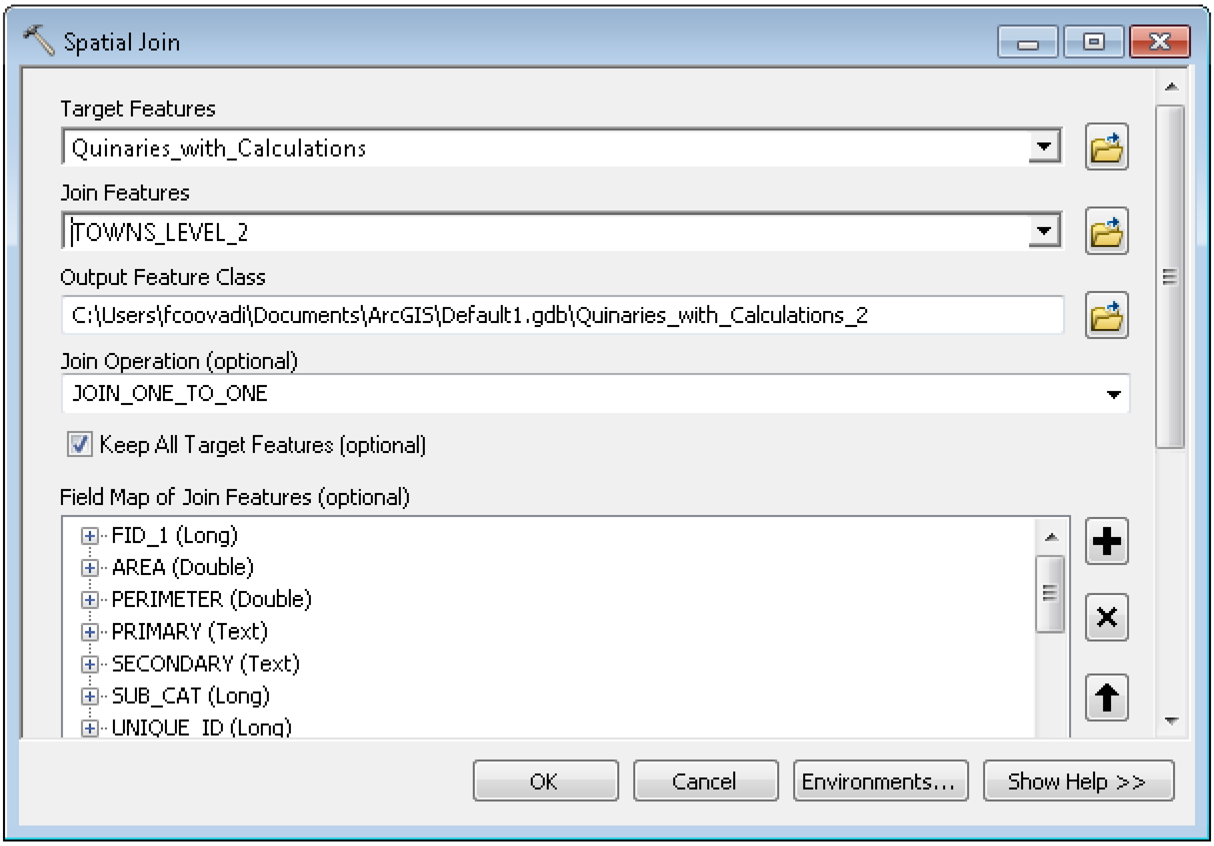
0 (0 out of 9 Selected)

Capital City

- The total number of Towns that will be used in the model is 160
- The only way to join these (the Quinary table and the town tables) together, as there were no unique fields, was to perform a spatial join.
- To do this the ArcToolbox is opened



- Level 2 Towns are joined to the Quinaries with Calculations



- The resultant table now has the Sub Catchment ID, the Town Name as well as the Evaporation Calculations

Table

Level_2_Towns_with_Calculations

SUB_CAT	TOWN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	N
5337	ZITENDE	197.22	167.58	167.77	135.79	119.99	102.93	110.6	132.81	150.39	167.35	173.09	214.48	1839.99	15
141	ZEERUST	211.47	173.04	172.26	137.17	115.64	97.61	105.38	138.43	173.71	204.74	212.85	223.26	1965.56	16
2856	WORCES	232.41	189.86	166.8	115.72	85.59	64.86	67.06	84.32	116.63	162.09	197.84	232.72	1715.9	14
457	WITBANK	181.95	154.26	152.32	121.73	102.92	84.53	91.21	121.51	150.69	167.42	171.31	184.25	1684.12	14
3480	WILLOWM	239.66	195.19	165.07	114.14	83.28	65.2	72.12	95.54	127.25	162.84	199.34	242.35	1761.97	14
2124	WILLISTO	270.18	218.9	184.56	126.04	93.19	63.45	72.65	104.2	141.47	184.64	226.59	262.14	1948.02	1
1405	WESSELS	222.55	179.18	168.69	126.09	104.11	85.24	93.79	125.28	162.52	191.22	210.97	232.67	1902.31	15
4947	WEMBESI	179.25	152.13	145.78	110.47	92.18	78.01	85.28	109.02	138.63	153.96	163.07	200.56	1608.33	13
1069	WELKOM	212.96	171.38	161.69	120.66	99.58	78.75	88.79	119.72	156.34	182.7	204.84	223.99	1821.4	15
5124	VRYHEID	178.95	151.62	151.92	119.45	101.46	87.98	95.93	119.4	143.95	156.48	163.5	199.56	1670.2	13
990	VRYBUR	241.52	192.88	182.48	140.7	113.71	95.03	105.4	140.11	180.46	212.96	234.64	253.72	2093.6	17
909	VREDE	184.17	158.88	149.48	112.62	90.14	70.96	77.13	103.46	136.91	158.64	170.08	199.69	1612.17	13
4991	VOLKSRU	166.61	141.11	139.72	105.36	87.09	72.64	79.85	104.02	135.42	148.92	153.92	187.52	1522.18	12
1317	VEREENIG	187.33	155.54	152.34	116.33	98.72	81.57	91.1	121.77	154.42	175.36	178.56	191.7	1704.75	14
1327	VANDERB	189.52	155.99	153.96	116.4	98.64	77.65	86.53	118.65	149.74	169.77	180.27	194.41	1691.54	14
740	TZANEEN	175.64	151.61	156.5	130.95	122.39	108.95	109.6	131.99	153.32	166.77	172.45	184.04	1764.21	14
881	TUTUKA	174.97	149.17	143.82	111.42	93.46	77.63	86	113.67	144.7	160.6	166.67	180.31	1602.43	13
4544	THE RIDG	144.09	125.44	126.66	96.77	85.19	69.58	77.33	97.06	114.66	119.97	126.26	166.94	1349.96	11
1082	TABANE	219.56	165.04	152.19	111.25	90.77	72.89	82.25	110.33	141.6	172.18	192.88	216.62	1727.57	14

0 (0 out of 149 Selected)

Level 2 Towns joined to Quinaries with Calculation | Level_2_Towns_with_Calculations

<u>THEMATIC MAPPING</u>

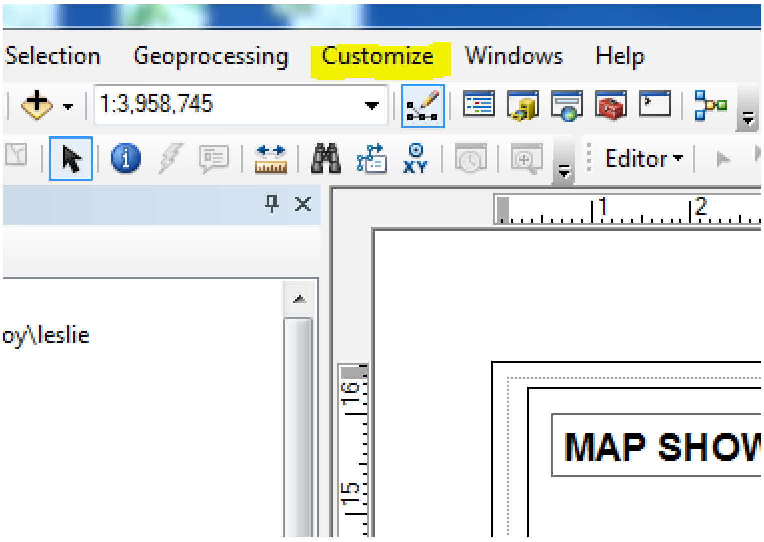
Thematic Mapping is used to display the Evapotranspiration as per the calculations as it centers on the spatial variability of the Evapotranspiration. The reason for joining the towns to the National Quinary Shapefile and Calculation table was to include some locational information, such as the names of the towns. This will assist in providing orientation and make the map more user friendly and will be used to generate the database and the model.

- The Evaporation figures were classed into 9 different ranges, mainly because the Minimum and the Maximum values varied throughout the year. By creating these 9 ranges it provides consistency to all the maps with regards to the ranges listed below.

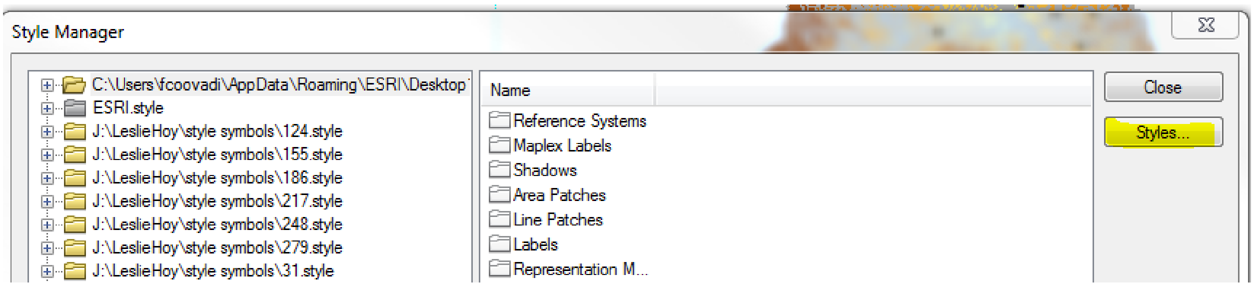
31.01 – 62
62.01 – 93
93.01 – 124
124.01 – 155
155.01 – 186
186.01 – 217
217.01 – 248
248.01 - 279

279.01 - 310

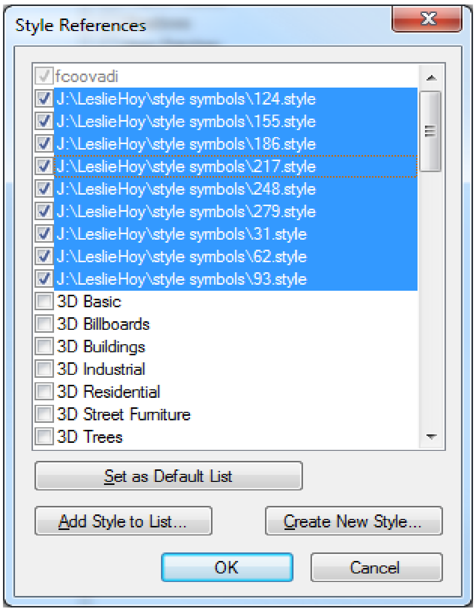
- To create the colour symbols, **Customize** on the main menu bar is chosen and from the drop down menu **“Style Manager”** is selected



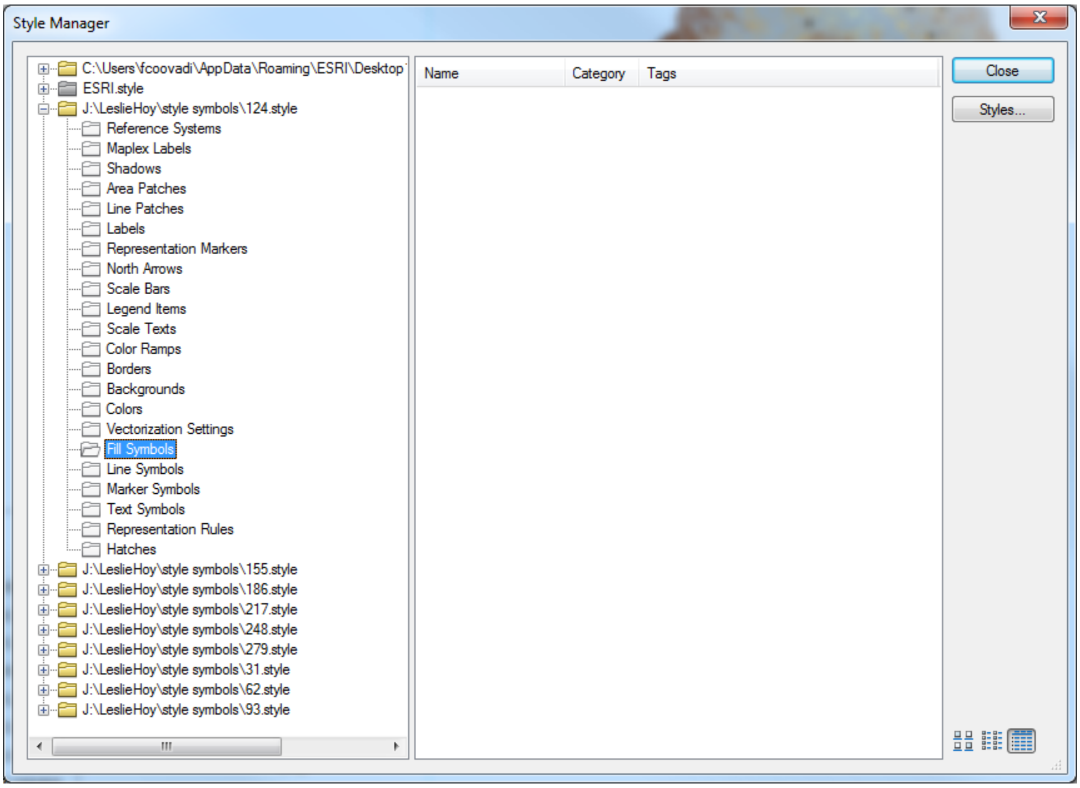
- In the Style Manager/References, the symbols are developed for the different ranges by clicking on styles



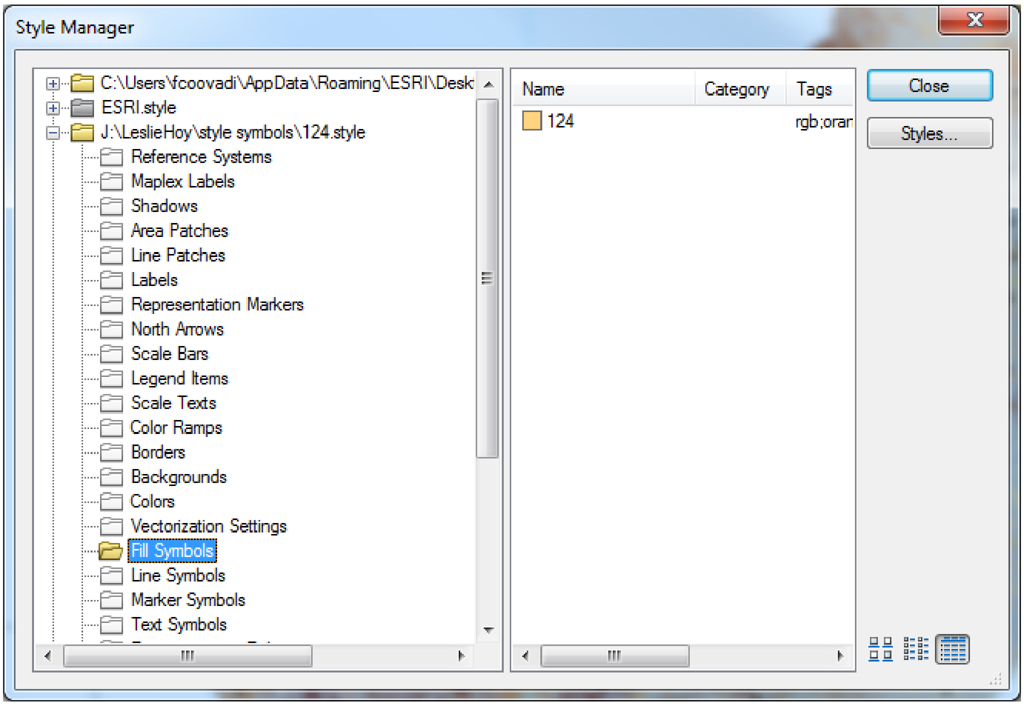
- Styles for the different ranges are then developed



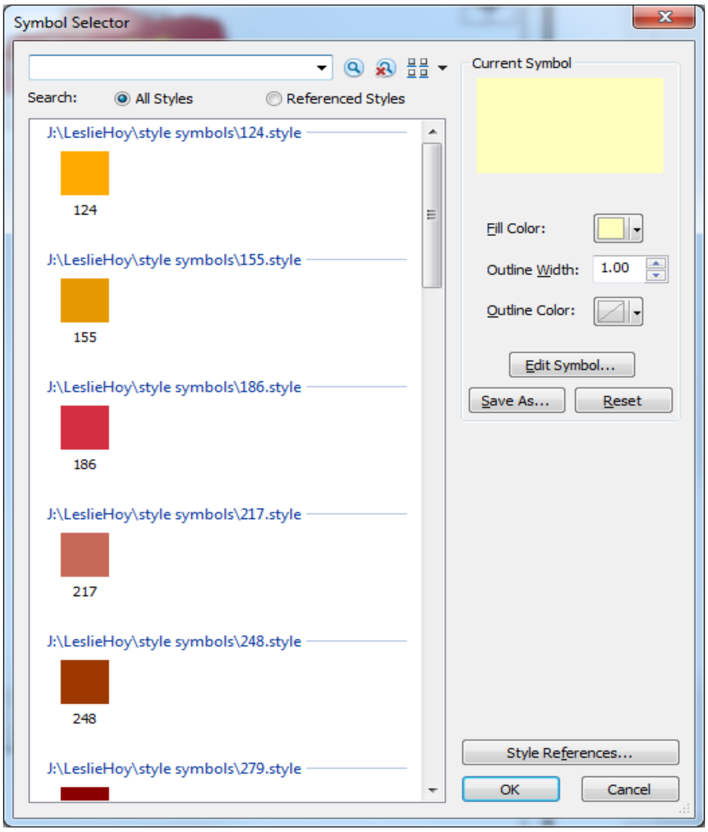
- To add the symbol to the style, open up the style and select the type of symbol wanted, in this case **a "Fill Symbol"**



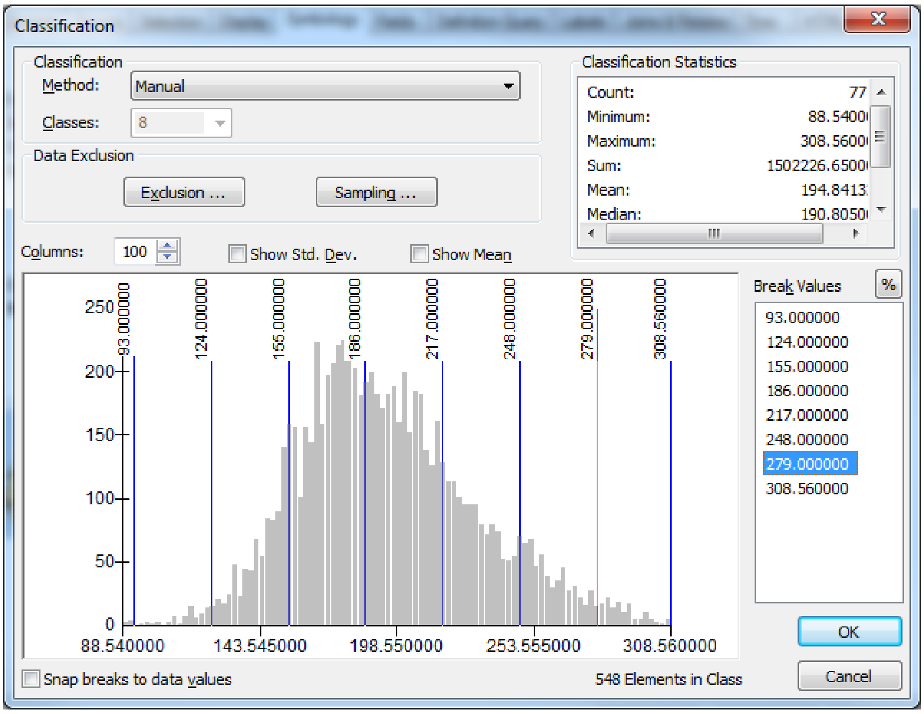
- Right click in the blank space on the right
  - Click New
  - Click Fill Symbol
  - Choose the colour
  - Label the colour according to the range

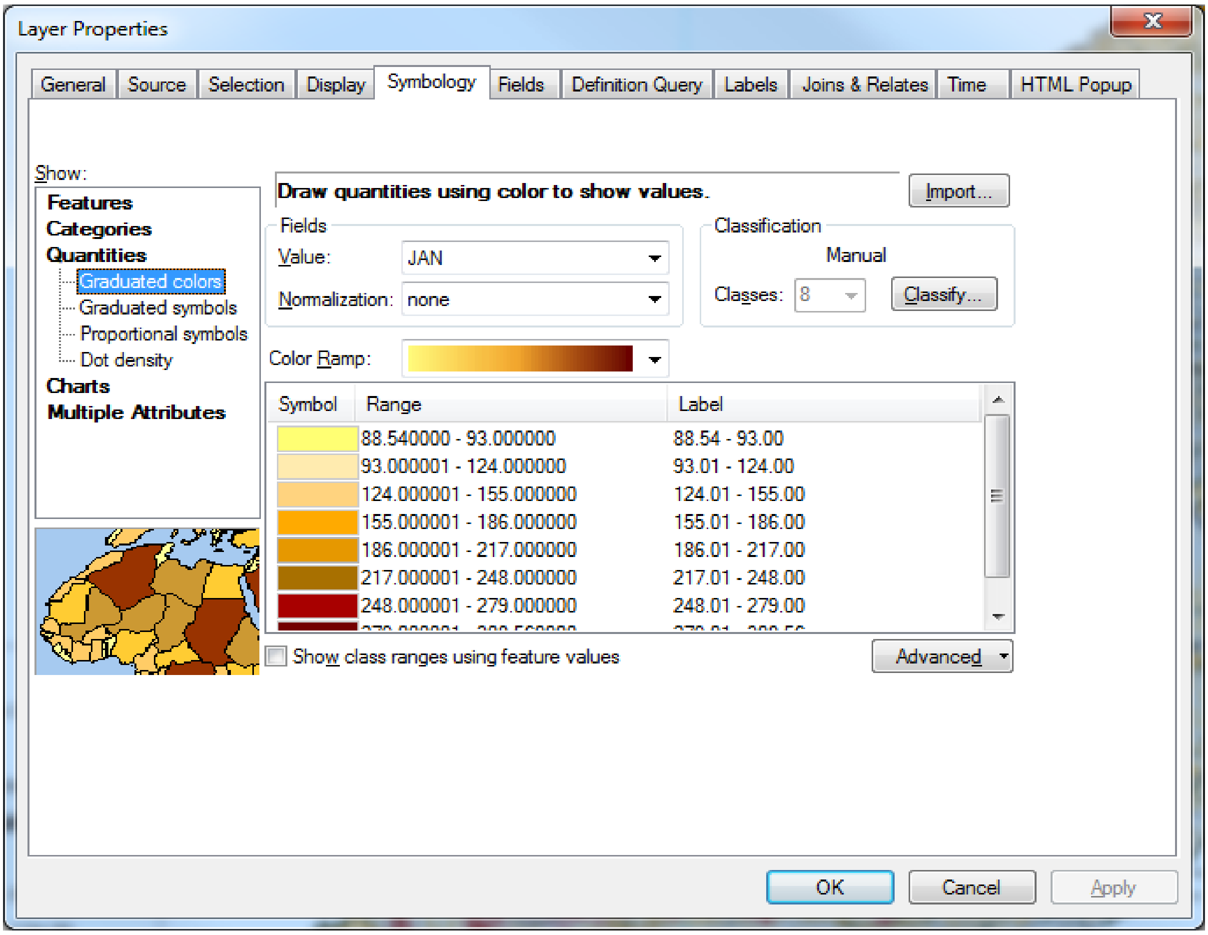


- This was done for all the required colours. If the symbol selector is opened, the new colours will be added to it.



- The symbology classification was done manually using the symbols that were created by allocating them to each of the 8 classes.

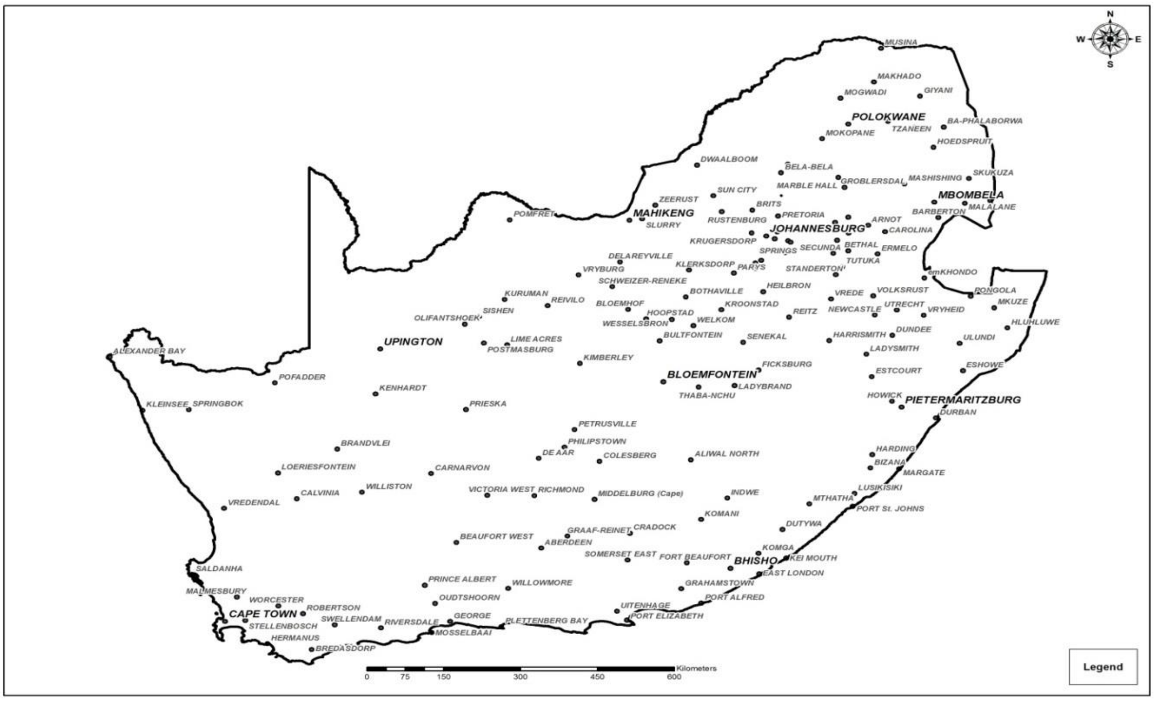




- To symbolize the Thematic Maps for each month, the evaporation figures per month are used and the symbology was based on Quantified Graduated colours. The "Value" was changed by month.

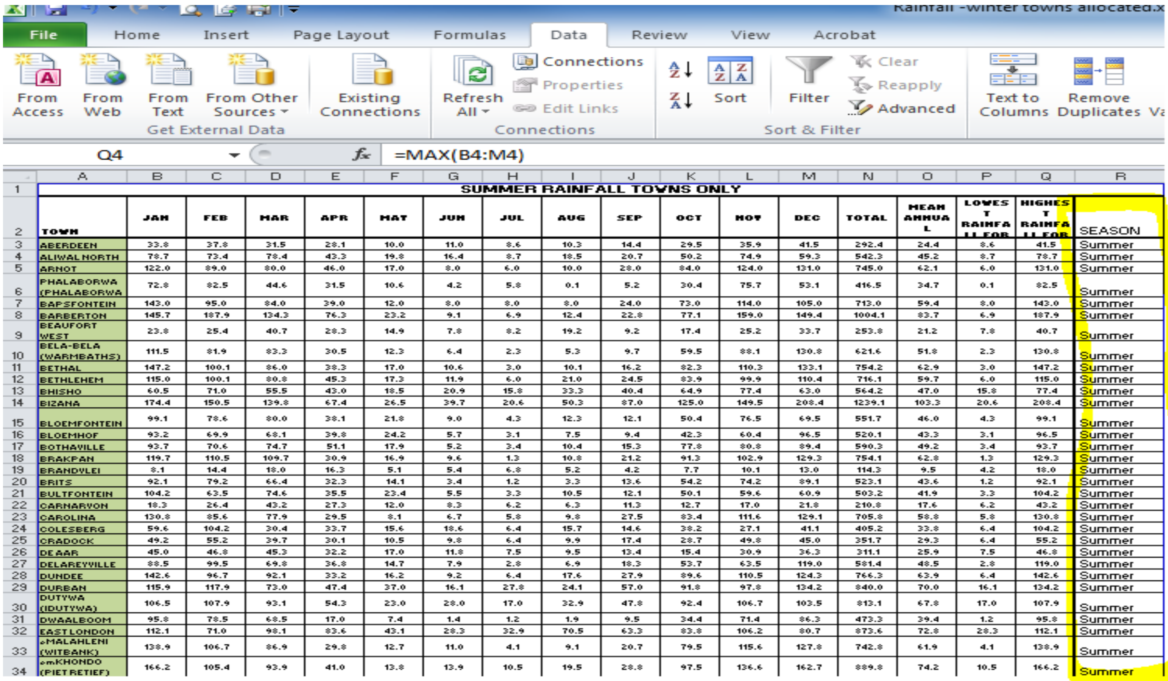
Annexure 4: Process followed to map the rainfall reading data provided.

- RSA Point Data Shape File



- An excel spreadsheet containing the rainfall readings per town, per month showing the season Summer or Winter

SUMMER



SUMMER RAINFALL TOWNS ONLY

TOWN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MEAN ANNUAL	LOWEST RAINFALL FOR	HIGHEST RAINFALL FOR	SEASON
ABERDEEN	33.8	37.8	31.5	28.1	10.0	11.0	8.6	10.3	14.4	29.5	35.9	41.5	292.4	24.4	8.6	41.5	Summer
ALIWAL NORTH	78.7	73.4	78.4	43.3	19.8	16.4	8.7	18.5	20.7	50.2	74.9	59.3	542.3	45.2	8.7	78.7	Summer
ARNOT	122.0	89.0	80.0	46.0	17.0	8.0	6.0	10.0	28.0	84.0	124.0	131.0	745.0	62.1	6.0	131.0	Summer
PHALABORWA (PHALABORWA	72.8	82.5	44.6	31.5	10.6	4.2	5.8	0.1	5.2	30.4	75.7	53.1	416.5	34.7	0.1	82.5	Summer
BAPSFONTEIN	143.0	95.0	84.0	39.0	12.0	8.0	8.0	8.0	24.0	73.0	114.0	105.0	713.0	59.4	8.0	143.0	Summer
BARBERTON	145.7	187.9	134.3	76.3	23.2	9.1	6.9	12.4	22.8	77.1	159.0	149.4	1004.1	83.7	6.9	187.9	Summer
BEAUFORT WEST	23.8	25.4	40.7	28.3	14.9	7.8	8.2	19.2	9.2	17.4	25.2	33.7	253.8	21.2	7.8	40.7	Summer
BELA-BELA (WARMBATHS)	111.5	81.9	83.3	30.5	12.3	6.4	2.3	5.3	9.7	59.5	88.1	130.8	621.6	51.8	2.3	130.8	Summer
BETHAL	147.2	100.1	86.0	38.3	17.0	10.6	3.0	10.1	16.2	82.3	110.3	133.1	754.2	62.9	3.0	147.2	Summer
BETHLEHEM	115.0	100.1	80.8	45.3	17.3	11.9	6.0	21.0	24.5	83.9	99.9	110.4	716.1	59.7	6.0	115.0	Summer
BHISHO	60.5	71.0	55.5	43.0	18.5	20.9	15.8	33.3	40.4	64.9	77.4	63.0	564.2	47.0	15.8	77.4	Summer
BIZANA	174.4	150.5	139.8	67.4	26.5	39.7	20.6	50.3	87.0	125.0	149.5	208.4	1239.1	103.3	20.6	208.4	Summer
BLOEMFONTEIN	99.1	78.6	80.0	38.1	21.8	9.0	4.3	12.3	12.1	50.4	76.5	69.5	551.7	46.0	4.3	99.1	Summer
BLOEMHOF	93.2	69.9	68.1	39.8	24.2	5.7	3.1	7.5	9.4	42.3	60.4	96.5	520.1	43.3	3.1	96.5	Summer
BOTHAVILLE	93.7	70.6	74.7	51.1	17.9	5.2	3.4	10.4	15.3	77.8	80.8	89.4	590.3	49.2	3.4	93.7	Summer
BRAKPAN	119.7	110.5	109.7	30.9	16.9	9.6	1.3	10.8	21.2	91.3	102.9	129.3	754.1	62.8	1.3	129.3	Summer
BRANDVLEI	8.1	14.4	18.0	16.3	5.1	5.4	6.8	5.2	4.2	7.7	10.1	13.0	114.3	9.5	4.2	18.0	Summer
BRITS	92.1	79.2	66.4	32.3	14.1	3.4	1.2	3.3	13.6	54.2	74.2	89.1	523.1	43.6	1.2	92.1	Summer
BULTFONTEIN	104.2	63.5	74.6	35.5	23.4	5.5	3.3	10.5	12.1	50.1	59.6	60.9	503.2	41.9	3.3	104.2	Summer
CARNARVON	18.3	26.4	43.2	27.3	12.0	8.3	6.2	6.3	11.3	12.7	17.0	21.8	210.8	17.6	6.2	43.2	Summer
CAROLINA	130.8	85.6	77.9	29.5	8.1	6.7	5.8	9.8	27.5	83.4	111.6	129.1	705.8	58.8	5.8	130.8	Summer
COLESBERG	59.6	104.2	30.4	33.7	15.6	18.6	6.4	15.7	14.6	38.2	27.1	41.1	405.2	33.8	6.4	104.2	Summer
CRADOCK	49.2	55.2	39.7	30.1	10.5	9.8	6.4	9.9	17.4	28.7	49.8	45.0	351.7	29.3	6.4	55.2	Summer
DE AAR	45.0	46.8	45.3	32.2	17.0	11.8	7.5	9.5	13.4	15.4	30.9	36.3	311.1	25.9	7.5	46.8	Summer
DELAREYVILLE	88.5	99.5	69.8	36.8	14.7	7.9	2.8	6.9	18.3	53.7	63.5	119.0	581.4	48.5	2.8	119.0	Summer
DUNDEE	142.6	96.7	92.1	33.2	16.2	9.2	6.4	17.6	27.9	89.6	110.5	124.3	766.3	63.9	6.4	142.6	Summer
DURBAN	115.9	117.9	73.0	47.4	37.0	16.1	27.8	24.1	57.0	91.8	97.8	134.2	840.0	70.0	16.1	134.2	Summer
DUTYWA (IDUTYWA)	106.5	107.9	93.1	54.3	23.0	28.0	17.0	32.9	47.8	92.4	106.7	103.5	813.1	67.8	17.0	107.9	Summer
DWAALBOOM	95.8	78.5	68.5	17.0	7.4	1.4	1.2	1.9	9.5	34.4	71.4	86.3	473.3	39.4	1.2	95.8	Summer
EAST LONDON	112.1	71.0	98.1	83.6	43.1	28.3	32.9	70.5	63.3	83.8	106.2	80.7	873.6	72.8	28.3	112.1	Summer
eMALAHLENI (WITBANK)	138.9	106.7	86.9	29.8	12.7	11.0	4.1	9.1	20.7	79.5	115.6	127.8	742.8	61.9	4.1	138.9	Summer
eMKHONDO (PIET RETIEF)	166.2	105.4	93.9	41.0	13.8	13.9	10.5	19.5	28.8	97.5	136.6	162.7	889.8	74.2	10.5	166.2	Summer

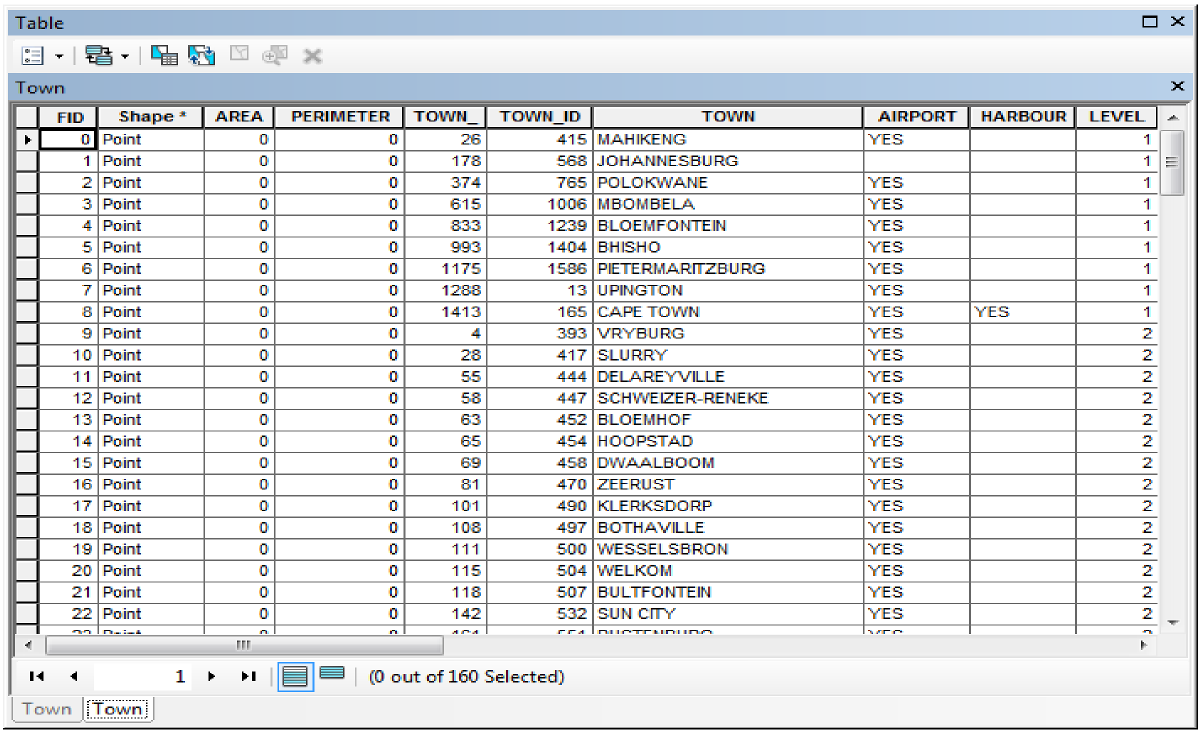
WINTER

WINTER RAINFALL TOWNS ONLY																	
TOWN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MEAN ANNUAL	LOWEST RAINFALL FOR	HIGHEST RAINFALL FOR	SEASON
ALEXANDER BAY	0.9	1.6	1.1	5.2	4.2	4.4	6.1	4.6	3.4	2.5	2.0	0.6	36.6	3.1	0.6	6.1	Winter
BREDASDORP	28.3	24.3	35.7	65.5	44.2	41.0	54.0	47.2	34.9	45.9	27.2	17.4	465.6	38.8	17.4	65.5	Winter
CALVINIA	6.7	15.7	18.0	26.1	20.8	22.7	27.3	19.9	15.0	11.8	11.5	12.2	207.7	17.3	6.7	27.3	Winter
CAPETOWN	10.1	9.6	10.1	44.2	71.9	90.4	88.7	77.9	45.8	32.8	26.7	14.5	522.7	43.6	9.6	90.4	Winter
HERMANUS	27.2	34.9	36.2	68.9	64.4	84.4	93.5	83.2	55.2	56.6	38.7	30.6	673.8	56.2	27.2	93.5	Winter
KLEINSEE	1.6	3.3	1.8	12.0	12.0	16.1	13.7	8.8	6.1	7.5	4.3	3.1	90.3	7.5	1.6	16.1	Winter
LOERIESFONTEIN	4.6	11.5	18.6	26.3	28.7	31.4	31.0	23.0	16.6	15.0	11.1	11.9	229.7	19.1	4.6	31.4	Winter
MALMESBURY	6.6	6.5	6.6	32.9	54.3	67.4	64.9	57.9	33.2	16.7	20.4	13.5	380.9	31.7	6.5	67.4	Winter
ROBERTSON	18.7	15.4	20.4	27.3	35.5	29.5	40.5	37.2	16.3	27.6	36.3	31.9	336.6	28.1	15.4	40.5	Winter
SALDANHA	1.4	16.7	8.2	13.6	70.6	56.7	29.1	33.5	33.9	15.5	40.2	8.2	327.6	27.3	1.4	70.6	Winter
SPRINGBOK	8.6	7.4	13.8	15.3	34.0	33.2	33.3	32.0	18.6	10.6	12.7	4.2	223.7	18.6	4.2	34.0	Winter
STELLENBOSCH	18.9	15.5	27.0	62.6	99.6	124.0	121.4	98.9	63.4	42.3	31.2	22.9	727.7	60.6	15.5	124.0	Winter
SWELLENDAM	37.3	34.6	49.4	70.2	43.4	41.3	50.9	48.5	34.6	58.6	42.6	41.7	553.1	46.1	34.6	70.2	Winter
VREDENDAL	3.5	2.7	5.3	13.9	21.8	25.2	28.7	20.0	12.9	10.5	6.1	10.1	160.7	13.4	2.7	28.7	Winter
WORCESTER	6.3	8.8	6.4	18.9	30.5	29.1	48.7	42.8	26.6	21.0	29.7	11.1	279.9	23.3	6.3	48.7	Winter

- Excel file with monthly figures showing per rainfall region

Hydrozone	Summer rainfall region				Winter rainfall region				Hydrozone	Annual rainfall
	Dec - Feb (mm/month)	March - May (mm/month)	June - Aug (mm/month)	Sept - Nov (mm/month)	Dec - Feb (mm/month)	March - May (mm/month)	June - August (mm/month)	Sept - Nov (mm/month)		Jan - Dec
No water (No watering required unless in extreme cases.)	0 to 52.0mm	0 to 20.0mm	0 to 6.0mm	0 to 25.0mm	0 to 28.0mm	0 to 25.0mm	0 to 37.0mm	0 to 20.0mm	No water	0 - 300
Low	52.01 to 86.67mm	20.01 to 33.33mm	6.01 to 10.0mm	25.01 to 41.67mm	28.01 to 46.67mm	25.01 to 41.67mm	37.01 to 61.67mm	20.01 to 33.33mm	Low	300,1 - 500
Medium	86.68 to 130.0mm	33.34 to 50.0mm	10.01 to 15.0mm	41.68 to 62.50mm	46.68 to 70.0mm	41.68 to 62.50mm	61.68 to 92.50mm	33.34 to 50.0mm	Medium	500,1 - 750
High	130.01 to >130.01mm	50.01 to >50.01mm	15.01 to >15.01mm	62.51 to 62.51mm	70.01 to >70.01mm	62.51 to >62.51	92.51 to >92.51mm	50.01 to >50.01mm	High	750,1 - >750,1

The shapefile showing the Town Names was available in GIS



Table

Town

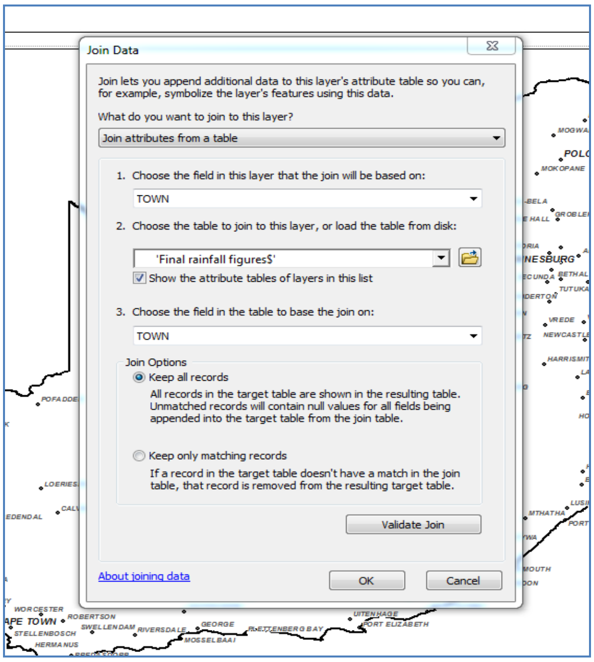
FID	Shape *	AREA	PERIMETER	TOWN_	TOWN_ID	TOWN	AIRPORT	HARBOUR	LEVEL
0	Point	0	0	26	415	MAHIKENG	YES		1
1	Point	0	0	178	568	JOHANNESBURG			1
2	Point	0	0	374	765	POLOKWANE	YES		1
3	Point	0	0	615	1006	MBOMBELA	YES		1
4	Point	0	0	833	1239	BLOEMFONTEIN	YES		1
5	Point	0	0	993	1404	BHISHO	YES		1
6	Point	0	0	1175	1586	PIETERMARITZBURG	YES		1
7	Point	0	0	1288	13	UPINGTON	YES		1
8	Point	0	0	1413	165	CAPE TOWN	YES	YES	1
9	Point	0	0	4	393	VRYBURG	YES		2
10	Point	0	0	28	417	SLURRY	YES		2
11	Point	0	0	55	444	DELAREYVILLE	YES		2
12	Point	0	0	58	447	SCHWEIZER-RENEKE	YES		2
13	Point	0	0	63	452	BLOEMHOF	YES		2
14	Point	0	0	65	454	HOOPSTAD	YES		2
15	Point	0	0	69	458	DWAALBOOM	YES		2
16	Point	0	0	81	470	ZEERUST	YES		2
17	Point	0	0	101	490	KLERKSDORP	YES		2
18	Point	0	0	108	497	BOTHAVILLE	YES		2
19	Point	0	0	111	500	WESSELSBRON	YES		2
20	Point	0	0	115	504	WELKOM	YES		2
21	Point	0	0	118	507	BULTFONTEIN	YES		2
22	Point	0	0	142	532	SUN CITY	YES		2

1 (0 out of 160 Selected)

Town | Town

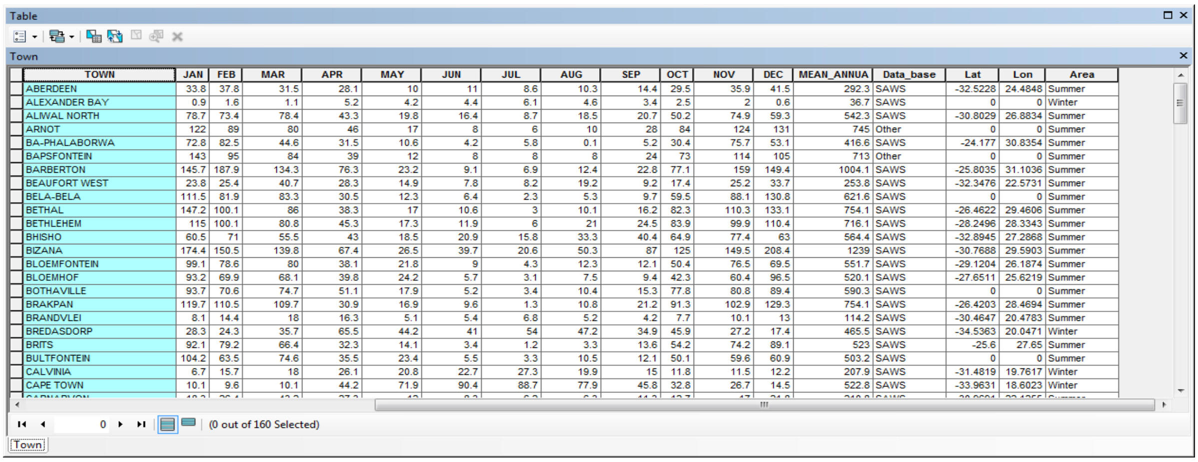
CREATING THE MAPS

- To join the tables in the ArcMap software an ***"Attribute Join"*** was performed, based on the town name and the excel data with the monthly readings was added to the shape file attribute data:
- Right click on the towns shapefile
  - From the drop-down menu select *"Joins and Relates"*
  - Select "Join"
- Fill in the information required



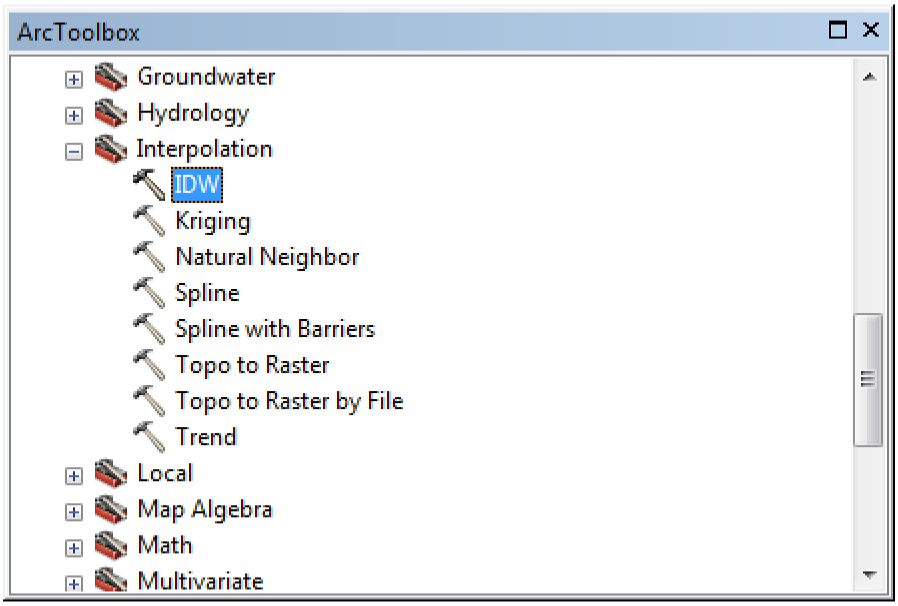
- Click ok

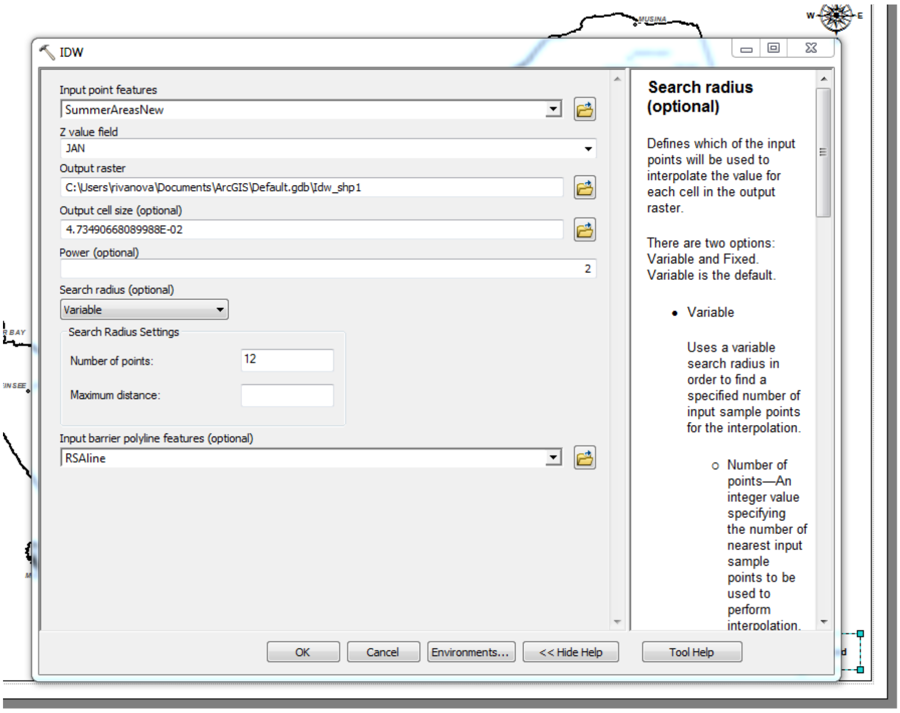
- The rainfall figures are now linked to the Town shapefile.



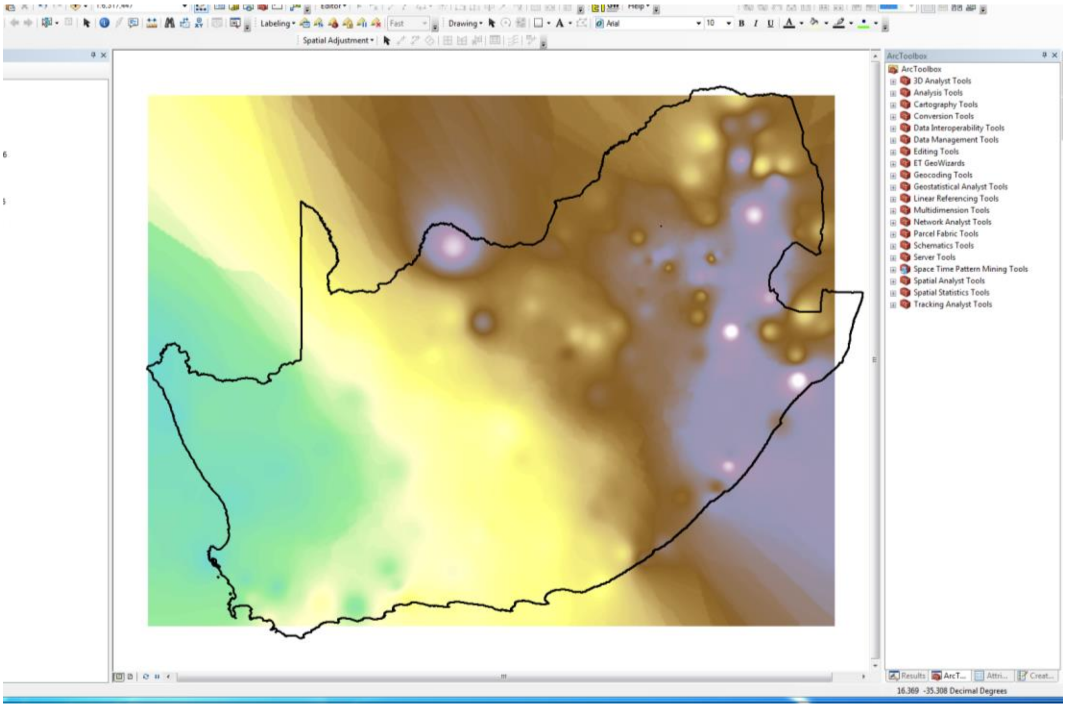
TOWN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN_ANNUA	Data_base	Lat	Lon	Area
ABERDEEN	33.8	37.8	31.5	28.1	10	11	8.6	10.3	14.4	29.5	35.9	41.5	292.3	SAWS	-32.5228	24.4848	Summer
ALEXANDER BAY	0.9	1.6	1.1	5.2	4.2	4.4	6.1	4.6	3.4	2.5	2	0.6	36.7	SAWS	0	0	Winter
ALIWAL NORTH	78.7	73.4	78.4	43.3	19.8	16.4	8.7	18.5	20.7	50.2	74.9	59.3	542.3	SAWS	-30.8029	26.8834	Summer
ARNOT	122	89	80	46	17	8	6	10	28	84	124	131	745	Other	0	0	Summer
BA-PHALABORWA	72.8	82.5	44.6	31.5	10.6	4.2	5.8	0.1	5.2	30.4	75.7	53.1	416.6	SAWS	-24.177	30.8354	Summer
BAPSFONTEIN	143	95	84	39	12	8	8	8	24	73	114	105	713	Other	0	0	Summer
BARBERTON	145.7	187.9	134.3	76.3	23.2	9.1	6.9	12.4	22.8	77.1	159	149.4	1004.1	SAWS	-25.8035	31.1036	Summer
BEAUFORT WEST	23.8	25.4	40.7	28.3	14.9	7.8	8.2	19.2	9.2	17.4	25.2	33.7	253.8	SAWS	-32.3476	22.5731	Summer
BELA-BELA	111.5	81.9	83.3	30.5	12.3	6.4	2.3	5.3	9.7	59.5	88.1	130.8	621.6	SAWS	0	0	Summer
BETHAL	147.2	100.1	86	38.3	17	10.6	3	10.1	16.2	82.3	110.3	133.1	754.1	SAWS	-26.4622	29.4606	Summer
BETHLEHEM	115	100.1	80.8	45.3	17.3	11.9	6	21	24.5	83.9	99.9	110.4	716.1	SAWS	-28.2496	28.3343	Summer
BHISHO	60.5	71	55.5	43	18.5	20.9	15.8	33.3	40.4	64.9	77.4	63	564.4	SAWS	-32.8945	27.2868	Summer
BIZANA	174.4	150.5	139.8	67.4	26.5	39.7	20.6	50.3	87	125	149.5	208.4	1239	SAWS	-30.7688	29.5903	Summer
BLOEMFONTEIN	99.1	78.6	80	38.1	21.8	9	4.3	12.3	12.1	50.4	76.5	69.5	551.7	SAWS	-29.1204	26.1874	Summer
BLOEMHOF	93.2	69.9	68.1	39.8	24.2	5.7	3.1	7.5	9.4	42.3	60.4	96.5	520.1	SAWS	-27.6511	25.6219	Summer
BOTHAVILLE	93.7	70.6	74.7	51.1	17.9	5.2	3.4	10.4	15.3	77.8	80.8	89.4	590.3	SAWS	0	0	Summer
BRAKPAN	119.7	110.5	109.7	30.9	16.9	9.6	1.3	10.8	21.2	91.3	102.9	129.3	754.1	SAWS	-26.4203	28.4694	Summer
BRANDVLEI	8.1	14.4	18	16.3	5.1	5.4	6.8	5.2	4.2	7.7	10.1	13	114.2	SAWS	-30.4647	20.4783	Summer
BREDASDORP	28.3	24.3	35.7	65.5	44.2	41	54	47.2	34.9	45.9	27.2	17.4	465.5	SAWS	-34.5363	20.0471	Winter
BRITS	92.1	79.2	66.4	32.3	14.1	3.4	1.2	3.3	13.6	54.2	74.2	89.1	523	SAWS	-25.6	27.65	Summer
BULTFONTEIN	104.2	63.5	74.6	35.5	23.4	5.5	3.3	10.5	12.1	50.1	59.6	60.9	503.2	SAWS	0	0	Summer
CALVINIA	6.7	15.7	18	26.1	20.8	22.7	27.3	19.9	15	11.8	11.5	12.2	207.9	SAWS	-31.4819	19.7617	Winter
CAPE TOWN	10.1	9.6	10.1	44.2	71.9	90.4	88.7	77.9	45.8	32.8	26.7	14.5	522.8	SAWS	-33.9631	18.6023	Winter

- To create the maps showing the rainfall per season, per month, the monthly reading fields were used. The **IDW** (Inverse Distance Weighted) Interpolation was used as this will determine the cell values using a linearly weighted combination of the rainfall points and will create the raster coverage for the required area.
- Open ArcToolbox
  - Scroll down to **"Interpolation"**
  - Select **IDW**

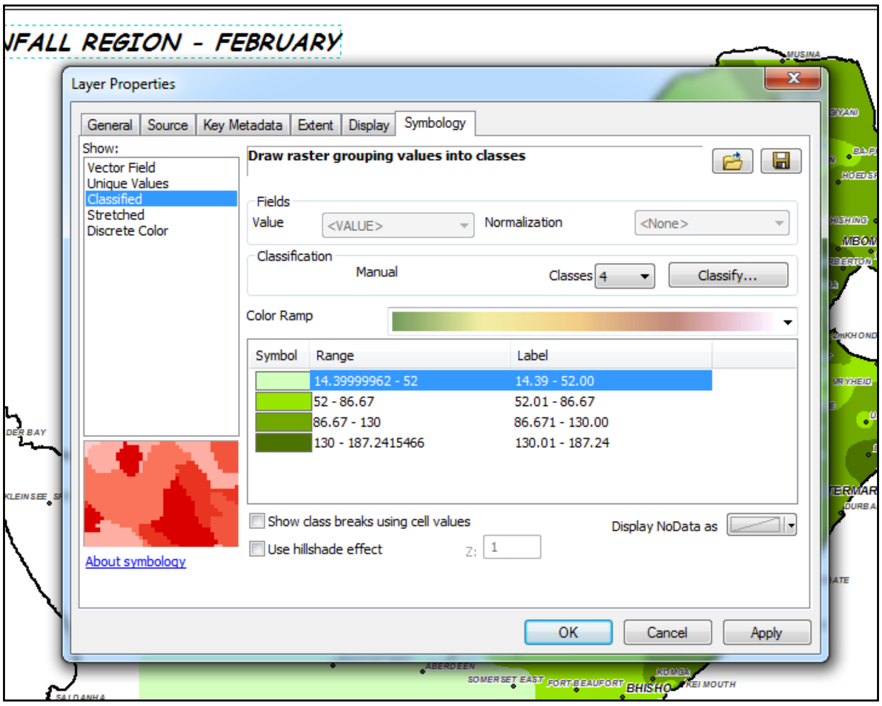




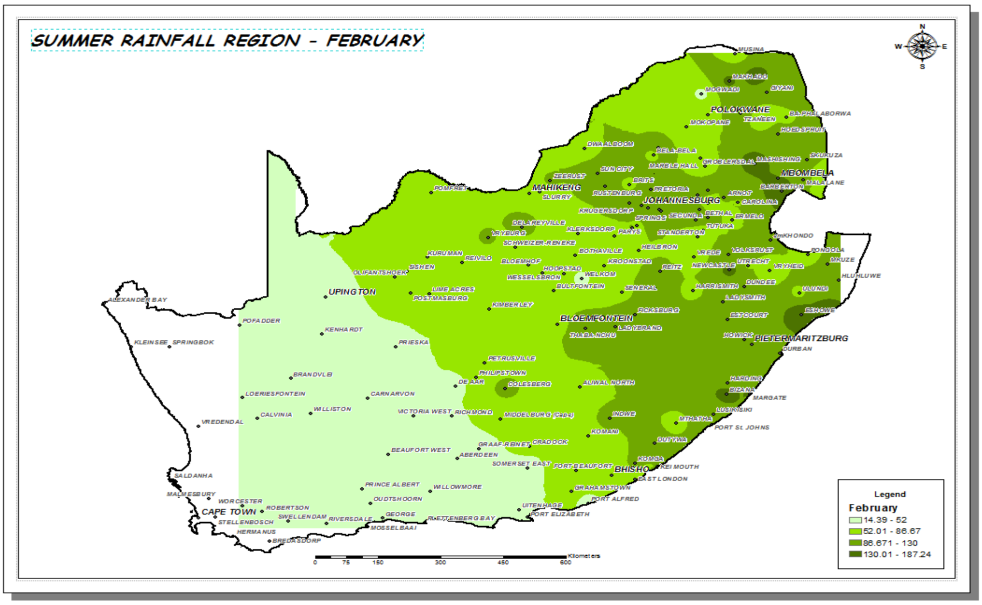
- The resultant map was a raster data set per month for the summer and winter regions.



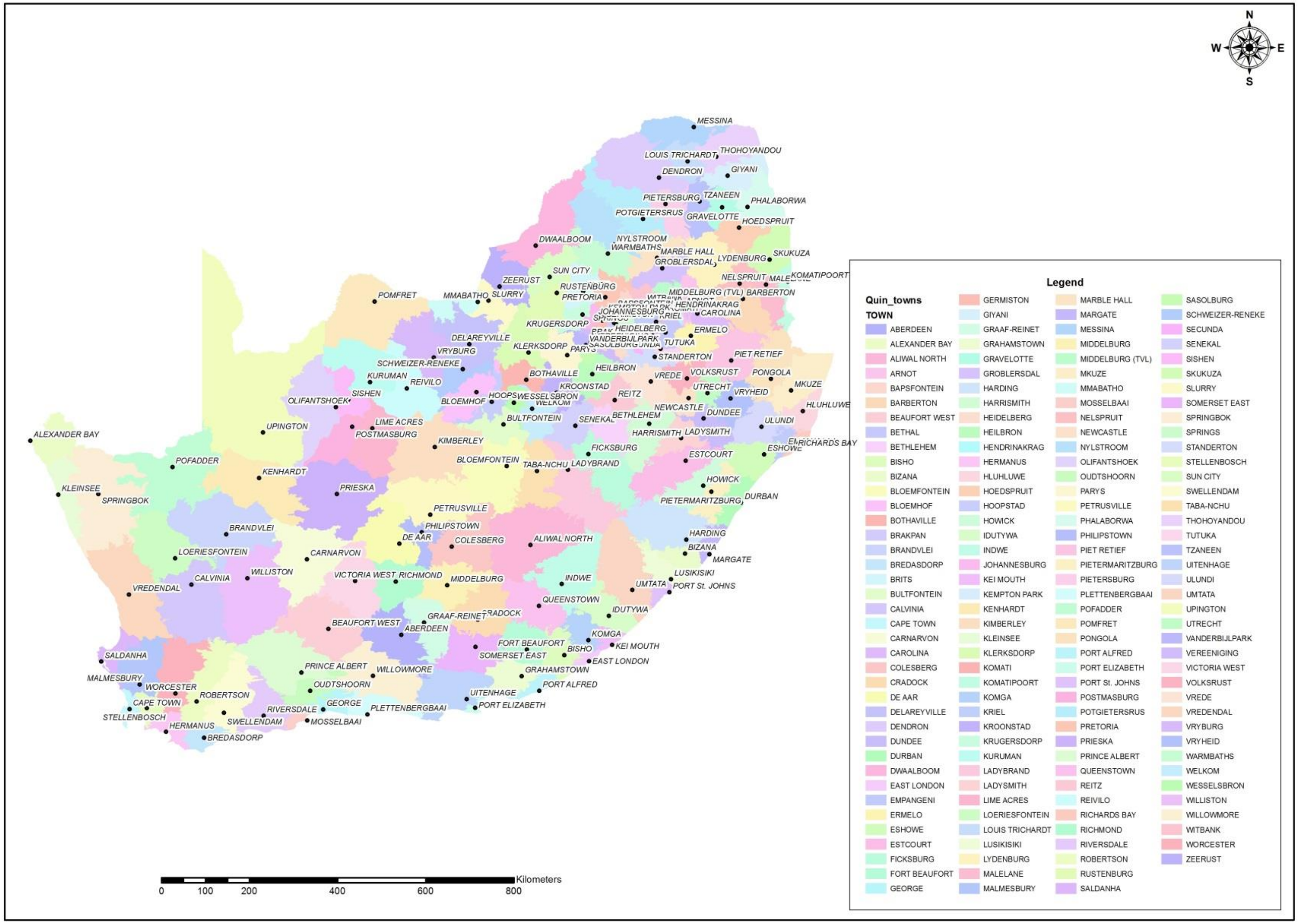
- The next step was to symbolise the raster data according to the figures provided per hydro-zone for the summer and winter regions.
  - The data was classified into four groups as per the table and relevant colours applied to achieve the final map.



- Sample of the final map:-



Annexure 5: Map indicating the 160 Quinaries linked to the database (evapotranspiration and rainfall).



Annexure 6: Average evapotranspiration figures for each of the level 1 or 2 towns selected.

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
L21D1	ABERDEEN	239,3	191,9	165,7	116,8	87,7	67,5	75,8	100,1	132,1	164,2	199,2	236,9	1777,2	148,1	148,2	67,5	239,3
D82G3	ALEXANDER BAY	248,1	209,3	187,8	135,1	99,1	77,0	84,1	109,9	144,0	182,3	218,7	242,9	1938,4	161,5	163,2	77,0	248,1
D18J2	ALIWAL NORTH	218,7	172,7	153,2	107,6	81,2	63,8	71,0	97,1	135,7	164,6	190,1	226,8	1682,4	140,2	144,4	63,8	226,8
B12A1	ARNOT	160,4	136,2	134,8	104,0	89,1	74,9	80,3	105,4	134,7	148,1	149,0	167,2	1484,1	123,7	134,8	74,9	167,2
B72D2	BA-PHALABORWA (PHALABORWA)	208,7	186,8	186,6	154,8	138,8	126,3	125,2	147,8	174,4	190,0	201,2	213,3	2053,9	171,2	180,5	125,2	213,3
A21A2	BAPSFONTEIN	179,6	155,5	150,5	120,1	102,1	85,8	93,1	118,6	150,4	167,2	171,2	179,0	1673,1	139,4	150,5	85,8	179,6

Average evapotranspiration figures for each quinary.																	
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
W55C3	BARBERTON	162,1	142,5	141,2	114,3	102,8	88,9	95,3	116,4	136,8	146,9	147,9	177,4	1572,5	131,0	139,0	88,9	177,4
D55A1	BEAUFORT WEST	242,4	190,4	167,0	114,0	84,5	67,9	75,7	98,0	133,0	168,5	203,8	238,3	1783,4	148,6	150,0	67,9	242,4
A23C1	BELA-BELA (WARMBATHS)	206,6	178,5	172,9	139,0	117,3	101,4	107,0	137,1	173,4	196,8	200,2	205,9	1936,2	161,4	173,1	101,4	206,6
B11A1	BETHAL	169,1	146,1	143,3	111,5	94,5	76,7	83,2	111,3	139,1	154,2	158,8	171,9	1559,5	130,0	141,2	76,7	171,9
C42A1	BETHLEHEM	174,7	142,5	134,1	100,0	80,1	64,7	71,3	95,8	123,4	143,7	156,1	187,1	1473,5	122,8	128,7	64,7	187,1
Q93C1	BHISHO	163,6	134,8	129,8	98,1	81,2	67,1	74,8	90,0	109,9	125,6	139,6	183,2	1397,6	116,5	117,7	67,1	183,2
T31H3	BIZANA	160,9	139,7	134,8	102,8	86,7	73,8	80,7	99,0	116,5	130,9	141,9	182,7	1450,5	120,9	123,7	73,8	182,7
C52D1	BLOEMFONTEI	229	182	165	120	93,	76,	84,	113	156	185	209	238	1853,	154,	160,	76,5	238,0

Average evapotranspiration figures for each quinary.

QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
	N	,8	,4	,1	,1	5	5	0	,3	,5	,1	,5	,0	8	5	8		
C25D2	BLOEMHOF	231,1	184,7	173,5	131,7	106,7	87,0	96,1	129,4	169,3	199,2	221,0	241,9	1971,7	164,3	171,4	87,0	241,9
C60H3	BOTHAVILLE	213,2	176,9	167,9	128,4	104,9	87,2	95,5	127,8	167,5	191,8	207,2	226,1	1894,3	157,9	167,7	87,2	226,1
C21D2	BRAKPAN	179,0	150,7	142,0	110,7	94,7	76,4	84,3	111,6	146,5	164,6	170,7	178,8	1609,9	134,2	144,2	76,4	179,0
D58C2	BRANDVLEI	276,8	227,1	198,3	136,5	100,0	77,1	85,5	114,3	155,0	198,0	239,9	271,8	2080,2	173,3	176,5	77,1	276,8
G40M1	BREDASDORP	189,8	156,5	136,3	97,5	70,9	55,9	57,9	72,0	98,3	137,0	166,8	192,8	1431,7	119,3	117,3	55,9	192,8
A21G3	BRITS	210,0	179,7	174,7	136,5	116,1	99,7	106,9	136,8	174,5	195,1	200,5	212,1	1942,7	161,9	174,6	99,7	212,1
C41H2	BULTFONTEIN	231,8	183,1	170,3	128,2	103,3	86,1	94,7	125,7	164,6	195,1	217,2	240,8	1940,8	161,7	167,4	86,1	240,8

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
D52A1	CALVINIA	254,9	211,3	180,5	123,3	89,9	64,5	71,2	98,1	134,4	177,0	216,0	248,1	1869,2	155,8	155,7	64,5	254,9
G21B2	CAPE TOWN	167,9	140,0	123,8	86,1	59,5	44,7	47,4	62,4	83,0	120,8	146,4	168,5	1250,4	104,2	103,4	44,7	168,5
D61F1	CARNARVON	255,5	204,2	178,5	121,2	88,3	67,8	75,9	104,9	146,0	183,5	220,8	251,9	1898,5	158,2	162,2	67,8	255,5
C11A1	CAROLINA	160,1	137,5	137,0	108,1	91,8	77,9	82,1	107,3	134,6	144,6	147,6	174,6	1503,4	125,3	135,8	77,9	174,6
C51G2	COLESBERG	234,7	179,8	159,4	109,0	82,3	64,0	71,7	98,8	138,2	171,4	203,9	235,9	1749,0	145,8	148,8	64,0	235,9
Q12A1	CRADOCK	204,9	165,4	151,6	109,7	84,7	68,1	76,3	101,4	134,0	154,7	179,1	215,1	1645,1	137,1	142,8	68,1	215,1
D61L1	DE AAR	254,3	200,8	179,6	123,9	93,3	71,2	79,4	110,8	154,3	188,3	223,1	256,6	1935,7	161,3	167,0	71,2	256,6
C31B2	DELAREYVILLE	208	175	166	127	106	85,	93,	126	166	191	208	222	1878,	156,	166,	85,1	222,3

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
		,8	,0	,0	,9	,3	1	5	,1	,4	,9	,7	,3	1	5	2		
V60B1	DUNDEE	183,2	157,5	153,4	119,5	98,8	84,0	91,1	115,6	140,6	157,5	168,3	204,4	1674,0	139,5	147,0	84,0	204,4
U10M2	DURBAN	142,1	125,8	129,4	105,1	93,5	81,4	86,1	99,8	109,8	119,7	129,1	163,8	1385,7	115,5	114,7	81,4	163,8
S50G2	DUTYWA (IDUTYWA)	174,1	147,1	142,3	110,1	91,5	78,3	86,1	104,4	123,3	138,8	153,0	192,7	1541,7	128,5	131,1	78,3	192,7
A10C1	DWAALBOOM	220,3	189,3	184,9	146,8	126,0	107,4	113,5	144,1	180,1	205,4	212,1	219,5	2049,4	170,8	182,5	107,4	220,3
R20F3	EAST LONDON	140,1	116,9	117,6	93,1	80,8	69,1	73,5	84,4	96,1	109,9	121,3	156,8	1259,4	105,0	103,0	69,1	156,8
B11F1	eMALAHLENI (WITBANK)	179,5	154,5	150,9	121,0	102,9	86,3	93,2	120,2	150,6	165,9	169,3	179,3	1673,6	139,5	150,7	86,3	179,5
W42B3	emKHONDO (PIET RETIEF)	162,1	140,3	140,3	111,4	98,1	82,3	90,3	112,8	133,1	144,9	147,8	183,2	1546,7	128,9	136,7	82,3	183,2

Average evapotranspiration figures for each quinary.

QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
W12D2	EMPANGENI	180,9	159,3	155,5	125,1	108,1	93,4	97,4	117,0	132,1	147,1	158,8	198,7	1673,4	139,5	139,6	93,4	198,7
C11A2	ERMELO	157,1	135,0	134,4	104,5	88,2	72,9	78,8	104,4	131,9	145,1	147,2	174,8	1474,3	122,9	133,2	72,9	174,8
U40E2	ESHOWE	161,1	141,2	140,6	113,9	99,2	85,2	90,4	108,8	122,8	135,7	145,1	182,0	1525,8	127,2	129,3	85,2	182,0
D16D3	ESTCOURT	170,1	144,1	135,6	103,8	82,8	69,3	76,7	99,2	125,2	142,8	155,2	190,5	1495,3	124,6	130,4	69,3	190,5
D11B1	FICKSBURG	175,5	142,7	133,4	94,0	71,3	57,0	64,2	87,9	120,0	143,8	157,4	195,1	1442,2	120,2	126,7	57,0	195,1
Q41A1	FORT BEAUFORT	188,8	158,0	145,7	109,8	86,6	72,7	79,5	99,4	125,5	143,0	163,8	204,3	1577,2	131,4	134,2	72,7	204,3
B11C3	GA-NALA (KRIEL)	174,7	152,3	145,7	116,3	98,2	80,7	87,3	115,5	145,7	160,1	165,9	174,9	1617,2	134,8	145,7	80,7	174,9
J34B1	GEORGE	131	110	106	79,	64,	53,	57,	68,	83,	104	122	136	1120,	93,4	94,2	53,7	136,4

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
		,6	,0	,4	9	7	7	3	9	8	,6	,9	,4	3				
C21D1	GERMISTON	175,1	148,5	140,4	107,0	92,3	74,5	82,3	110,2	145,8	161,9	166,8	177,8	1582,6	131,9	143,1	74,5	177,8
B81G3	GIYANI	207,6	184,5	183,6	154,6	140,1	125,8	124,9	148,4	175,3	190,3	202,4	214,0	2051,3	170,9	179,4	124,9	214,0
N11A1	GRAAF-REINET	221,9	176,2	157,9	114,4	88,8	71,3	80,2	104,2	135,9	160,7	189,2	223,7	1724,4	143,7	146,9	71,3	223,7
P10A1	GRAHAMSTOWN	185,0	153,9	143,8	108,7	88,5	72,6	80,0	97,0	119,0	137,4	156,2	201,5	1543,6	128,6	128,2	72,6	201,5
B71H1	GRAVELOTTE	191,2	171,1	168,0	141,4	129,8	114,5	115,8	138,9	159,5	173,6	184,2	194,6	1882,7	156,9	163,8	114,5	194,6
B31H1	GROBLERSDAL	196,6	169,5	165,6	131,2	112,5	95,2	100,6	127,7	160,4	179,5	182,3	195,0	1816,1	151,3	163,0	95,2	196,6
D17H1	HARDING	168,6	142,3	135,8	104,9	86,6	73,5	81,4	102,6	124,8	140,7	151,0	188,4	1500,7	125,1	130,3	73,5	188,4

Average evapotranspiration figures for each quinary.

QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
C81A1	HARRISMITH	178,0	148,5	139,7	106,1	85,2	70,9	78,8	101,0	130,4	150,3	162,8	195,4	1547,1	128,9	135,0	70,9	195,4
C12G1	HEIDELBERG	181,3	157,2	148,2	118,2	99,1	81,6	89,7	117,8	148,6	164,2	173,9	183,6	1663,3	138,6	148,4	81,6	183,6
C60C1	HEILBRON	193,6	162,4	154,0	118,4	98,3	81,0	89,2	118,8	150,2	169,8	181,9	197,8	1715,4	142,9	152,1	81,0	197,8
B12A2	HENDRINAKRAG	170,5	147,7	144,2	114,6	95,8	78,4	85,2	112,9	139,7	154,4	158,1	178,4	1579,8	131,7	141,9	78,4	178,4
G40B3	HERMANUS	182,9	152,5	130,2	90,7	63,8	49,0	51,2	65,8	89,2	127,3	158,4	182,9	1343,9	112,0	109,0	49,0	182,9
W22L1	HLUHLUWE	185,8	164,3	161,7	130,4	112,8	96,2	100,8	121,1	137,4	151,1	162,4	202,3	1726,4	143,9	144,3	96,2	202,3
B60B2	HOEDSPRUIT	179,7	162,5	158,8	134,4	119,1	104,9	106,3	126,9	151,1	161,3	171,6	181,1	1757,8	146,5	154,9	104,9	181,1
C43C3	HOOPSTAD	231	187	173	132	105	89,	99,	131	172	202	223	243	1992,	166,	173,	89,2	243,6

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
		,8	,6	,8	,0	,8	2	0	,7	,1	,6	,5	,6	7	1	0		
T51A3	HOWICK	162,1	139,6	135,8	105,5	87,1	74,2	81,8	102,5	122,7	136,5	146,4	183,1	1477,3	123,1	129,3	74,2	183,1
D18G1	INDWE	186,6	153,7	139,5	102,6	79,1	62,3	70,3	93,5	122,3	143,7	162,4	203,7	1519,6	126,6	130,9	62,3	203,7
A21C1	JOHANNESBURG	176,0	148,4	144,6	112,3	96,0	77,4	84,3	111,5	145,3	162,2	168,9	178,0	1604,8	133,7	144,9	77,4	178,0
R30A2	KEI MOUTH	151,9	128,4	125,7	100,7	88,0	75,5	81,2	96,1	109,5	119,6	131,5	169,5	1377,5	114,8	114,5	75,5	169,5
A21A1	KEMPTON PARK	177,7	149,0	142,5	112,0	95,7	77,3	84,7	109,2	144,0	163,4	169,1	176,0	1600,6	133,4	143,2	77,3	177,7
D57E1	KENHARDT	287,5	233,6	209,5	149,1	113,8	87,2	95,5	130,1	172,1	212,5	252,0	283,2	2226,2	185,5	190,8	87,2	287,5
C33C3	KIMBERLEY	257,8	204,7	184,7	134,9	105,9	86,3	94,9	126,8	170,6	206,1	235,0	264,1	2072,0	172,7	177,7	86,3	264,1

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
F20A3	KLEINSEE	229,5	197,1	172,9	125,9	93,8	74,6	79,2	102,8	134,8	174,5	207,7	224,7	1817,6	151,5	153,9	74,6	229,5
C31C1	KLERKSDORP	200,8	169,7	162,4	126,6	105,8	86,7	95,1	126,7	164,9	185,8	198,1	210,1	1832,6	152,7	163,7	86,7	210,1
D14B1	KOMANI (QUEENSTOWN)	202,1	165,2	148,3	109,0	83,7	68,1	75,2	99,2	130,7	151,7	175,1	216,0	1624,3	135,4	139,5	68,1	216,0
B11B1	KOMATI	173,9	149,8	145,7	116,5	97,9	80,0	86,9	115,4	142,5	156,2	162,2	172,5	1599,4	133,3	144,1	80,0	173,9
W60F1	KOMATIPOORT	195,6	177,3	171,8	142,9	126,3	115,5	116,8	137,2	160,4	172,5	188,0	205,2	1909,6	159,1	166,1	115,5	205,2
R30A1	KOMGA	171,8	143,2	138,9	108,9	90,7	76,7	84,5	103,9	123,5	135,0	148,1	188,5	1513,7	126,1	129,3	76,7	188,5
C42H1	KROONSTAD	205,1	169,6	161,2	119,3	98,1	80,7	89,0	120,1	159,6	181,8	194,6	215,3	1794,2	149,5	160,4	80,7	215,3

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
A21D1	KRUGERSDORP	184,6	156,3	152,0	116,7	99,1	81,8	88,0	117,0	152,0	170,7	175,6	188,1	1681,9	140,2	152,0	81,8	188,1
D41G2	KURUMAN	247,7	199,8	187,8	138,9	112,4	86,9	98,9	134,5	173,9	208,4	236,8	254,5	2080,5	173,4	180,8	86,9	254,5
C41B1	LADYBRAND	198,3	156,9	144,9	101,4	77,1	61,4	68,8	94,6	130,4	157,1	173,9	213,5	1578,4	131,5	137,6	61,4	213,5
V11H2	LADYSMITH	203,9	173,8	165,6	128,2	104,9	93,7	101,1	125,2	155,0	174,7	188,8	225,7	1840,6	153,4	160,3	93,7	225,7
C92A1	LIME ACRES	250,0	195,2	182,2	134,5	107,6	85,3	96,2	128,6	168,7	201,8	231,1	255,5	2036,7	169,7	175,4	85,3	255,5
E40C2	LOERIESFONTEIN	249,9	211,5	184,6	130,7	92,8	70,1	75,0	99,5	135,9	178,9	216,0	244,3	1889,3	157,4	157,4	70,1	249,9
T32F2	LUSIKISIKI	172,3	150,4	142,6	105,7	89,0	77,7	84,0	102,3	119,3	136,5	149,2	191,0	1519,9	126,7	127,9	77,7	191,0
D41A3	MAHIKENG	224	190	179	136	115	91,	100	135	179	206	214	232	2005,	167,	179,	91,4	232,1

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
	(MMABATHO)	,9	,0	,3	,6	,1	4	,4	,8	,0	,6	,2	,1	4	1	1		
A71H1	MAKHADO (LOUIS TRICHARDT)	164,8	145,4	149,2	127,8	115,9	101,6	101,2	124,0	148,8	164,6	167,9	175,0	1686,2	140,5	147,1	101,2	175,0
W60E1	MALALANE (MALELANE)	185,6	168,2	162,7	134,1	120,1	108,3	110,6	131,5	152,8	163,6	175,7	194,6	1807,7	150,6	157,8	108,3	194,6
E21G1	MALMESBURY	199,2	167,1	144,3	98,4	71,3	53,0	55,9	71,5	97,9	140,9	173,8	201,0	1474,4	122,9	119,7	53,0	201,0
B31F1	MARBLE HALL	208,2	179,9	175,1	140,2	119,7	101,8	107,8	136,6	171,9	192,2	193,0	206,0	1932,6	161,0	173,5	101,8	208,2
T40F1	MARGATE	132,4	115,8	119,4	99,6	88,9	76,8	81,1	91,7	98,5	110,0	119,4	151,6	1285,3	107,1	104,8	76,8	151,6
B42A1	MASHISHING (LYDENBURG)	156,4	134,5	136,3	109,7	96,9	84,3	86,4	107,4	132,0	143,8	148,6	157,3	1493,5	124,5	133,3	84,3	157,3
X21H1	MBOMBELA	158	138	139	113	105	94,	95,	116	136	143	147	162	1552,	129,	137,	94,9	162,4

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
	(NELSPRUIT)	,9	,4	,3	,6	,0	9	2	,0	,9	,8	,5	,4	0	3	7		
D34B1	MIDDELBURG (Cape)	228,7	177,5	158,0	111,9	83,9	65,2	73,7	99,1	137,4	166,1	196,8	232,2	1730,5	144,2	147,7	65,2	232,2
B12C3	MIDDELBURG (Mpumalanga)	185,5	157,5	154,1	119,7	101,8	85,4	92,0	119,8	150,7	169,8	171,5	185,6	1693,4	141,1	152,4	85,4	185,6
W22K1	MKUZE	193,0	165,0	163,8	133,1	116,2	100,9	107,2	128,3	143,1	158,8	165,5	209,6	1784,6	148,7	151,0	100,9	209,6
A41B1	MODIMOLLE (NYLSTROOM)	199,8	170,3	168,5	134,8	116,9	99,3	105,8	134,2	168,6	191,5	192,1	199,0	1880,7	156,7	168,5	99,3	199,8
A50H1	MOGWADI (DENDRON)	195,2	171,8	173,3	142,1	124,9	108,9	109,8	137,8	166,8	185,5	189,5	198,9	1904,4	158,7	169,3	108,9	198,9
A42J2	MOKOPANE (POTGIETERSRUS)	196,6	170,2	170,0	136,4	118,3	101,1	104,5	133,2	165,6	187,8	187,5	196,8	1868,0	155,7	167,8	101,1	196,8
J40C1	MOSSELBAAI	157	127	118	88,	69,	57,	61,	75,	92,	119	138	158	1264,	105,	105,	57,8	158,8

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
		,4	,0	,7	5	0	8	5	4	8	,3	,0	,8	2	3	7		
T11D1	MTHATHA (UMTATA)	172,5	145,6	139,6	106,2	87,1	75,6	83,2	102,5	123,4	140,6	153,0	192,7	1522,0	126,8	131,5	75,6	192,7
A63E1	MUSINA (MESSINA)	214,5	187,3	190,0	158,0	141,7	123,7	126,2	152,1	179,0	198,4	205,0	217,3	2093,0	174,4	183,1	123,7	217,3
C13C1	NEWCASTLE	185,3	154,7	154,1	121,2	100,1	85,3	93,3	116,8	144,2	161,7	172,8	207,8	1697,4	141,4	149,2	85,3	207,8
D73C1	OLIFANTSHOEK	256,4	203,3	189,7	138,4	110,3	86,0	96,8	129,8	171,5	207,9	237,3	263,5	2090,8	174,2	180,6	86,0	263,5
J25E2	OUDTSHOORN	198,2	163,9	148,2	102,7	76,0	61,6	68,1	86,1	112,4	144,9	177,5	200,3	1539,9	128,3	128,6	61,6	200,3
C70E1	PARYS	197,3	164,2	159,5	123,4	102,3	83,9	92,6	123,8	159,3	179,3	189,3	203,8	1778,8	148,2	159,4	83,9	203,8
C51H1	PETRUSVILLE	253,2	197,2	176,8	126,3	97,3	77,8	85,6	115,7	155,6	192,6	224,7	255,2	1958,0	163,2	166,2	77,8	255,2

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
D32F1	PHILIPSTOWN	243,9	186,2	170,7	117,8	89,9	68,7	78,2	107,9	148,7	181,3	213,9	246,3	1853,5	154,5	159,7	68,7	246,3
U10J1	PIETERMARITZBURG	157,2	138,6	136,4	109,5	93,5	79,7	86,2	104,9	121,5	132,1	142,3	178,7	1480,7	123,4	126,8	79,7	178,7
J34A3	PLETTENBERG BAY	169,1	144,4	125,1	92,2	71,2	57,1	61,8	77,3	98,3	121,4	144,8	168,6	1331,3	110,9	109,8	57,1	169,1
D53F1	POFADDER	279,1	231,7	205,9	142,6	107,6	76,5	84,3	116,0	158,8	202,7	244,5	274,6	2124,3	177,0	180,8	76,5	279,1
A71A1	POLOKWANE (PIETERSBURG)	173,6	151,6	153,5	125,8	110,7	95,7	96,9	122,4	149,3	164,5	167,6	175,7	1687,4	140,6	150,4	95,7	175,7
D41C3	POMFRET	258,6	211,6	195,7	151,3	124,0	100,7	113,4	149,6	187,3	221,5	243,9	261,8	2219,4	185,0	191,5	100,7	261,8
W31B1	PONGOLA	183,4	157,6	156,4	125,3	110,6	94,8	102,1	124,0	143,5	154,8	161,2	200,6	1714,4	142,9	149,1	94,8	200,6

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
P10G3	PORT ALFRED	147,0	120,2	118,9	92,6	79,6	67,1	71,7	83,5	95,1	111,4	124,9	165,5	1277,3	106,4	103,2	67,1	165,5
M10D1	PORT ELIZABETH	182,6	150,3	132,3	100,0	78,8	68,0	73,4	88,3	107,0	134,1	155,7	187,4	1458,0	121,5	119,7	68,0	187,4
T36B2	PORT St. JOHNS	166,4	143,7	136,1	104,2	90,8	83,1	88,9	101,7	111,3	127,6	142,8	180,5	1477,2	123,1	119,5	83,1	180,5
D71B3	POSTMASBURG	257,6	199,6	188,1	136,3	108,6	83,1	94,0	126,6	167,9	204,4	236,1	263,1	2065,6	172,1	178,0	83,1	263,1
A21B2	PRETORIA	195,4	168,0	162,8	126,5	108,2	92,0	97,8	126,7	161,5	181,1	184,1	193,7	1798,0	149,8	162,2	92,0	195,4
D33J1	PRIESKA	269,9	217,1	194,9	136,0	106,0	85,7	94,6	128,6	171,5	206,5	241,0	272,2	2124,0	177,0	183,2	85,7	272,2
J11A1	PRINCE ALBERT	215,6	172,3	152,1	102,2	79,3	61,9	67,8	85,8	116,4	149,2	183,4	214,8	1600,7	133,4	132,8	61,9	215,6
C60B1	REITZ	191	160	148	112	92,	75,	82,	110	140	162	176	195	1647,	137,	144,	75,5	195,8

Average evapotranspiration figures for each quinary.

QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
		,6	,0	,9	,0	2	5	8	,0	,1	,4	,3	,8	6	3	5		
C32D1	REIVILO	236,6	185,4	177,0	134,8	109,7	87,9	99,4	132,6	170,6	202,7	227,0	245,8	2009,7	167,5	173,8	87,9	245,8
W12F3	RICHARDS BAY	166,5	146,3	144,5	113,9	101,0	87,2	89,6	106,6	121,2	132,1	145,5	182,0	1536,4	128,0	126,7	87,2	182,0
D32A2	RICHMOND	224,0	177,5	155,4	108,6	80,6	61,8	70,2	97,4	132,1	160,6	192,7	222,4	1683,5	140,3	143,7	61,8	224,0
H70J3	RIVERSDALE	204,9	166,7	145,4	101,9	79,4	62,5	67,5	84,7	112,4	145,5	176,2	206,5	1553,6	129,5	128,9	62,5	206,5
E22A1	ROBERTSON	202,6	162,0	141,4	96,2	73,8	58,0	61,0	77,4	104,6	143,8	173,4	205,7	1499,9	125,0	123,0	58,0	205,7
A21K3	RUSTENBURG	192,0	160,7	157,1	123,2	105,7	87,8	93,6	123,5	159,7	180,5	189,2	196,1	1769,0	147,4	158,4	87,8	196,1
G10K1	SALDANHA	197,9	168,7	145,7	102,5	73,2	54,5	58,3	76,9	103,4	145,3	175,3	198,0	1499,6	125,0	124,3	54,5	198,0

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
C22G3	SASOLBURG	190,4	158,0	153,9	117,6	99,6	79,9	89,5	121,0	151,9	173,0	180,6	195,4	1710,9	142,6	152,9	79,9	195,4
C31F1	SCHWEIZER-RENEKE	229,7	179,7	173,3	133,3	110,0	86,1	96,8	130,7	168,1	198,1	221,2	239,3	1966,2	163,8	170,7	86,1	239,3
C12D1	SECUNDA	174,8	150,9	143,8	114,2	96,2	78,9	86,0	113,6	145,7	161,1	167,2	179,1	1611,6	134,3	144,7	78,9	179,1
C41A1	SENEKAL	207,1	167,4	155,1	115,5	93,5	76,8	84,6	112,9	147,8	171,9	187,9	214,1	1734,6	144,6	151,4	76,8	214,1
D41J2	SISHEN	249,9	199,0	186,6	136,3	109,3	84,6	95,3	129,6	172,9	207,5	234,6	257,3	2062,8	171,9	179,7	84,6	257,3
X24G1	SKUKUZA	200,0	177,8	177,2	148,1	132,5	122,5	122,9	143,6	166,1	180,0	191,4	203,8	1965,8	163,8	171,7	122,5	203,8
A31C2	SLURRY	194,3	162,6	160,3	127,6	107,7	90,0	98,5	130,9	166,7	190,6	200,0	207,8	1836,8	153,1	161,4	90,0	207,8
N22A3	SOMERSET	213	175	160	117	91,	75,	83,	105	135	159	184	226	1730,	144,	147,	75,5	226,3

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
	EAST	,8	,9	,1	,8	4	5	9	,6	,8	,2	,8	,3	1	2	5		
D82C3	SPRINGBOK	238,5	203,8	181,0	127,8	93,8	69,6	74,3	100,1	134,9	175,3	208,6	233,6	1841,2	153,4	155,1	69,6	238,5
B20A1	SPRINGS	173,5	150,4	144,8	117,7	99,4	82,8	89,8	117,1	147,1	161,3	167,2	173,1	1624,4	135,4	145,9	82,8	173,5
C11M1	STANDERTON	186,9	161,5	152,4	118,4	98,0	81,0	88,5	116,6	152,0	168,7	176,4	193,8	1694,1	141,2	152,2	81,0	193,8
G10A1	STELLENBOSCH	188,5	156,8	134,7	90,9	62,3	48,2	51,3	66,2	88,5	128,6	159,8	185,8	1361,5	113,5	109,7	48,2	188,5
A22A3	SUN CITY	212,4	180,0	174,3	136,2	116,8	99,2	105,6	136,1	174,6	197,6	205,9	214,1	1952,8	162,7	174,5	99,2	214,1
G50K1	SWELLENDAM	206,3	168,0	146,4	102,2	77,4	59,9	63,8	81,9	110,6	147,4	177,9	209,1	1550,8	129,2	128,5	59,9	209,1
C41C3	THABA-NCHU	217,2	169,3	155,5	112,9	89,4	72,9	80,2	108,5	146,3	173,2	194,1	221,8	1741,3	145,1	150,9	72,9	221,8

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
A80A1	THOHOYANDOU	182,3	160,6	164,4	138,8	127,1	112,5	109,3	133,6	160,3	172,4	182,7	190,6	1834,4	152,9	160,4	109,3	190,6
C11J1	TUTUKA	177,0	153,8	147,1	111,5	93,5	77,5	85,4	113,5	145,8	162,4	164,5	186,1	1618,0	134,8	146,5	77,5	186,1
B52E1	TZANEEN	160,3	141,0	140,6	117,9	108,7	97,2	95,6	118,3	140,7	152,2	157,8	167,0	1597,2	133,1	140,7	95,6	167,0
K80F1	UITENHAGE	189,5	157,1	139,9	105,5	83,2	70,3	76,0	91,8	113,6	141,6	165,1	194,9	1528,5	127,4	126,7	70,3	194,9
V40A1	ULUNDI	165,6	142,1	142,4	114,0	101,6	84,5	90,3	111,0	128,6	137,9	145,1	184,6	1547,7	129,0	133,3	84,5	184,6
D73D2	UPINGTON	281,6	232,5	212,4	154,9	120,9	95,6	104,8	139,4	183,0	222,9	258,2	285,6	2291,8	191,0	197,7	95,6	285,6
V31A1	UTRECHT	174,4	145,5	146,7	113,3	93,3	79,9	86,8	109,8	136,6	151,5	157,5	194,5	1590,0	132,5	141,0	79,9	194,5
C22F2	VANDERBIJLPA	184	153	151	115	97,	79,	88,	118	151	170	177	189	1676,	139,	151,	79,2	189,5

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
	RK	,4	,8	,3	,5	8	2	0	,5	,1	,5	,1	,5	9	7	2		
C12L2	VEREENIGING	184,9	155,9	150,5	117,2	99,0	81,8	91,1	120,8	151,8	170,4	176,6	188,9	1689,1	140,8	151,2	81,8	188,9
D61C2	VICTORIA WEST	248,1	196,1	169,3	115,4	83,7	66,7	74,4	101,4	140,3	176,0	212,3	243,7	1827,3	152,3	154,8	66,7	248,1
C11C1	VOLKSRUST	169,5	143,8	141,7	108,2	89,2	74,3	81,5	105,3	135,1	150,2	155,1	188,9	1543,0	128,6	138,4	74,3	188,9
C13E1	VREDE	185,7	159,0	149,9	113,6	91,3	73,4	79,9	106,8	140,2	160,3	172,1	197,7	1629,8	135,8	145,1	73,4	197,7
E21K1	VREDENDAL	218,1	188,5	161,9	115,5	85,6	65,1	67,8	88,9	117,4	159,9	191,9	214,9	1675,5	139,6	138,7	65,1	218,1
C32A2	VRYBURG	238,7	189,7	181,1	140,5	114,9	93,7	104,9	138,9	176,5	209,2	230,7	248,2	2067,1	172,3	178,8	93,7	248,2
V32G3	VRYHEID	169,3	144,1	144,4	113,5	98,0	82,9	90,3	113,1	135,4	145,5	152,4	188,6	1577,4	131,5	139,8	82,9	188,6

Average evapotranspiration figures for each quinary.																	
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
C41E1	WELKOM	216,3	174,1	162,4	120,3	98,2	80,0	88,8	119,5	157,4	184,4	203,0	225,4	1829,8	152,5	159,9	80,0	225,4
C41J3	WESSELSBRON	226,8	183,2	171,1	129,2	105,4	87,6	96,3	127,8	165,6	194,8	215,4	238,1	1941,4	161,8	168,3	87,6	238,1
D51A1	WILLISTON	249,2	202,8	172,4	115,0	82,4	58,1	65,4	92,6	130,2	169,4	207,8	240,7	1786,0	148,8	149,8	58,1	249,2
J31A1	WILLOWMORE	202,4	169,0	145,9	103,1	77,7	61,7	67,9	86,6	113,6	144,7	176,8	206,7	1556,1	129,7	129,2	61,7	206,7
E21A1	WORCESTER	187,6	153,2	132,1	88,4	67,0	51,0	53,0	68,2	93,3	130,7	158,1	188,0	1370,4	114,2	112,0	51,0	188,0
A10A1	ZEERUST	209,6	175,0	171,8	136,0	115,2	96,9	104,1	135,3	171,8	198,9	207,1	215,7	1937,3	161,4	171,8	96,9	215,7
Average all towns														1707,94	142,33	148,03	80,26	206,38
Average for Summer														1720.	143.	149.	82.3	205.8

Average evapotranspiration figures for each quinary.																		
QUINARY	TOWN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 12 months	Mean for 12 months	Median for 12 months	Lowest Eto for this quinary	Highest Eto for this quinary
rainfall towns														39	37	75	9	5
Average for Winter rainfall towns														1587.59	132.30	131.39	59.68	211.57

Annexure 7: Average rainfall data for the summer rainfall region for each of the level 1 or 2 towns selected in South Africa.

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
ABERDEEN	33.8	37.8	31.5	28.1	10.0	11.0	8.6	10.3	14.4	29.5	35.9	41.5	292.4	24.4	8.6	41.5	Summer
ALIWAL NORTH	78.7	73.4	78.4	43.3	19.8	16.4	8.7	18.5	20.7	50.2	74.9	59.3	542.3	45.2	8.7	78.7	Summer
ARNOT	122.0	89.0	80.0	46.0	17.0	8.0	6.0	10.0	28.0	84.0	124.0	131.0	745.0	62.1	6.0	131.0	Summer
BA-PHALABORWA (PHALABORWA)	72.8	82.5	44.6	31.5	10.6	4.2	5.8	0.1	5.2	30.4	75.7	53.1	416.5	34.7	0.1	82.5	Summer
BAPSFONTEIN	143.0	95.0	84.0	39.0	12.0	8.0	8.0	8.0	24.0	73.0	114.0	105.0	713.0	59.4	8.0	143.0	Summer
BARBERTON	145.7	187.9	134.3	76.3	23.2	9.1	6.9	12.4	22.8	77.1	159.0	149.4	1004.1	83.7	6.9	187.9	Summer
BEAUFORT	23.	25.	40.	28.	14.	7.8	8.2	19.	9.2	17.	25.	33.	253.8	21.2	7.8	40.7	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
WEST	8	4	7	3	9			2		4	2	7					er
BELA-BELA (WARMBATHS)	111.5	81.9	83.3	30.5	12.3	6.4	2.3	5.3	9.7	59.5	88.1	130.8	621.6	51.8	2.3	130.8	Summer
BETHAL	147.2	100.1	86.0	38.3	17.0	10.6	3.0	10.1	16.2	82.3	110.3	133.1	754.2	62.9	3.0	147.2	Summer
BETHLEHEM	115.0	100.1	80.8	45.3	17.3	11.9	6.0	21.0	24.5	83.9	99.9	110.4	716.1	59.7	6.0	115.0	Summer
BHISHO	60.5	71.0	55.5	43.0	18.5	20.9	15.8	33.3	40.4	64.9	77.4	63.0	564.2	47.0	15.8	77.4	Summer
BIZANA	174.4	150.5	139.8	67.4	26.5	39.7	20.6	50.3	87.0	125.0	149.5	208.4	1239.1	103.3	20.6	208.4	Summer
BLOEMFONTEIN	99.1	78.6	80.0	38.1	21.8	9.0	4.3	12.3	12.1	50.4	76.5	69.5	551.7	46.0	4.3	99.1	Summer
BLOEMHOF	93.2	69.9	68.1	39.8	24.2	5.7	3.1	7.5	9.4	42.3	60.4	96.5	520.1	43.3	3.1	96.5	Summer
BOTHAVILLE	93.	70.	74.	51.	17.	5.2	3.4	10.	15.	77.	80.	89.	590.3	49.2	3.4	93.7	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
	7	6	7	1	9			4	3	8	8	4					er
BRAKPAN	119.7	110.5	109.7	30.9	16.9	9.6	1.3	10.8	21.2	91.3	102.9	129.3	754.1	62.8	1.3	129.3	Summer
BRANDVLEI	8.1	14.4	18.0	16.3	5.1	5.4	6.8	5.2	4.2	7.7	10.1	13.0	114.3	9.5	4.2	18.0	Summer
BRITS	92.1	79.2	66.4	32.3	14.1	3.4	1.2	3.3	13.6	54.2	74.2	89.1	523.1	43.6	1.2	92.1	Summer
BULTFONTEIN	104.2	63.5	74.6	35.5	23.4	5.5	3.3	10.5	12.1	50.1	59.6	60.9	503.2	41.9	3.3	104.2	Summer
CARNARVON	18.3	26.4	43.2	27.3	12.0	8.3	6.2	6.3	11.3	12.7	17.0	21.8	210.8	17.6	6.2	43.2	Summer
CAROLINA	130.8	85.6	77.9	29.5	8.1	6.7	5.8	9.8	27.5	83.4	111.6	129.1	705.8	58.8	5.8	130.8	Summer
COLESBERG	59.6	104.2	30.4	33.7	15.6	18.6	6.4	15.7	14.6	38.2	27.1	41.1	405.2	33.8	6.4	104.2	Summer
CRADOCK	49.	55.	39.	30.	10.	9.8	6.4	9.9	17.	28.	49.	45.	351.7	29.3	6.4	55.2	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
	2	2	7	1	5				4	7	8	0					er
DE AAR	45.0	46.8	45.3	32.2	17.0	11.8	7.5	9.5	13.4	15.4	30.9	36.3	311.1	25.9	7.5	46.8	Summer
DELAREYVILLE	88.5	99.5	69.8	36.8	14.7	7.9	2.8	6.9	18.3	53.7	63.5	119.0	581.4	48.5	2.8	119.0	Summer
DUNDEE	142.6	96.7	92.1	33.2	16.2	9.2	6.4	17.6	27.9	89.6	110.5	124.3	766.3	63.9	6.4	142.6	Summer
DURBAN	115.9	117.9	73.0	47.4	37.0	16.1	27.8	24.1	57.0	91.8	97.8	134.2	840.0	70.0	16.1	134.2	Summer
DUTYWA (IDUTYWA)	106.5	107.9	93.1	54.3	23.0	28.0	17.0	32.9	47.8	92.4	106.7	103.5	813.1	67.8	17.0	107.9	Summer
DWAALBOOM	95.8	78.5	68.5	17.0	7.4	1.4	1.2	1.9	9.5	34.4	71.4	86.3	473.3	39.4	1.2	95.8	Summer
EAST LONDON	112.1	71.0	98.1	83.6	43.1	28.3	32.9	70.5	63.3	83.8	106.2	80.7	873.6	72.8	28.3	112.1	Summer
eMALAHLENI	138	106	86.	29.	12.	11.	4.1	9.1	20.	79.	115	127	742.8	61.9	4.1	138.9	Summ

SUMMER RAINFALL TOWNS ONLY																		
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
(WITBANK)	.9	.7	9	8	7	0			7	5	.6	.8					er
emKHONDO (PIET RETIEF)	166.2	105.4	93.9	41.0	13.8	13.9	10.5	19.5	28.8	97.5	136.6	162.7	889.8	74.2	10.5	166.2	Summer
EMPANGENI	147.1	137.9	107.7	59.4	55.9	51.1	40.5	45.0	84.2	114.1	122.8	91.2	1056.9	88.1	40.5	147.1	Summer
ERMELO	141.0	84.1	72.9	36.0	11.5	9.2	4.3	10.9	15.4	86.5	99.0	144.9	715.7	59.6	4.3	144.9	Summer
ESHOWE	194.2	173.1	92.2	77.6	27.6	19.7	21.1	39.1	79.8	144.9	163.6	111.0	1143.9	95.3	19.7	194.2	Summer
ESTCOURT	135.3	104.9	81.8	39.9	13.7	11.2	8.3	20.8	26.5	77.7	99.4	136.1	755.6	63.0	8.3	136.1	Summer
FICKSBURG	113.9	95.0	96.1	49.1	21.8	13.8	3.8	24.1	22.1	78.1	90.6	106.5	714.9	59.6	3.8	113.9	Summer
FORT BEAUFORT	60.9	64.3	57.0	47.1	15.4	14.7	14.3	23.0	29.0	54.0	67.6	70.6	517.9	43.2	14.3	70.6	Summer
GA-NALA	136	102	100	44.	16.	12.	1.6	9.2	26.	97.	153	152	853.2	71.1	1.6	153.4	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
(KRIEL)	.1	.8	.7	4	2	1			1	9	.4	.7					er
GEORGE	56.8	51.6	75.7	60.9	41.0	35.6	38.3	70.9	44.8	79.7	93.2	65.9	714.4	59.5	35.6	93.2	Summer
GERMISTON	128.0	91.5	82.0	45.5	16.0	6.5	4.0	7.0	22.5	78.0	113.5	127.5	722.0	60.2	4.0	128.0	Summer
GIYANI	91.0	88.5	56.5	21.5	12.0	4.5	7.0	7.0	17.5	33.0	63.5	59.5	461.5	38.5	4.5	91.0	Summer
GRAAF-REINET	49.4	43.5	38.5	26.6	10.2	8.6	8.7	15.8	15.3	18.7	38.9	35.1	309.3	25.8	8.6	49.4	Summer
GRAHAMSTOWN	59.6	66.1	75.6	58.7	24.7	30.7	28.7	49.9	56.5	85.0	94.6	77.6	707.7	59.0	24.7	94.6	Summer
GRAVELOTTE	57.5	47.0	47.0	34.5	40.0	40.0	36.0	39.5	40.0	47.0	60.0	68.0	556.5	46.4	34.5	68.0	Summer
GROBLERSDAL	93.0	81.4	68.6	24.3	11.3	4.7	2.7	5.4	13.5	60.3	86.8	102.0	554.0	46.2	2.7	102.0	Summer
HARDING	127	107	88.	42.	20.	25.	19.	26.	55.	88.	102	134	839.3	69.9	19.3	134.1	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
	.3	.8	1	7	1	8	3	7	8	7	.9	.1					er
HARRISMITH	113.1	78.9	67.1	33.0	11.8	8.3	2.3	18.5	21.7	70.1	87.7	96.8	609.3	50.8	2.3	113.1	Summer
HEIDELBERG	112.6	104.1	82.6	34.5	15.6	8.1	1.2	5.8	20.1	74.0	86.8	101.3	646.7	53.9	1.2	112.6	Summer
HEILBRON	125.6	80.6	94.6	34.4	17.2	9.9	3.7	15.0	19.1	82.3	87.5	102.1	672.0	56.0	3.7	125.6	Summer
HENDRINAKRAG	137.4	84.8	85.3	28.3	12.3	7.7	4.1	11.4	20.3	98.5	113.5	147.5	751.1	62.6	4.1	147.5	Summer
HLUHLUWE	111.9	117.6	106.8	54.0	42.0	36.9	20.7	31.5	50.7	106.3	103.2	86.1	867.7	72.3	20.7	117.6	Summer
HOEDSPRUIT	155.5	100.0	89.5	35.0	13.5	6.0	6.0	7.0	13.5	44.5	86.5	136.5	693.5	57.8	6.0	155.5	Summer
HOOPSTAD	93.9	84.5	76.9	43.5	17.5	6.6	3.7	10.3	15.4	46.2	58.8	85.2	542.5	45.2	3.7	93.9	Summer
HOWICK	131	110	105	45.	19.	14.	15.	25.	50.	89.	113	129	850.2	70.9	14.9	131.5	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
	.5	.9	.4	4	1	9	4	4	4	3	.1	.4					er
INDWE	92.0	91.7	85.2	44.2	12.1	13.0	12.4	19.9	30.0	51.7	71.0	78.8	602.0	50.2	12.1	92.0	Summer
JOHANNESBURG	105.8	95.7	89.2	44.4	16.2	11.5	10.5	18.5	31.9	62.4	81.0	97.8	664.9	55.4	10.5	105.8	Summer
KEI MOUTH	120.3	86.8	106.9	79.5	29.9	24.6	36.9	57.2	67.6	109.8	131.5	82.7	933.7	77.8	24.6	131.5	Summer
KEMPTON PARK	145.4	119.2	102.7	40.5	23.0	8.9	1.4	6.9	15.7	72.3	98.3	126.2	760.5	63.4	1.4	145.4	Summer
KENHARDT	17.5	26.2	22.4	11.0	9.2	6.8	2.3	3.5	5.4	9.5	9.5	17.3	140.6	11.7	2.3	26.2	Summer
KIMBERLEY	74.1	66.0	62.7	36.8	16.6	5.4	3.2	5.2	13.6	32.4	45.9	55.9	417.8	34.8	3.2	74.1	Summer
KLERKSDORP	100.4	71.6	80.5	41.8	14.7	6.2	1.4	6.9	12.6	67.2	68.5	100.3	572.1	47.7	1.4	100.4	Summer
KOMANI	87.	83.	66.	42.	13.	12.	10.	15.	22.	50.	68.	70.	542.9	45.2	10.3	87.0	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
(QUEENSTOWN)	0	0	4	2	2	7	3	9	0	4	9	9					er
KOMATI	83.5	49.3	49.1	33.3	7.6	5.5	6.3	7.1	11.6	31.9	26.9	83.6	395.7	33.0	5.5	83.6	Summer
KOMATIPOORT	83.5	49.3	49.1	33.3	7.6	5.5	6.3	7.1	11.6	31.9	26.9	83.6	395.7	33.0	5.5	83.6	Summer
KOMGA	102.3	91.1	85.0	44.7	18.7	23.4	23.8	31.0	52.1	89.4	105.3	94.9	761.7	63.5	18.7	105.3	Summer
KROONSTAD	88.2	71.6	65.8	36.8	23.7	6.5	3.6	9.6	7.9	42.5	65.4	89.7	511.3	42.6	3.6	89.7	Summer
KRUGERSDORP	126.1	97.1	91.6	38.0	12.2	6.7	2.6	7.2	17.3	63.4	92.2	119.3	673.7	56.1	2.6	126.1	Summer
KURUMAN	60.8	52.6	45.2	34.6	13.1	6.4	1.1	3.6	8.3	26.9	33.9	57.5	344.0	28.7	1.1	60.8	Summer
LADYBRAND	104.6	92.3	83.7	51.2	22.4	14.9	7.3	23.1	21.5	69.0	86.8	89.1	665.9	55.5	7.3	104.6	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
LADYSMITH	144.6	93.5	91.8	30.0	15.7	9.4	9.2	13.6	24.8	65.1	87.3	119.4	704.4	58.7	9.2	144.6	Summer
LIME ACRES	59.3	66.7	63.7	32.7	13.4	9.6	2.6	3.5	10.0	22.1	29.8	49.2	362.6	30.2	2.6	66.7	Summer
LUSIKISIKI	107.4	96.7	110.9	62.9	42.3	68.1	31.5	35.7	75.1	75.7	144.4	121.5	972.2	81.0	31.5	144.4	Summer
MAHIKENG (MMABATHO)	109.0	81.3	73.8	50.8	15.5	5.0	2.3	5.0	13.5	44.3	67.3	83.0	550.5	45.9	2.3	109.0	Summer
MAKHADO (LOUIS TRICHARDT)	119.4	138.0	94.7	34.0	13.4	14.2	13.8	7.6	16.8	48.9	92.2	101.8	694.8	57.9	7.6	138.0	Summer
MALALANE (MALELANE)	98.2	91.9	76.0	51.3	11.1	6.3	7.3	8.1	15.0	46.1	94.1	84.1	589.5	49.1	6.3	98.2	Summer
MARBLE HALL	95.8	73.6	69.6	22.2	10.0	5.9	2.2	3.2	11.5	61.5	94.9	114.4	564.8	47.1	2.2	114.4	Summer
MARGATE	143	131	163	74.	43.	51.	39.	50.	107	157	171	160	1294.	107.8	39.7	171.4	Summ

SUMMER RAINFALL TOWNS ONLY																
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
	.7	.6	.3	6	3	2	7	1	.8	.0	.4	.4	1				er
MASHISHING (LYDENBURG)	180.1	157.9	101.0	53.8	13.6	10.9	9.7	10.7	30.6	94.2	139.0	152.8	954.3	79.5	9.7	180.1	Summer
MBOMBELA (NELSPRUIT)	129.4	129.8	114.5	58.6	14.4	5.6	8.6	9.8	17.7	57.9	103.5	123.3	773.1	64.4	5.6	129.8	Summer
MIDDELBURG (Cape)	53.4	59.0	57.1	26.7	11.1	9.5	6.1	9.9	10.8	32.6	34.7	43.9	354.8	29.6	6.1	59.0	Summer
MIDDELBURG (Mpumalanga)	128.0	94.2	73.7	41.2	12.4	8.0	3.4	9.3	18.6	82.3	115.2	138.2	724.5	60.4	3.4	138.2	Summer
MKUZE	88.0	92.8	78.1	41.8	29.4	19.4	9.6	19.5	24.3	71.6	102.5	92.7	669.7	55.8	9.6	102.5	Summer
MODIMOLLE (NYLSTROOM)	112.6	102.4	81.5	40.7	10.6	5.4	1.8	2.4	12.2	51.6	100.1	134.4	655.7	54.6	1.8	134.4	Summer
MOGWADI (DENDRON)	57.7	43.2	46.4	29.4	6.8	10.0	0.7	0.0	3.0	36.8	80.7	79.9	394.6	32.9	0.0	80.7	Summer
MOKOPANE	71.	70.	35.	19.	9.9	3.7	1.7	0.9	4.6	38.	96.	79.	433.5	36.1	0.9	96.8	Summ

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
(POTGIETERSRUS)	9	5	6	7						4	8	8					er
MOSSELBAAI	35.3	37.8	51.1	60.2	32.6	27.0	36.2	52.8	29.5	66.4	52.8	49.1	530.8	44.2	27.0	66.4	Summer
MTHATHA (UMTATA)	101.6	71.7	93.7	45.7	17.5	16.2	14.8	22.6	38.2	66.4	97.7	91.6	677.7	56.5	14.8	101.6	Summer
MUSINA (MESSINA)	65.7	63.3	41.4	16.0	5.8	5.2	3.6	0.4	10.7	17.2	57.4	57.3	344.0	28.7	0.4	65.7	Summer
NEWCASTLE	197.4	151.7	92.6	47.2	13.1	11.0	7.9	18.1	33.9	93.8	114.1	133.2	914.0	76.2	7.9	197.4	Summer
OLIFANTSHOEK	62.8	74.5	59.9	40.2	15.7	6.9	2.0	3.6	7.5	22.2	32.1	45.6	373.0	31.1	2.0	74.5	Summer
OUDTSHOORN	17.3	18.9	21.7	24.2	23.7	14.2	22.0	22.9	11.0	24.5	28.9	23.1	252.4	21.0	11.0	28.9	Summer
PARYS	114.8	75.7	71.3	36.3	18.5	8.8	3.0	11.1	20.7	73.6	84.0	109.9	627.7	52.3	3.0	114.8	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
PETRUSVILLE	32.9	55.7	47.1	33.2	13.7	9.8	5.9	10.0	14.9	35.8	30.6	39.5	329.1	27.4	5.9	55.7	Summer
PHILIPSTOWN	39.6	54.5	45.1	29.9	15.6	12.9	6.5	13.7	15.7	29.0	32.4	39.8	334.7	27.9	6.5	54.5	Summer
PIETERMARITZBURG	136.5	100.9	104.6	53.0	26.2	17.7	19.9	21.2	41.0	87.3	107.1	168.4	883.8	73.7	17.7	168.4	Summer
PLETTENBERG BAY	44.5	33.8	51.1	63.0	52.7	52.3	62.2	79.7	67.1	60.8	76.7	65.2	709.1	59.1	33.8	79.7	Summer
POFADDER	8.0	20.4	18.9	21.8	7.2	5.2	5.5	3.7	4.8	7.8	6.7	9.2	119.2	9.9	3.7	21.8	Summer
POLOKWANE (PIETERSBURG)	88.2	68.2	53.6	26.7	13.9	6.9	2.5	2.9	8.2	34.4	80.3	61.7	447.5	37.3	2.5	88.2	Summer
POMFRET	173.5	74.4	62.4	28.1	22.3	28.3	1.1	0.5	28.7	54.7	54.4	51.3	579.7	48.3	0.5	173.5	Summer
PONGOLA	67.0	69.4	52.6	26.7	13.0	9.0	6.6	9.8	15.6	57.4	86.9	94.6	508.6	42.4	6.6	94.6	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
PORT ALFRED	46.2	39.3	66.6	44.6	40.3	46.7	38.0	61.9	48.3	74.2	59.0	49.8	614.9	51.2	38.0	74.2	Summer
PORT ELIZABETH	42.6	36.2	48.5	47.2	50.8	47.4	41.0	75.9	47.0	49.8	58.6	50.8	595.8	49.7	36.2	75.9	Summer
PORT St. JOHNS	140.8	124.5	147.6	99.1	42.1	43.5	42.1	54.0	93.3	135.4	146.5	129.6	1198.5	99.9	42.1	147.6	Summer
POSTMASBURG	50.4	65.9	51.8	32.0	11.3	9.8	2.6	4.5	9.2	21.6	28.0	39.1	326.2	27.2	2.6	65.9	Summer
PRETORIA	120.7	94.8	83.3	34.2	15.0	8.8	2.8	5.1	15.9	63.9	88.3	114.4	647.2	53.9	2.8	120.7	Summer
PRIESKA	36.1	36.0	33.7	22.6	12.6	7.3	3.6	3.8	9.1	10.4	20.3	26.3	221.8	18.5	3.6	36.1	Summer
PRINCE ALBERT	13.8	14.4	25.5	24.5	20.0	12.2	11.1	11.7	7.9	14.6	21.4	17.1	194.2	16.2	7.9	25.5	Summer
REITZ	116.6	99.8	78.8	33.5	18.8	10.4	3.3	20.1	23.2	77.6	89.9	100.1	672.1	56.0	3.3	116.6	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
REIVILO	123.3	75.8	69.3	22.4	23.8	13.0	0.0	11.9	11.9	37.3	51.1	71.9	511.7	42.6	0.0	123.3	Summer
RICHARDS BAY	127.6	144.1	100.3	116.8	62.2	98.6	80.6	60.0	75.8	102.4	121.1	66.6	1156.1	96.3	60.0	144.1	Summer
RICHMOND	46.7	49.4	48.5	34.5	18.1	16.8	9.0	12.0	14.0	21.5	33.0	36.8	340.3	28.4	9.0	49.4	Summer
RIVERSDALE	9.6	30.1	15.9	25.1	32.0	42.8	34.6	19.8	15.1	57.0	92.5	28.9	403.4	33.6	9.6	92.5	Summer
RUSTENBURG	113.8	93.2	71.5	34.5	20.1	3.0	1.1	4.0	10.2	59.2	80.6	99.3	590.5	49.2	1.1	113.8	Summer
SASOLBURG	109.5	71.1	82.1	34.6	15.1	7.6	1.6	11.8	20.0	69.9	85.2	105.8	614.3	51.2	1.6	109.5	Summer
SCHWEIZER-RENEKE	81.0	69.0	69.0	35.0	14.9	5.4	3.1	6.6	14.9	44.2	55.9	69.9	468.9	39.1	3.1	81.0	Summer
SECUNDA	154.3	97.2	88.2	33.1	11.0	8.8	1.5	7.6	22.2	88.1	115.3	145.2	772.5	64.4	1.5	154.3	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
SENEKAL	116.2	83.8	87.1	46.0	20.4	10.2	5.9	17.4	18.9	72.7	92.7	90.1	661.4	55.1	5.9	116.2	Summer
SISHEN	68.9	58.5	42.8	33.5	22.8	6.1	1.5	4.0	6.8	31.0	37.4	42.1	355.4	29.6	1.5	68.9	Summer
SKUKUZA	101.3	91.7	69.8	43.4	11.4	7.0	7.6	8.3	15.4	36.3	94.4	102.3	588.9	49.1	7.0	102.3	Summer
SLURRY	110.3	76.9	73.2	35.2	18.5	5.2	2.3	3.8	10.8	52.3	63.9	100.9	553.3	46.1	2.3	110.3	Summer
SOMERSET EAST	44.4	44.9	44.2	39.5	10.6	13.5	15.1	20.7	21.9	32.9	42.3	35.1	365.1	30.4	10.6	44.9	Summer
SPRINGS	81.4	77.6	59.7	25.8	17.6	6.6	1.1	5.5	5.7	47.0	84.8	88.9	501.7	41.8	1.1	88.9	Summer
STANDERTON	88.3	63.2	69.4	22.2	6.6	6.8	3.6	8.4	20.7	89.6	97.1	81.6	557.5	46.5	3.6	97.1	Summer
SUN CITY	101.2	96.3	89.1	34.1	14.7	6.3	2.0	5.0	11.6	60.1	83.4	105.6	609.4	50.8	2.0	105.6	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
THABA-NCHU	111.4	119.9	84.7	56.3	25.0	14.2	8.5	17.5	22.5	68.7	92.5	83.6	704.8	58.7	8.5	119.9	Summer
THOHOYANDOU	123.2	159.6	100.7	60.0	8.7	11.0	11.2	4.0	19.7	50.3	103.2	134.0	785.6	65.5	4.0	159.6	Summer
TUTUKA	119.5	82.5	73.0	39.8	10.8	8.3	5.8	9.8	23.3	88.3	105.3	104.3	670.3	55.9	5.8	119.5	Summer
TZANEEN	160.4	125.6	72.6	89.2	12.9	16.7	20.2	9.4	20.8	56.2	190.6	205.0	979.6	81.6	9.4	205.0	Summer
UITENHAGE	51.5	35.0	51.6	53.5	21.2	18.8	17.5	41.6	28.7	38.0	42.8	57.0	457.2	38.1	17.5	57.0	Summer
ULUNDI	85.9	76.9	45.7	29.7	13.2	17.9	18.0	12.1	24.6	65.8	99.7	96.3	585.8	48.8	12.1	99.7	Summer
UPINGTON	30.6	29.3	35.5	13.7	8.1	4.8	3.3	1.6	4.2	15.1	20.4	20.1	186.7	15.6	1.6	35.5	Summer
UTRECHT	123.9	84.5	75.6	35.7	13.8	11.4	9.2	19.4	27.2	74.9	92.9	103.9	672.4	56.0	9.2	123.9	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
VANDERBIJLPARK	121.4	90.3	82.4	42.2	16.5	7.8	6.4	12.6	23.4	86.5	96.5	124.2	710.2	59.2	6.4	124.2	Summer
VEREENIGING	120.3	81.5	81.7	32.3	17.1	4.4	1.3	7.3	18.3	60.4	93.4	126.8	644.8	53.7	1.3	126.8	Summer
VICTORIA WEST	36.4	42.6	45.6	27.2	14.1	9.4	5.3	7.4	8.9	16.6	24.8	27.5	265.8	22.2	5.3	45.6	Summer
VOLKSRUST	139.2	106.4	79.4	30.1	12.8	10.3	5.0	15.1	24.0	94.8	107.2	124.2	748.5	62.4	5.0	139.2	Summer
VREDE	92.2	60.9	60.5	21.2	17.6	5.9	2.6	9.5	17.6	59.6	75.2	86.0	508.8	42.4	2.6	92.2	Summer
VRYBURG	94.0	90.2	66.1	36.9	17.6	6.7	1.5	4.5	16.1	38.4	52.1	61.1	485.2	40.4	1.5	94.0	Summer
VRYHEID	80.4	55.5	58.3	28.5	7.9	7.7	6.4	16.7	16.6	65.8	77.8	87.5	509.1	42.4	6.4	87.5	Summer
WELKOM	75.0	39.7	57.3	31.4	18.8	4.3	5.6	8.7	8.2	38.4	63.2	77.4	428.0	35.7	4.3	77.4	Summer

SUMMER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
WESSELSBRON	74.4	63.1	76.1	40.6	21.4	6.8	5.6	11.1	15.9	63.5	77.8	80.3	536.6	44.7	5.6	80.3	Summer
WILLISTON	11.2	22.0	30.9	22.1	11.5	8.8	7.6	7.4	7.9	11.9	12.6	17.5	171.4	14.3	7.4	30.9	Summer
WILLOWMORE	25.8	33.6	34.6	30.3	16.4	12.5	11.3	15.5	9.7	20.4	31.7	32.7	274.5	22.9	9.7	34.6	Summer
ZEERUST	98.0	88.6	82.5	32.8	15.5	9.5	0.7	5.7	9.6	51.9	73.5	94.4	562.7	46.9	0.7	98.0	Summer
Average													**598.3**				

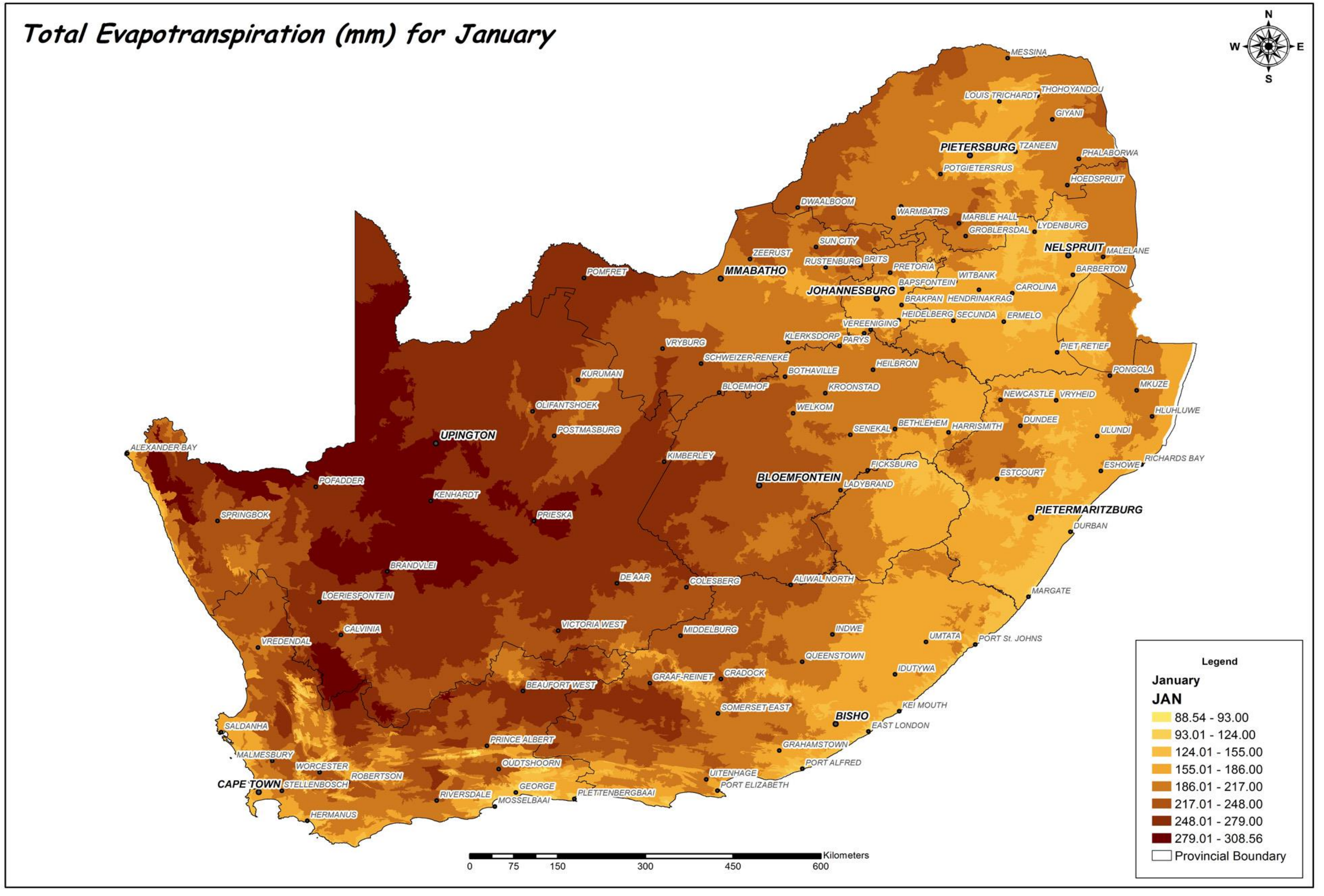
Annexure 8: Average rainfall data for the winter rainfall region for each of the level 1 or 2 towns selected in South Africa.

WINTER RAINFALL TOWNS ONLY																	
TOWN	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**	**MEAN ANNUAL**	**LOWEST RAINFALL FOR THIS TOWN**	**HIGHEST RAINFALL FOR THIS TOWN**	
ALEXANDER BAY	0.9	1.6	1.1	5.2	4.2	4.4	6.1	4.6	3.4	2.5	2.0	0.6	36.6	3.1	0.6	6.1	Winter
BREDASDORP	28.3	24.3	35.7	65.5	44.2	41.0	54.0	47.2	34.9	45.9	27.2	17.4	465.6	38.8	17.4	65.5	Winter
CALVINIA	6.7	15.7	18.0	26.1	20.8	22.7	27.3	19.9	15.0	11.8	11.5	12.2	207.7	17.3	6.7	27.3	Winter
CAPE TOWN	10.1	9.6	10.1	44.2	71.9	90.4	88.7	77.9	45.8	32.8	26.7	14.5	522.7	43.6	9.6	90.4	Winter
HERMANUS	27.2	34.9	36.2	68.9	64.4	84.4	93.5	83.2	55.2	56.6	38.7	30.6	673.8	56.2	27.2	93.5	Winter
KLEINSEE	1.6	3.3	1.8	12.0	12.0	16.1	13.7	8.8	6.1	7.5	4.3	3.1	90.3	7.5	1.6	16.1	Winter
LOERIESFO	4.6	11.5	18.6	26.3	28.7	31.4	31.0	23.0	16.6	15.0	11.1	11.9	229.	19.1	4.6	31.4	Wint

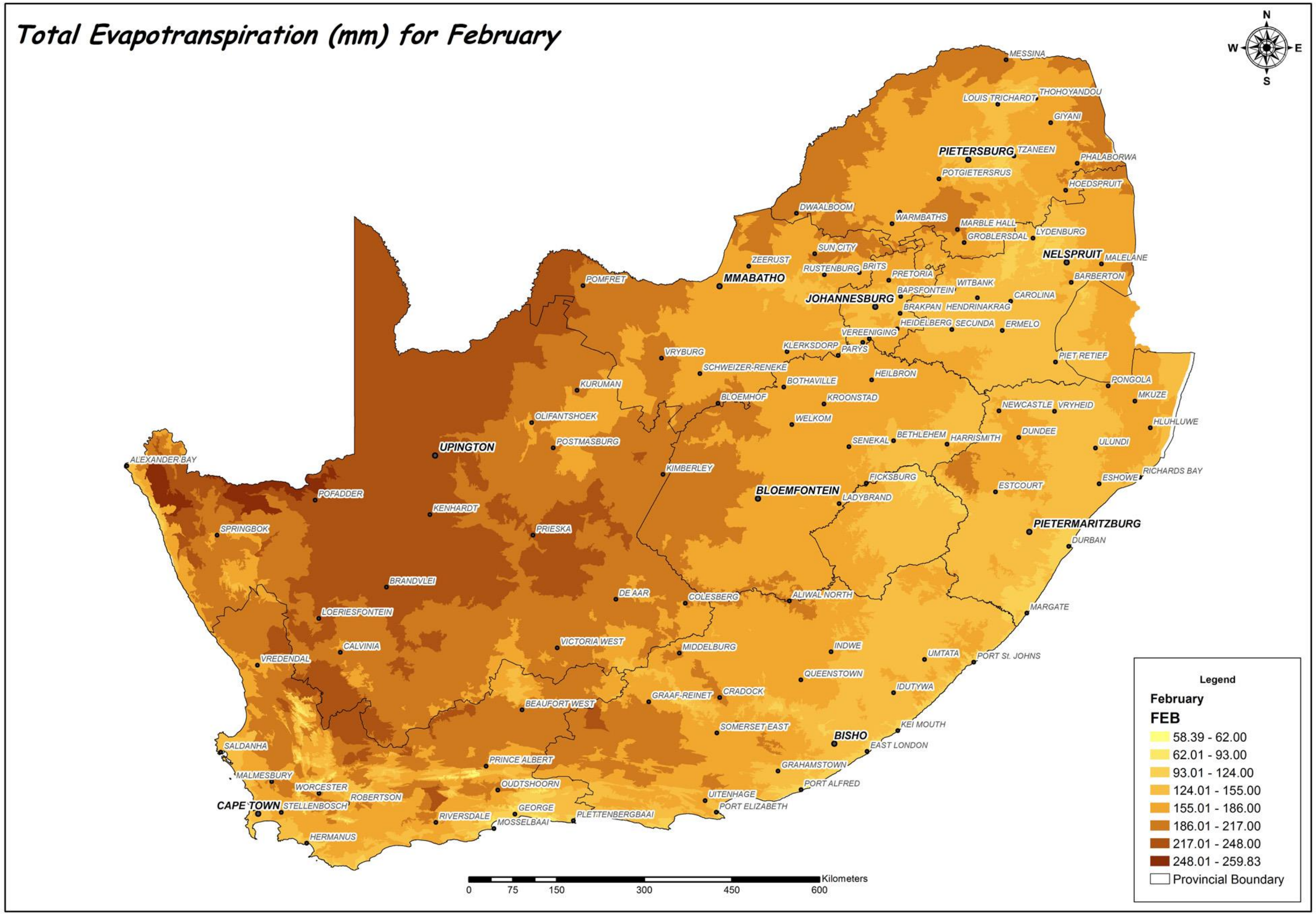
NTEIN												7				er
MALMESBU RY	6.6	6.5	6.6	32.9	54.3	67.4	64.9	57.9	33.2	16.7	20.4	13.5	380. 9	31.7	6.5	67.4	Wint er
ROBERTSO N	18.7	15.4	20.4	27.3	35.5	29.5	40.5	37.2	16.3	27.6	36.3	31.9	336. 6	28.1	15.4	40.5	Wint er
SALDANHA	1.4	16.7	8.2	13.6	70.6	56.7	29.1	33.5	33.9	15.5	40.2	8.2	327. 6	27.3	1.4	70.6	Wint er
SPRINGBO K	8.6	7.4	13.8	15.3	34.0	33.2	33.3	32.0	18.6	10.6	12.7	4.2	223. 7	18.6	4.2	34.0	Wint er
STELLENB OSCH	18.9	15.5	27.0	62.6	99.6	124. 0	121. 4	98.9	63.4	42.3	31.2	22.9	727. 7	60.6	15.5	124.0	Wint er
SWELLEND AM	37.3	34.6	49.4	70.2	43.4	41.3	50.9	48.5	34.6	58.6	42.6	41.7	553. 1	46.1	34.6	70.2	Wint er
VREDENDA L	3.5	2.7	5.3	13.9	21.8	25.2	28.7	20.0	12.9	10.5	6.1	10.1	160. 7	13.4	2.7	28.7	Wint er
WORCESTE R	6.3	8.8	6.4	18.9	30.5	29.1	48.7	42.8	26.6	21.0	29.7	11.1	279. 9	23.3	6.3	48.7	Wint er
Average													**347. 8**				

Annexure 9: Evapotranspiration rates represented diagrammatically for South Africa, January to December.

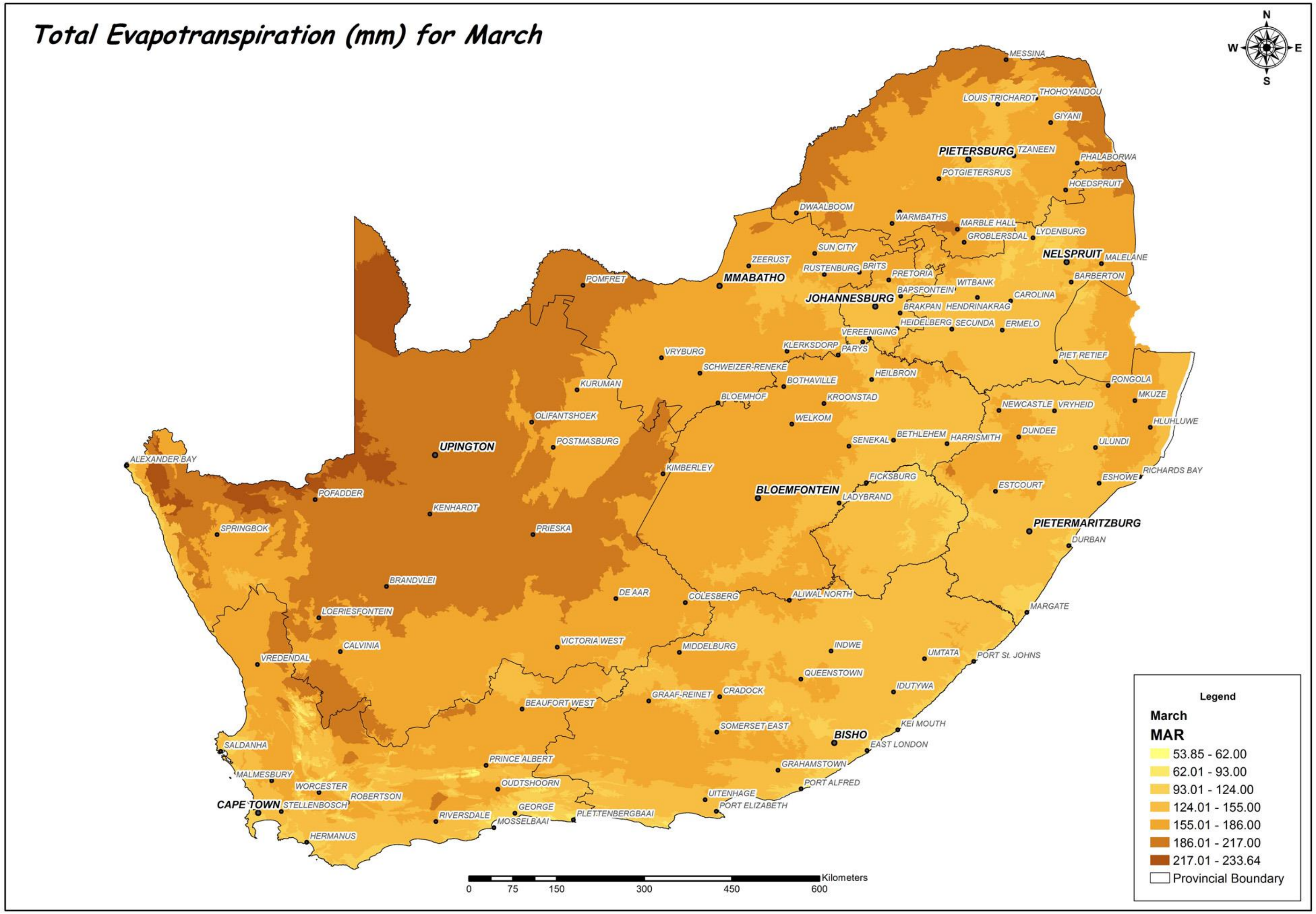
January evapotranspiration.



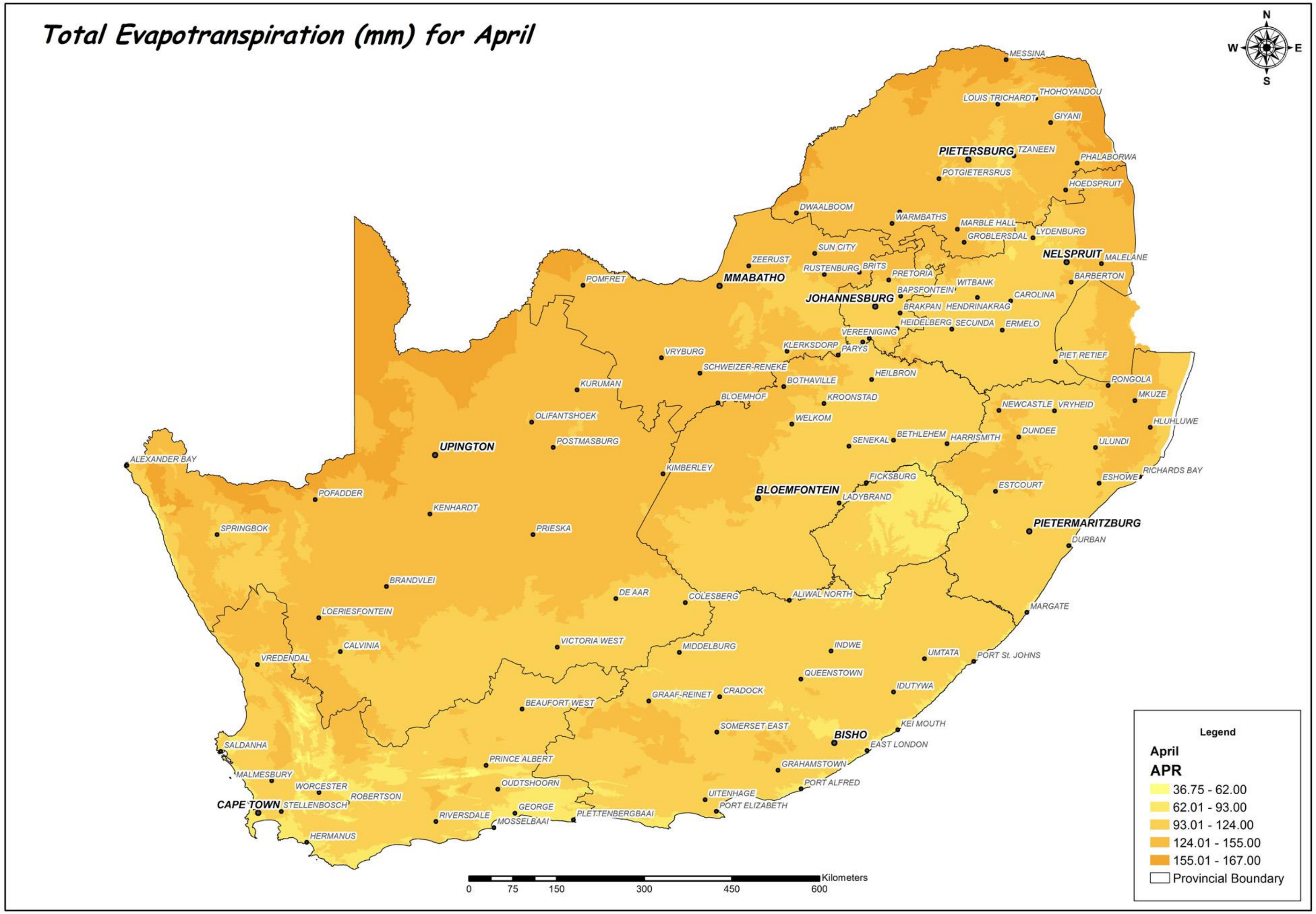
February evapotranspiration.



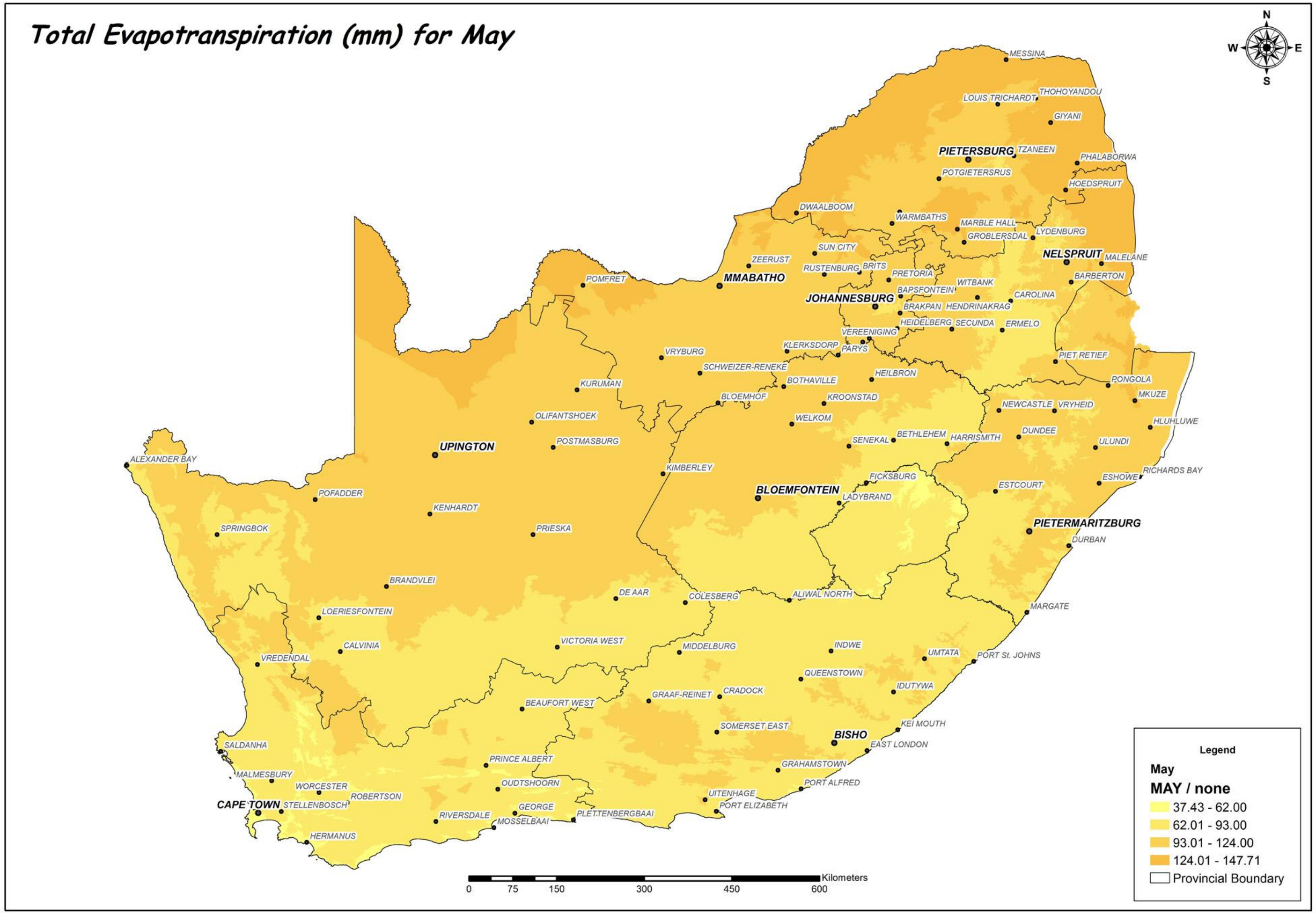
March evapotranspiration.



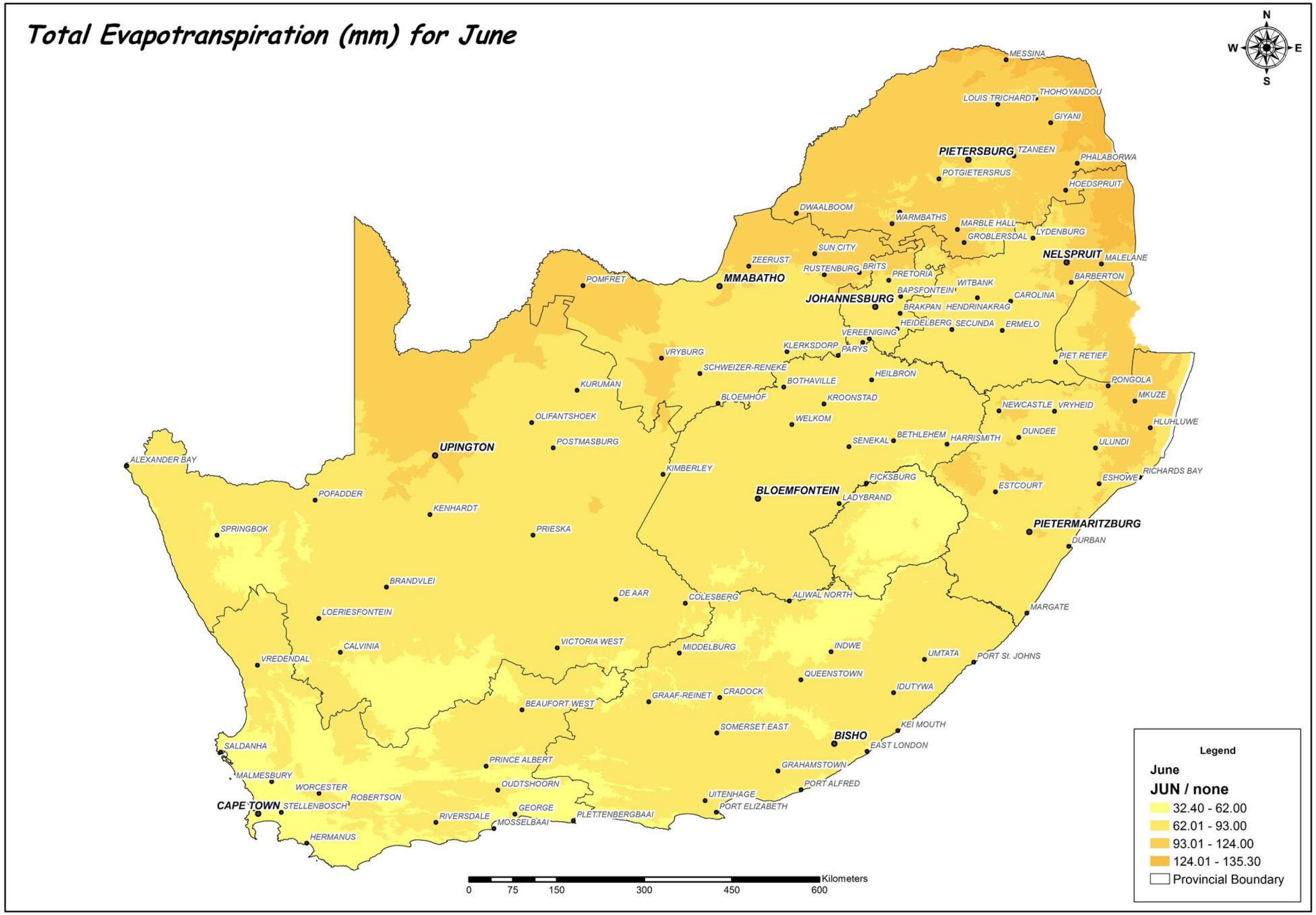
April evapotranspiration.



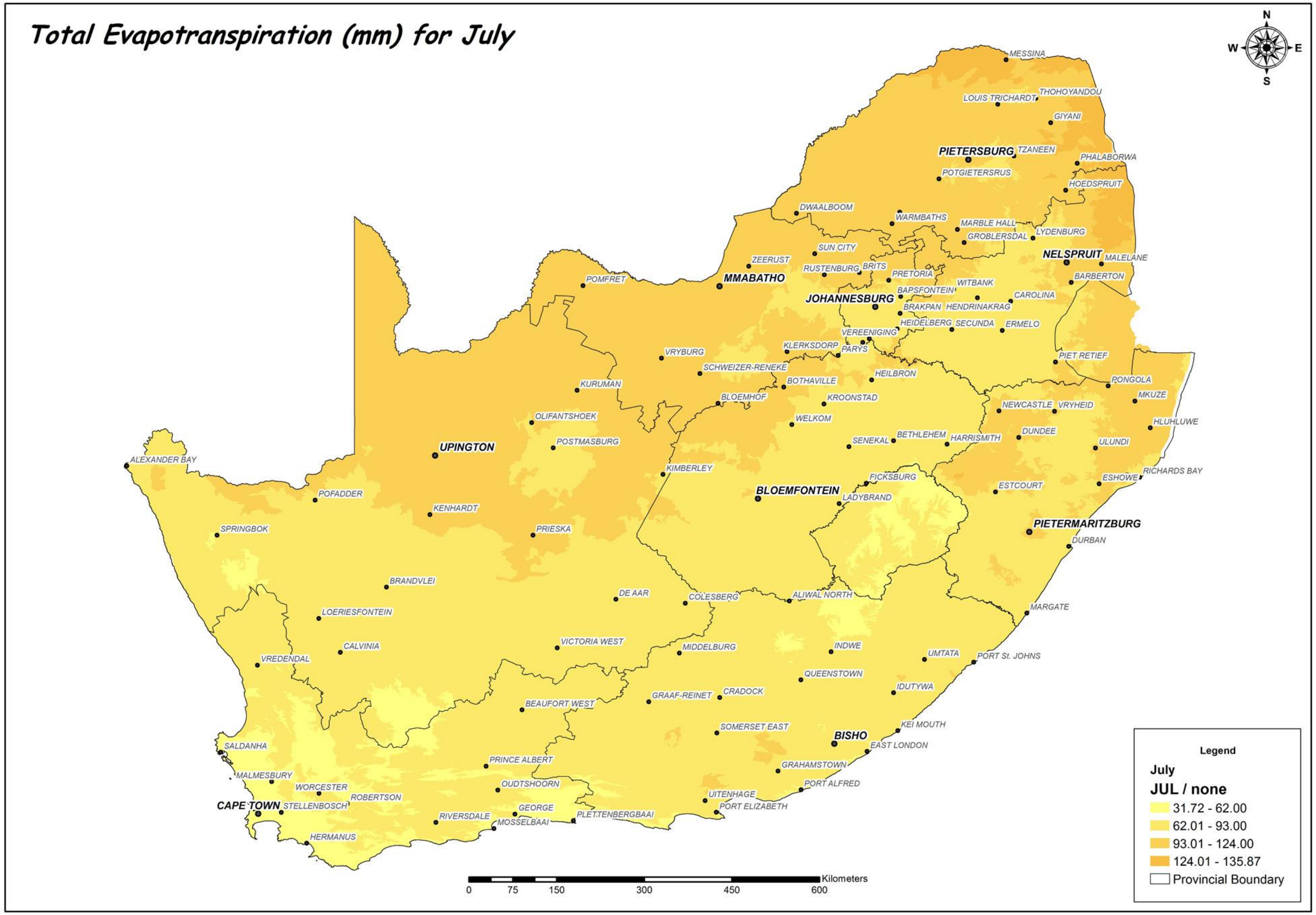
May evapotranspiration



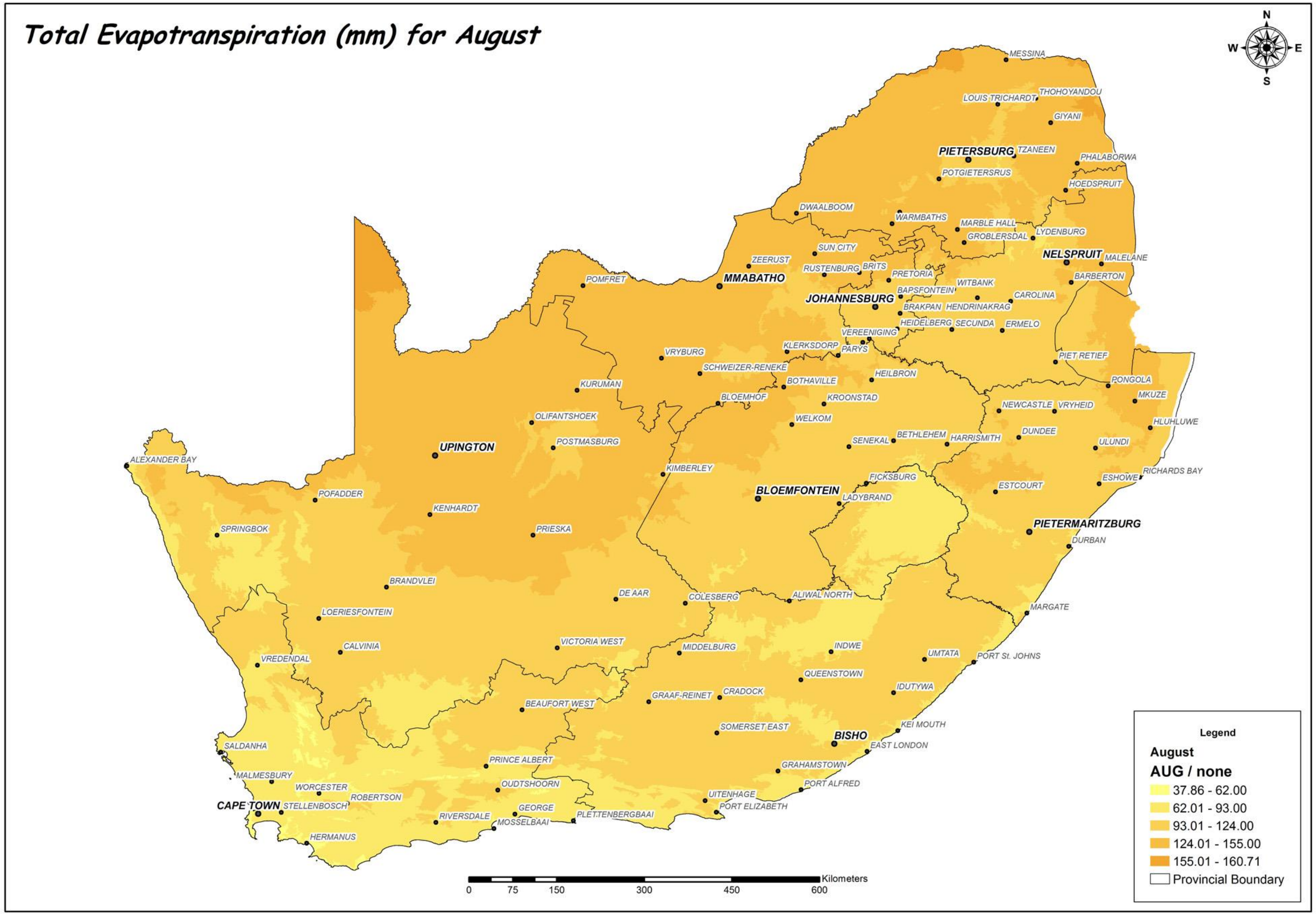
June evapotranspiration.



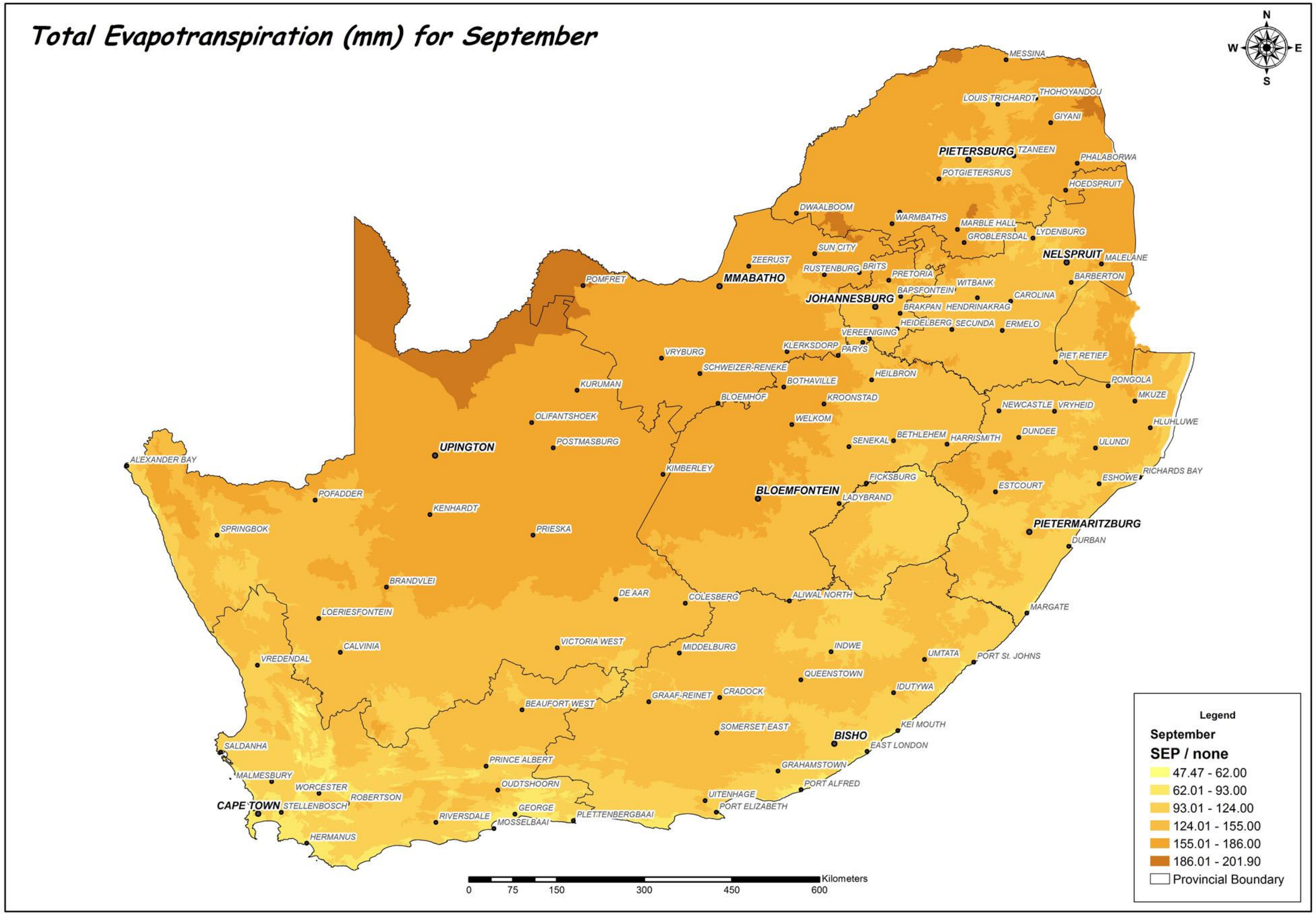
July evapotranspiration.



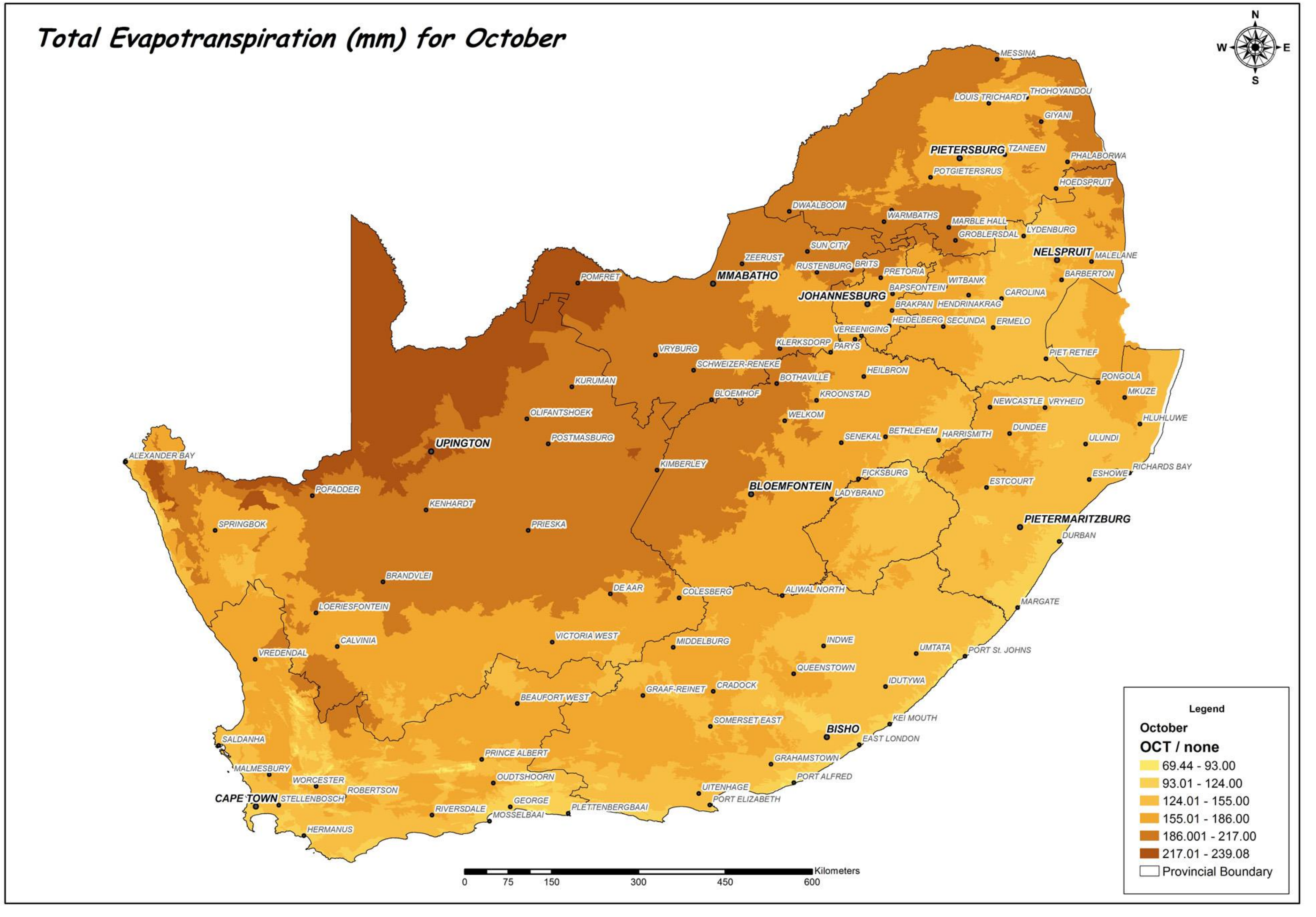
August evapotranspiration.



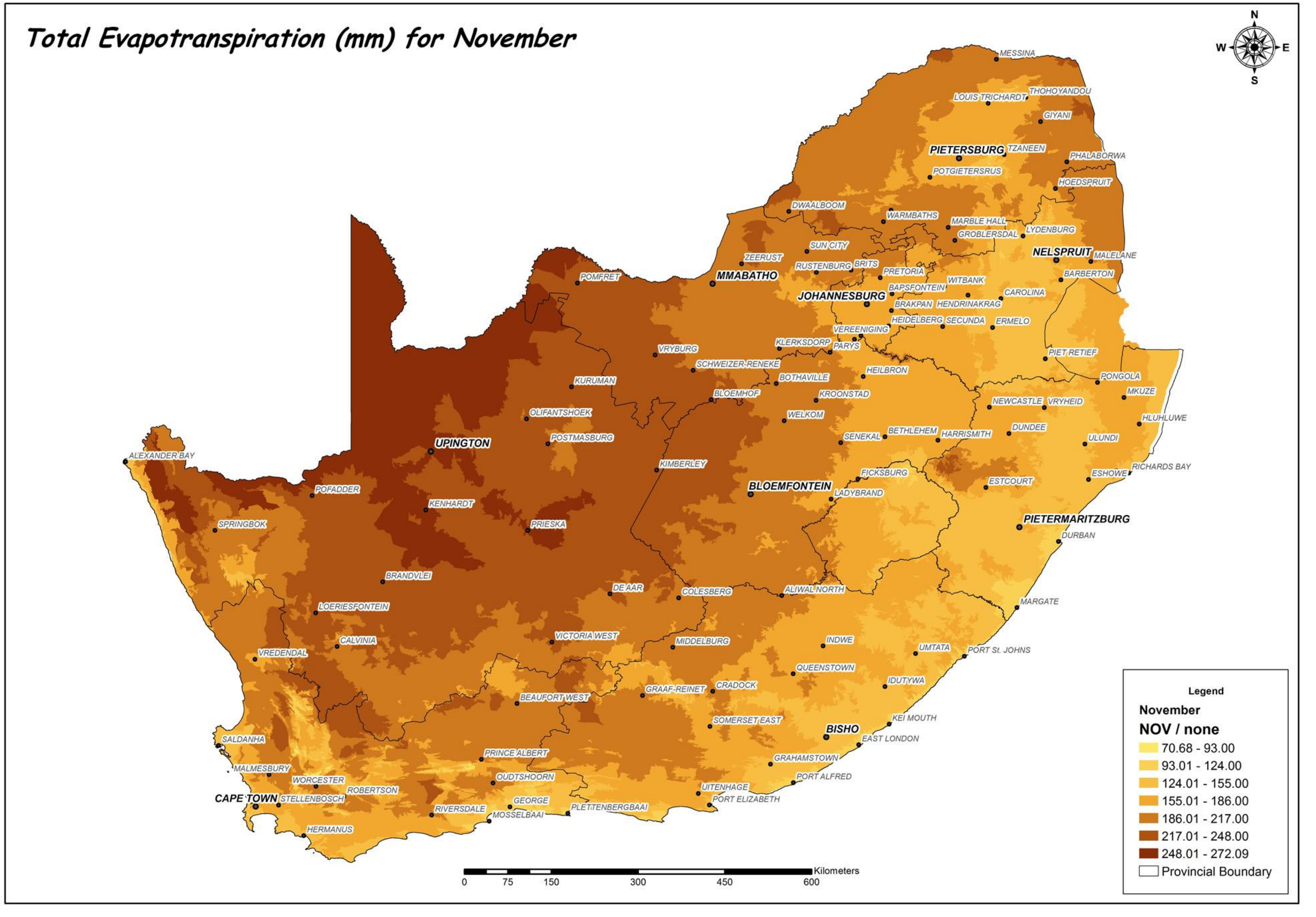
September evapotranspiration.



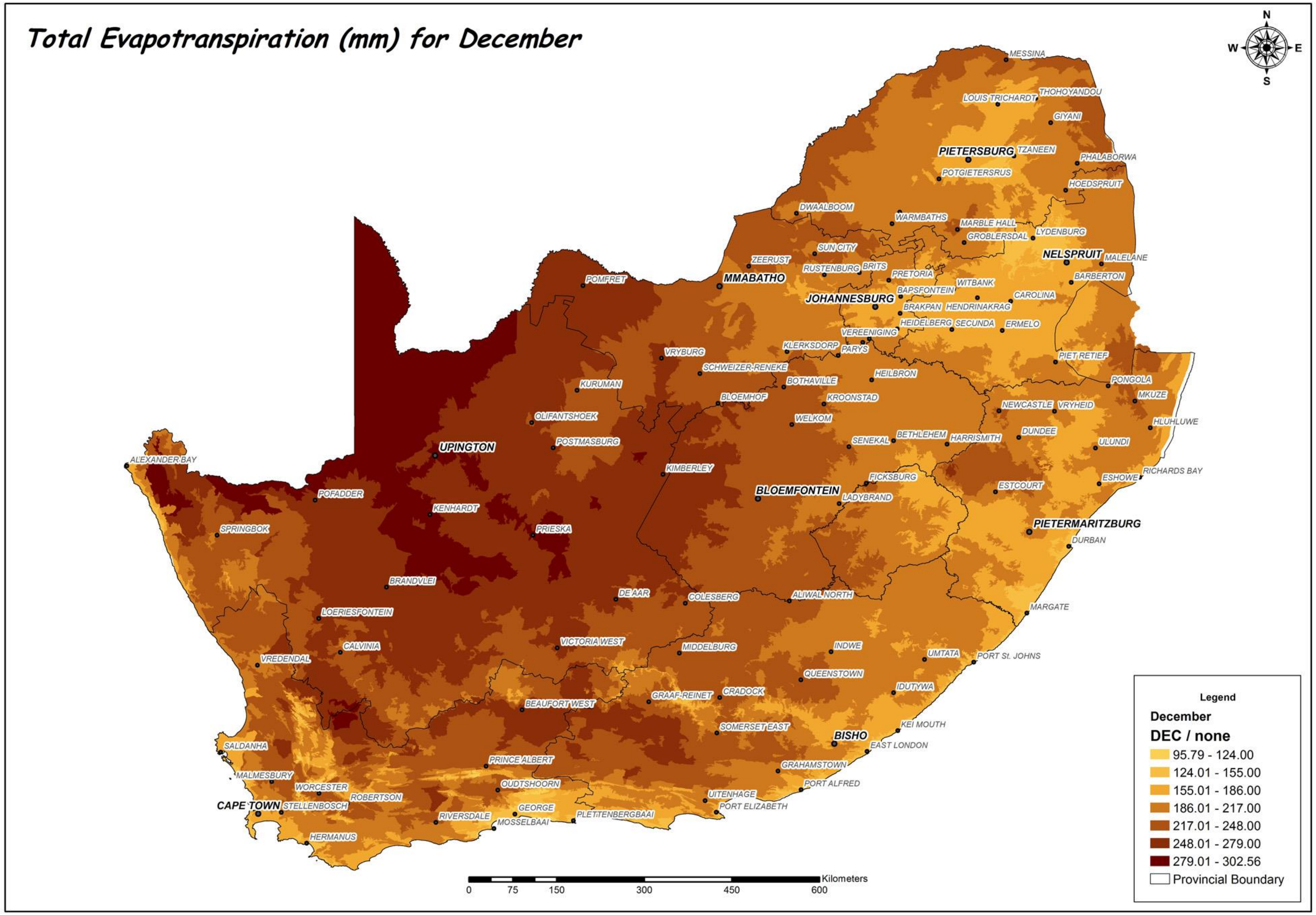
October evapotranspiration.



November evapotranspiration.

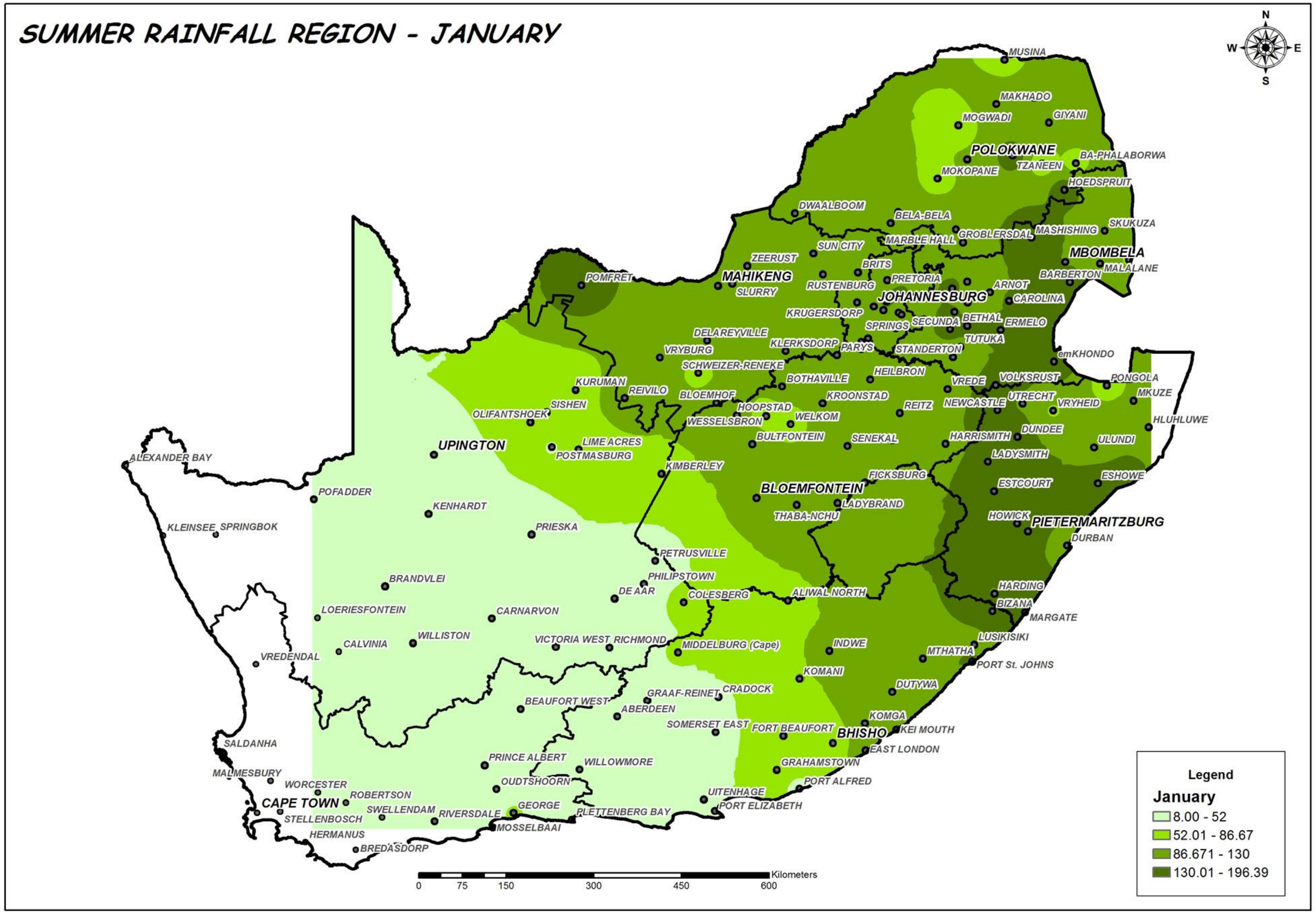


December evapotranspiration.

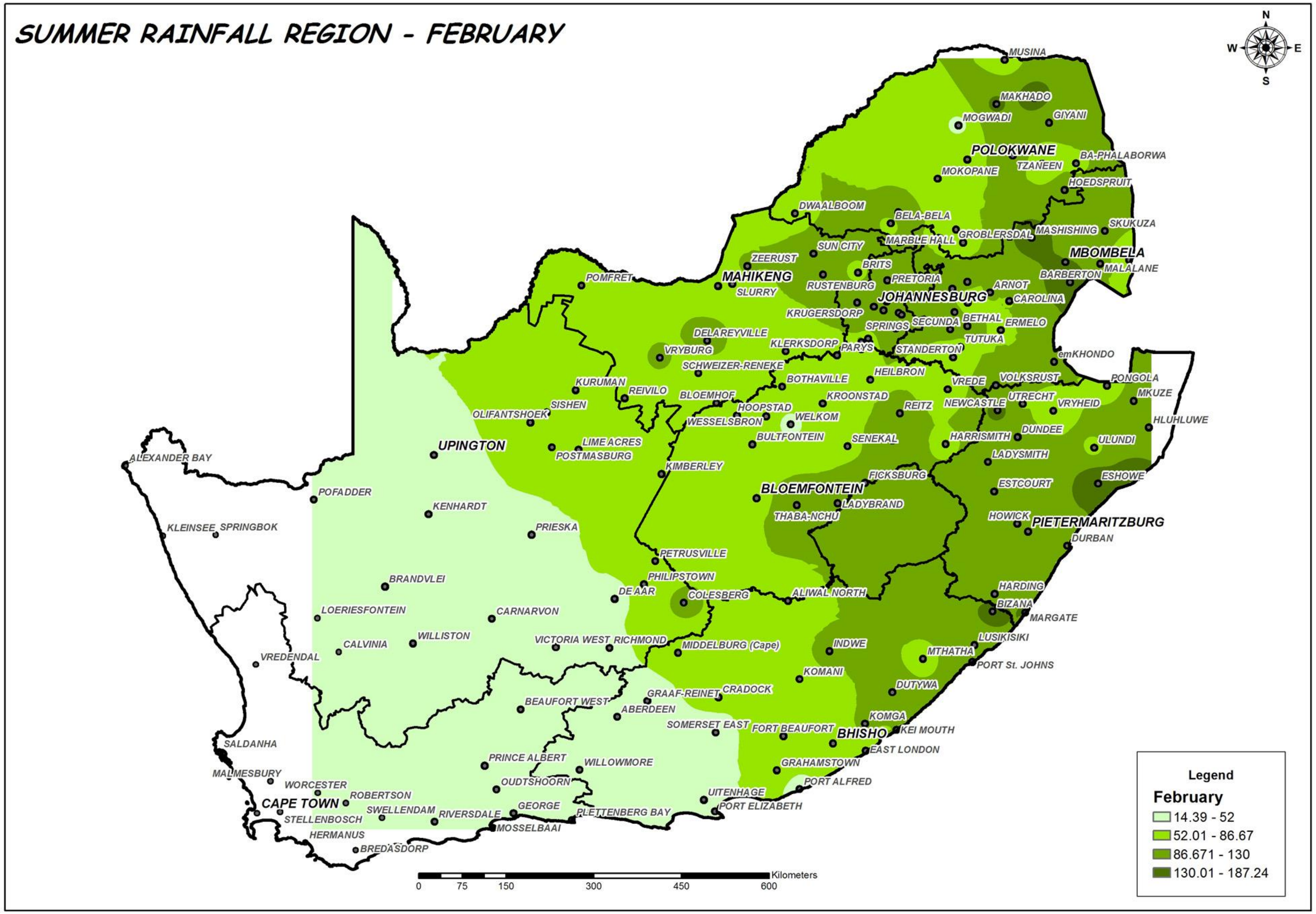


Annexure 10: Summer and winter rainfall regions linked to monthly average rainfall and hydrozone data.

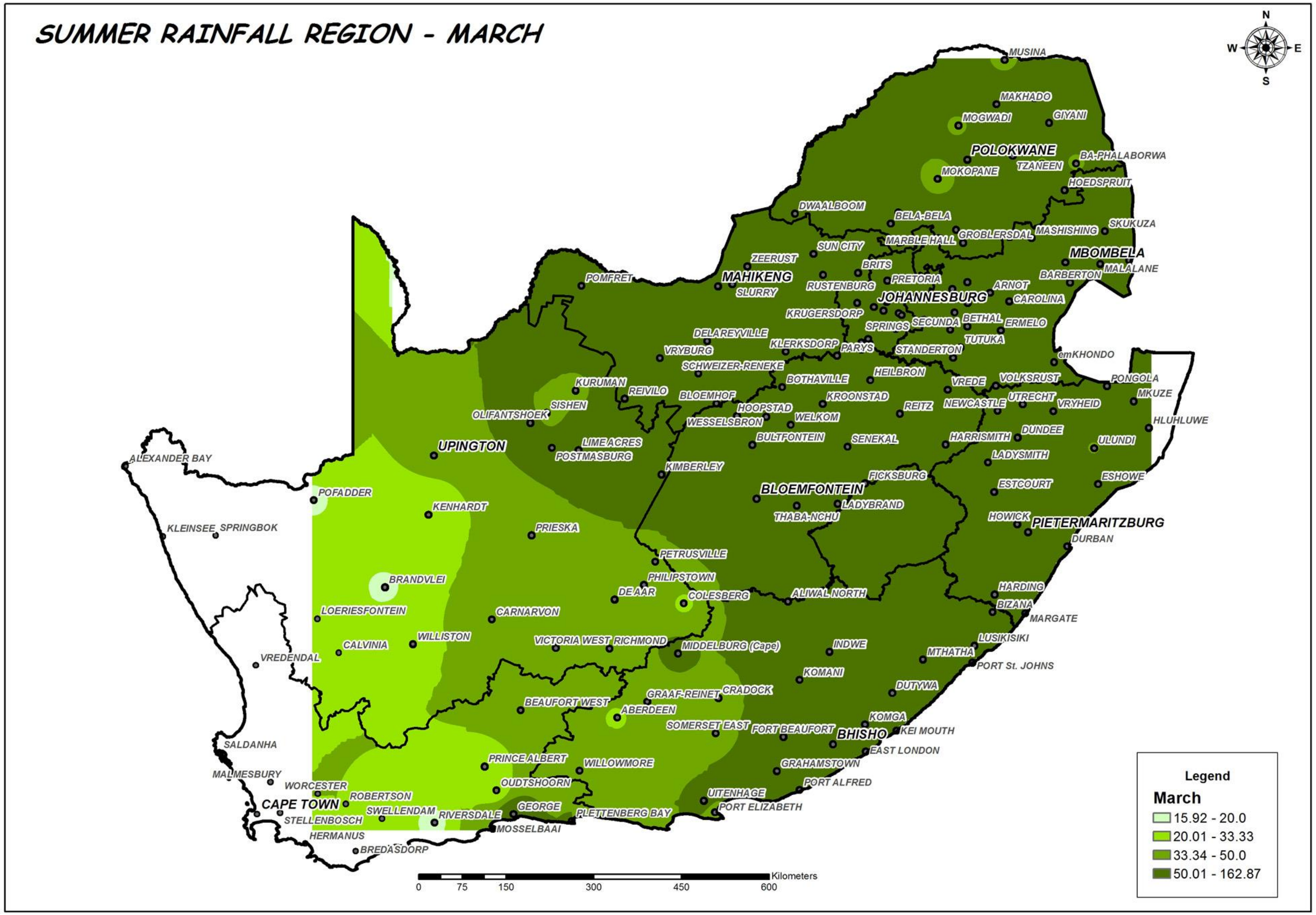
January summer rainfall region linked to monthly average rainfall and hydrozone data.



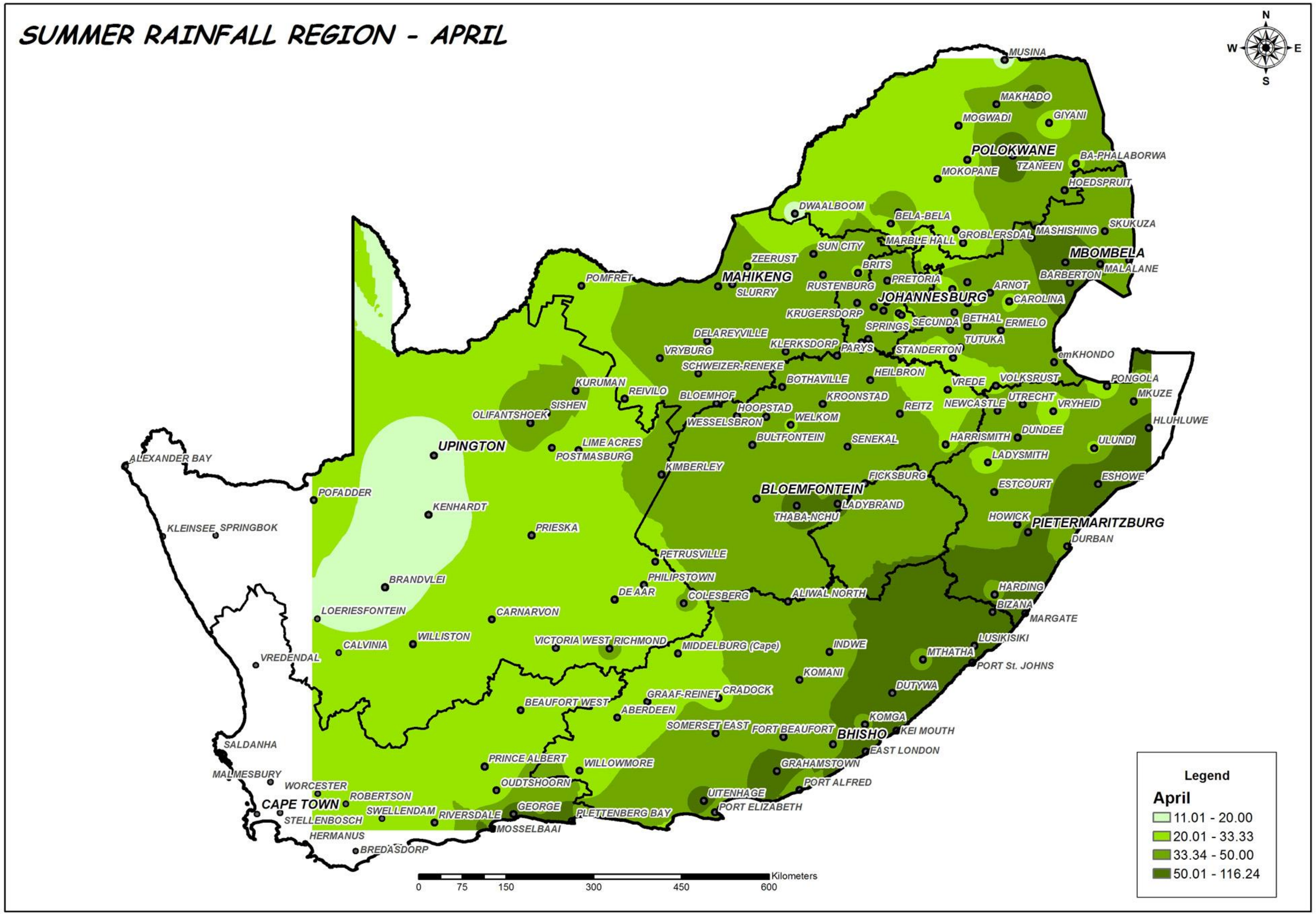
February summer rainfall region linked to monthly average rainfall and hydrozone data



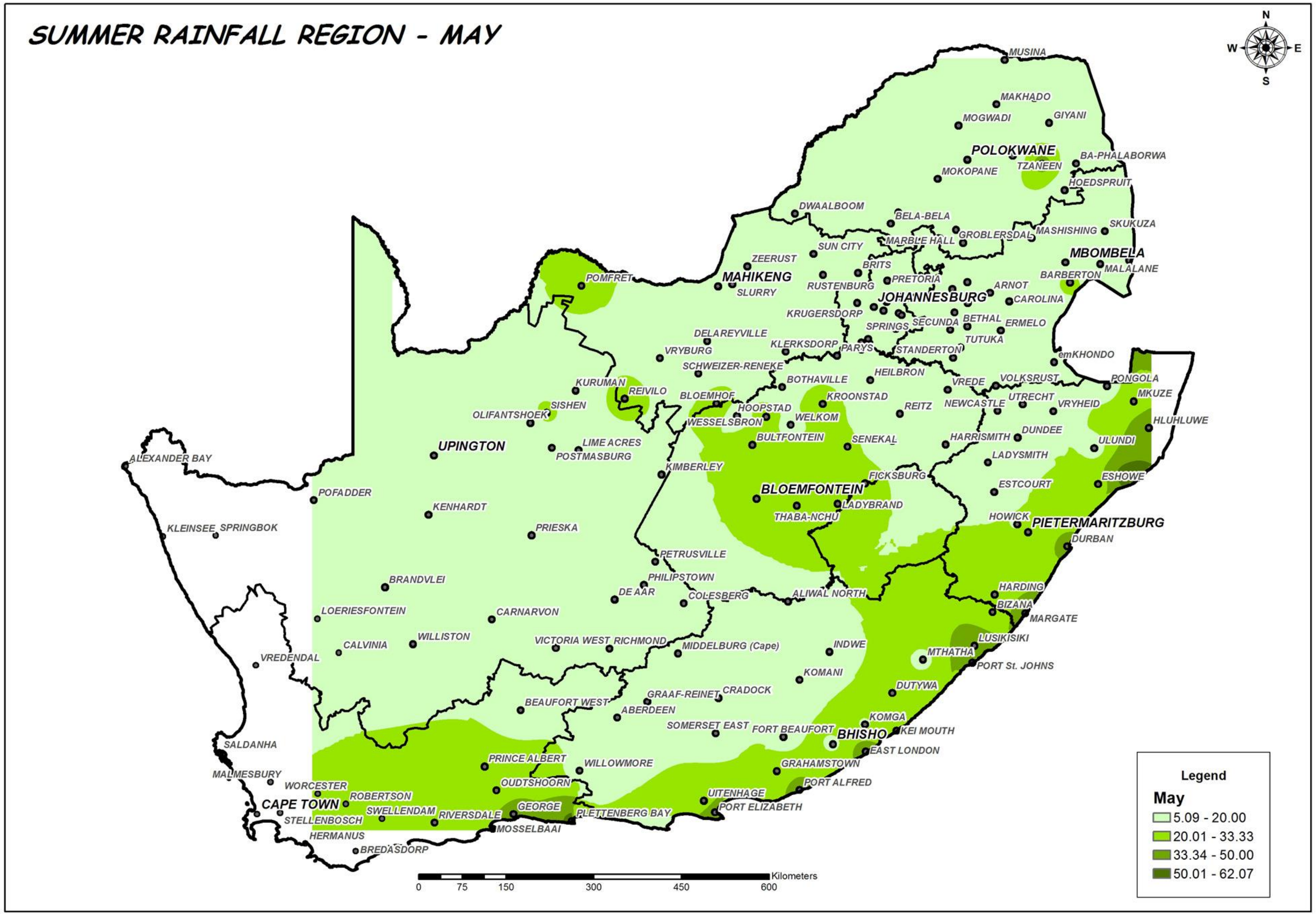
March summer rainfall region linked to monthly average rainfall and hydrozone data



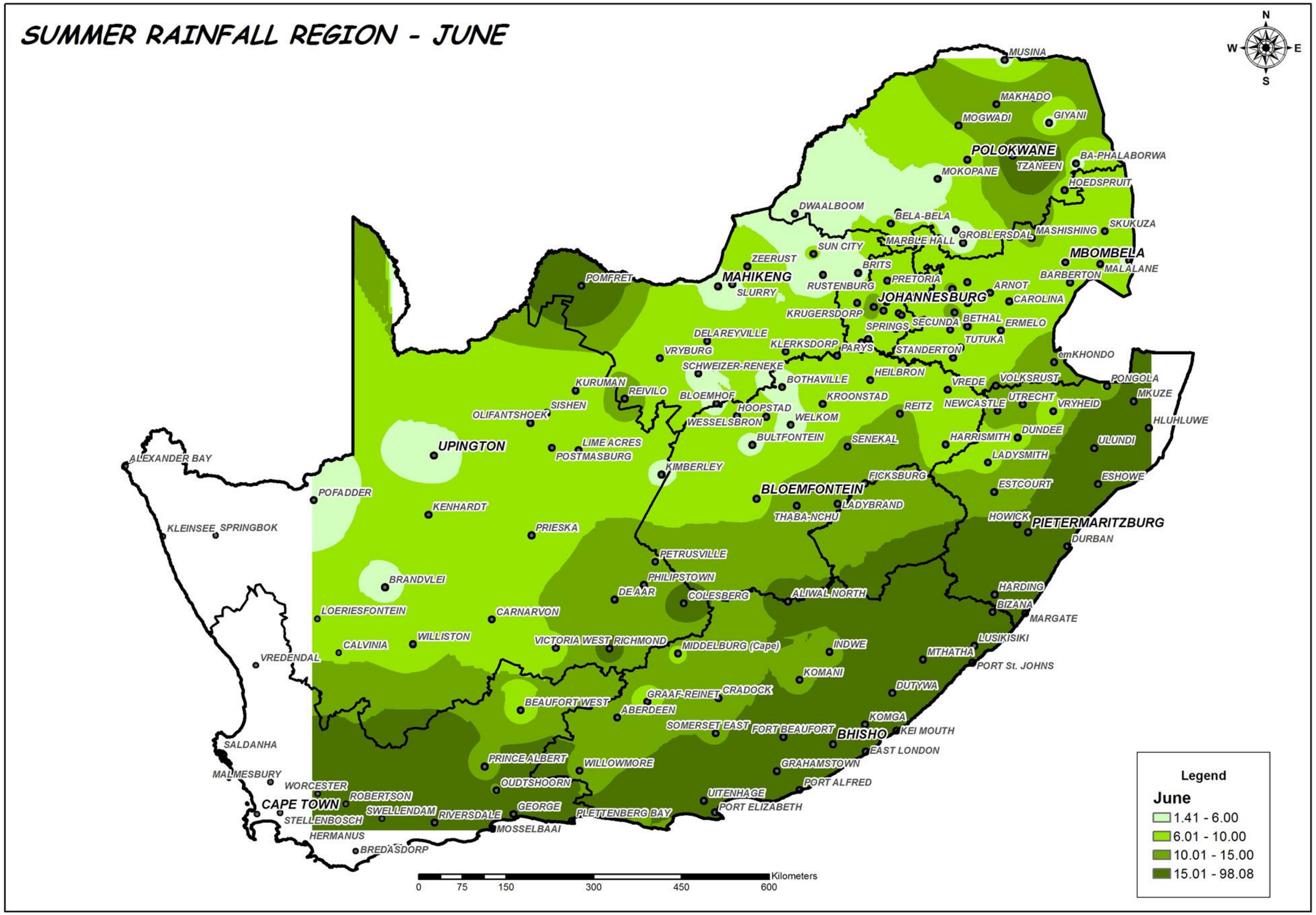
April summer rainfall region linked to monthly average rainfall and hydrozone data.



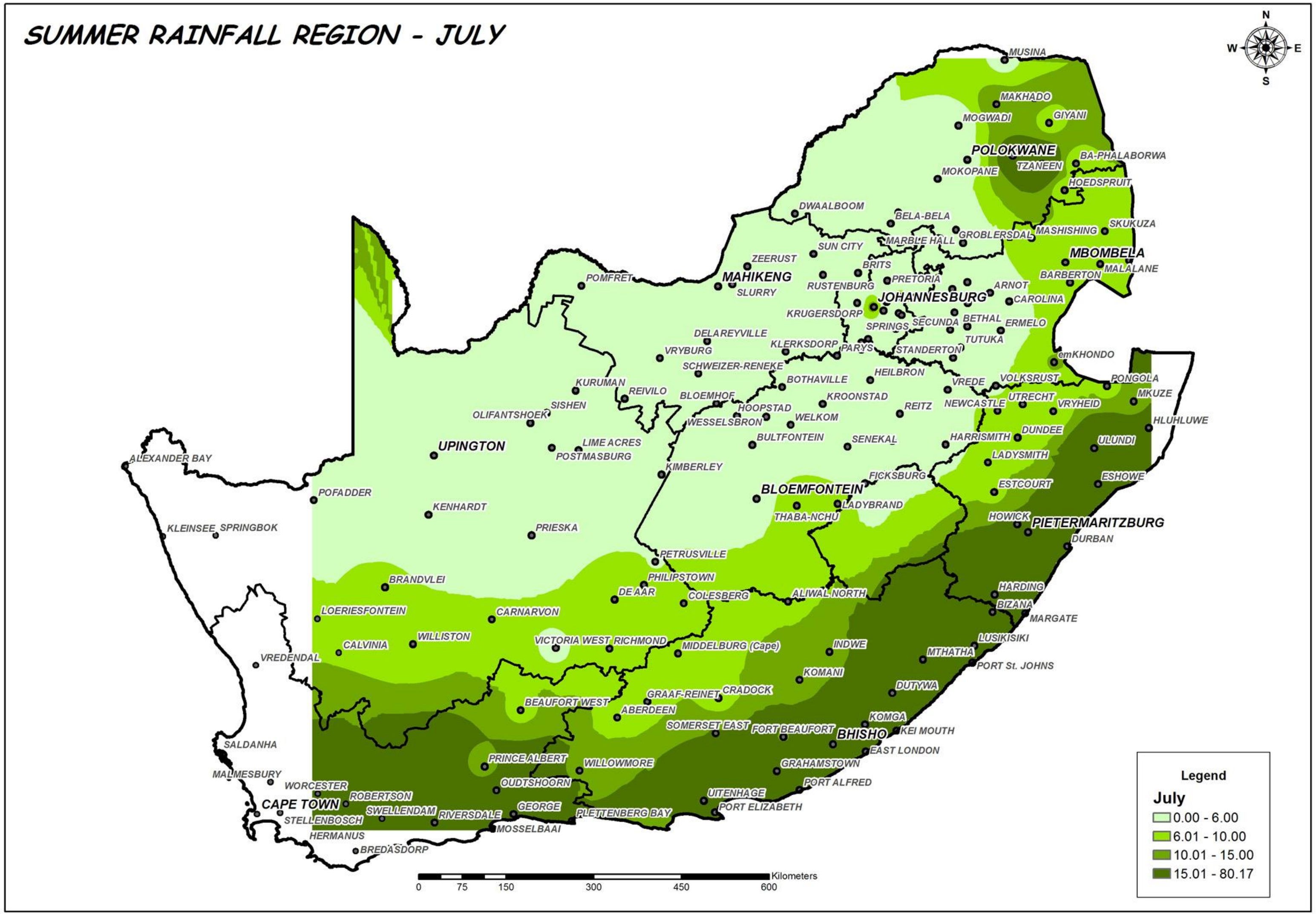
May summer rainfall region linked to monthly average rainfall and hydrozone data.



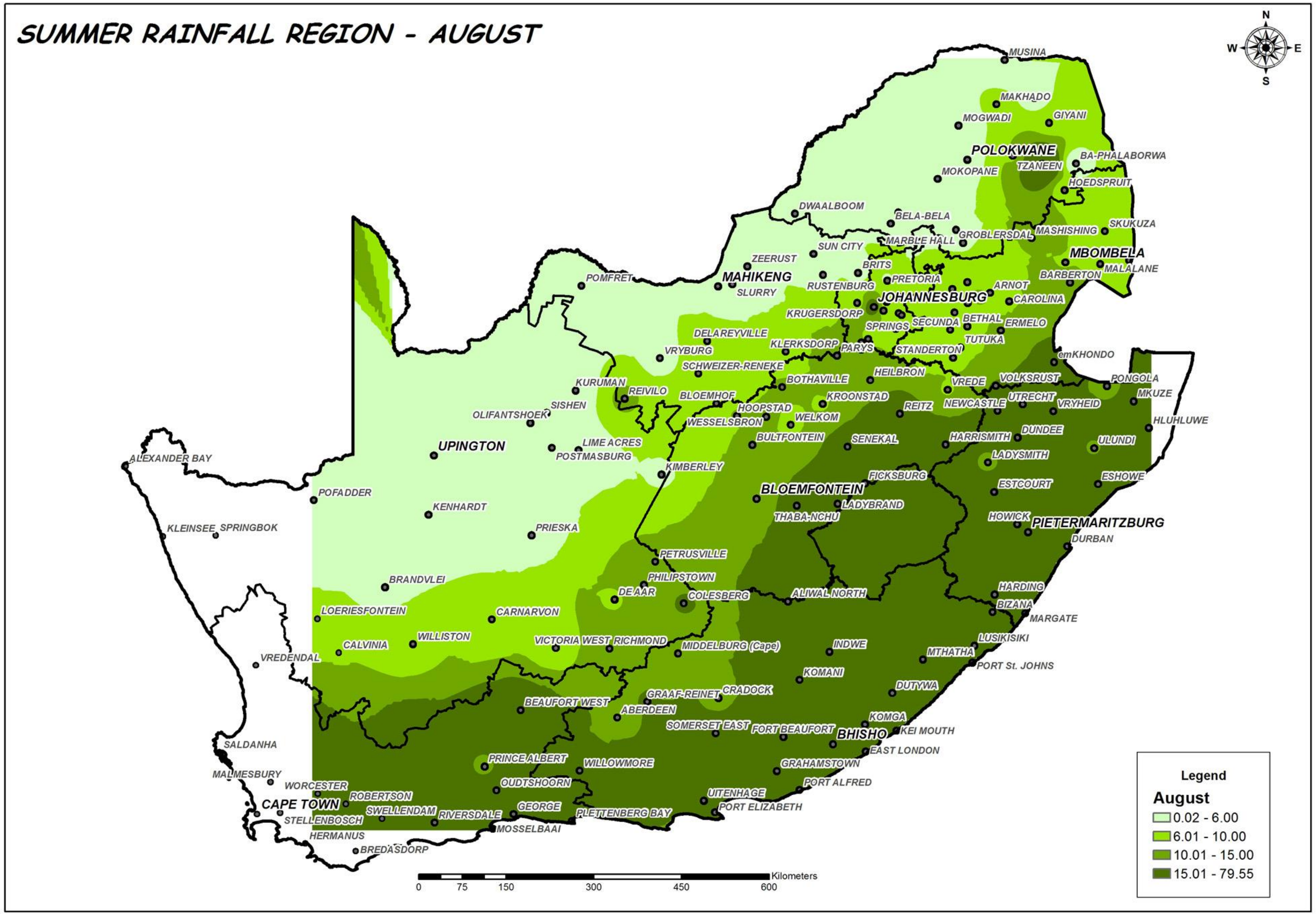
June summer rainfall region linked to monthly average rainfall and hydrozone data



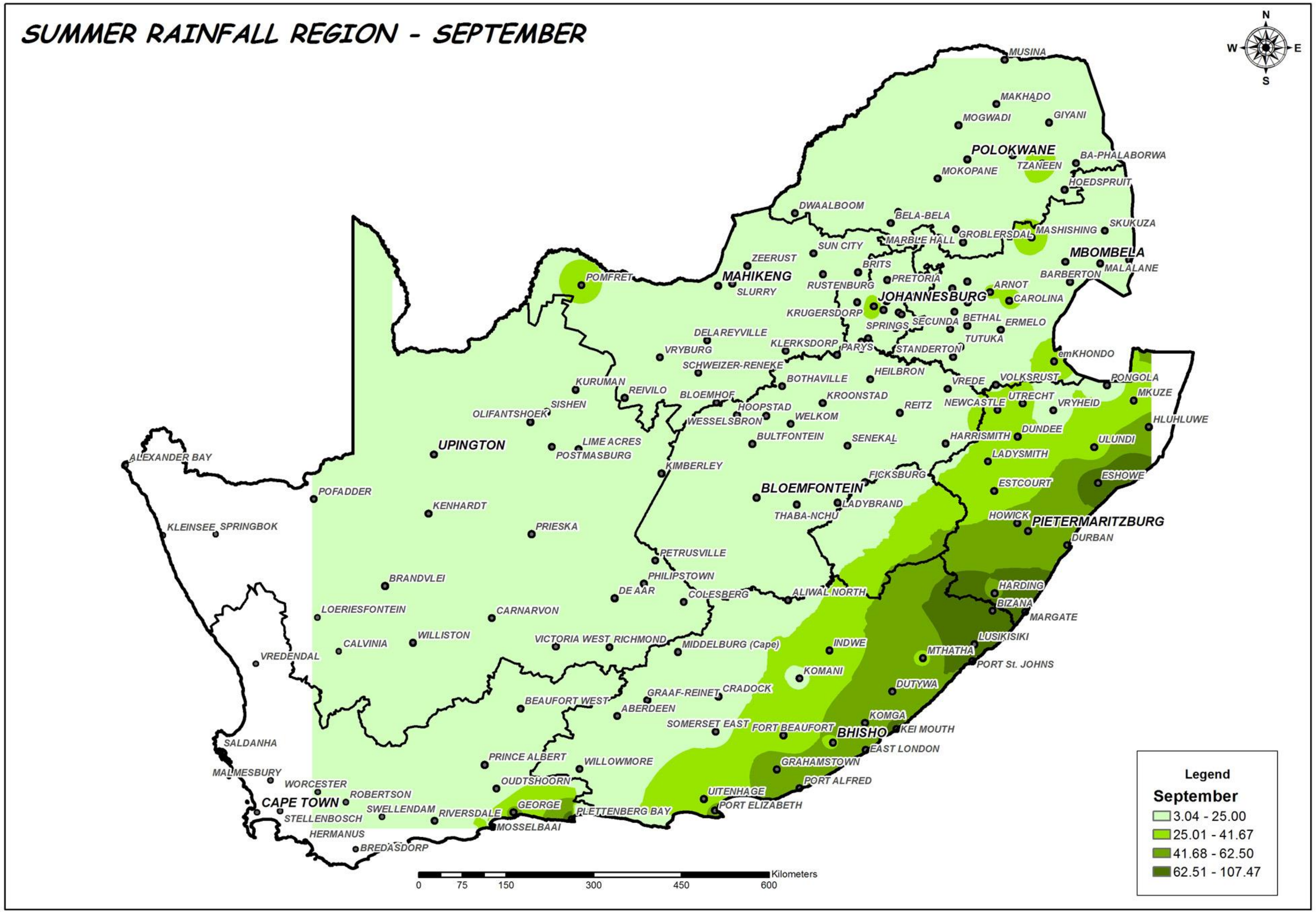
July summer rainfall region linked to monthly average rainfall and hydrozone data.



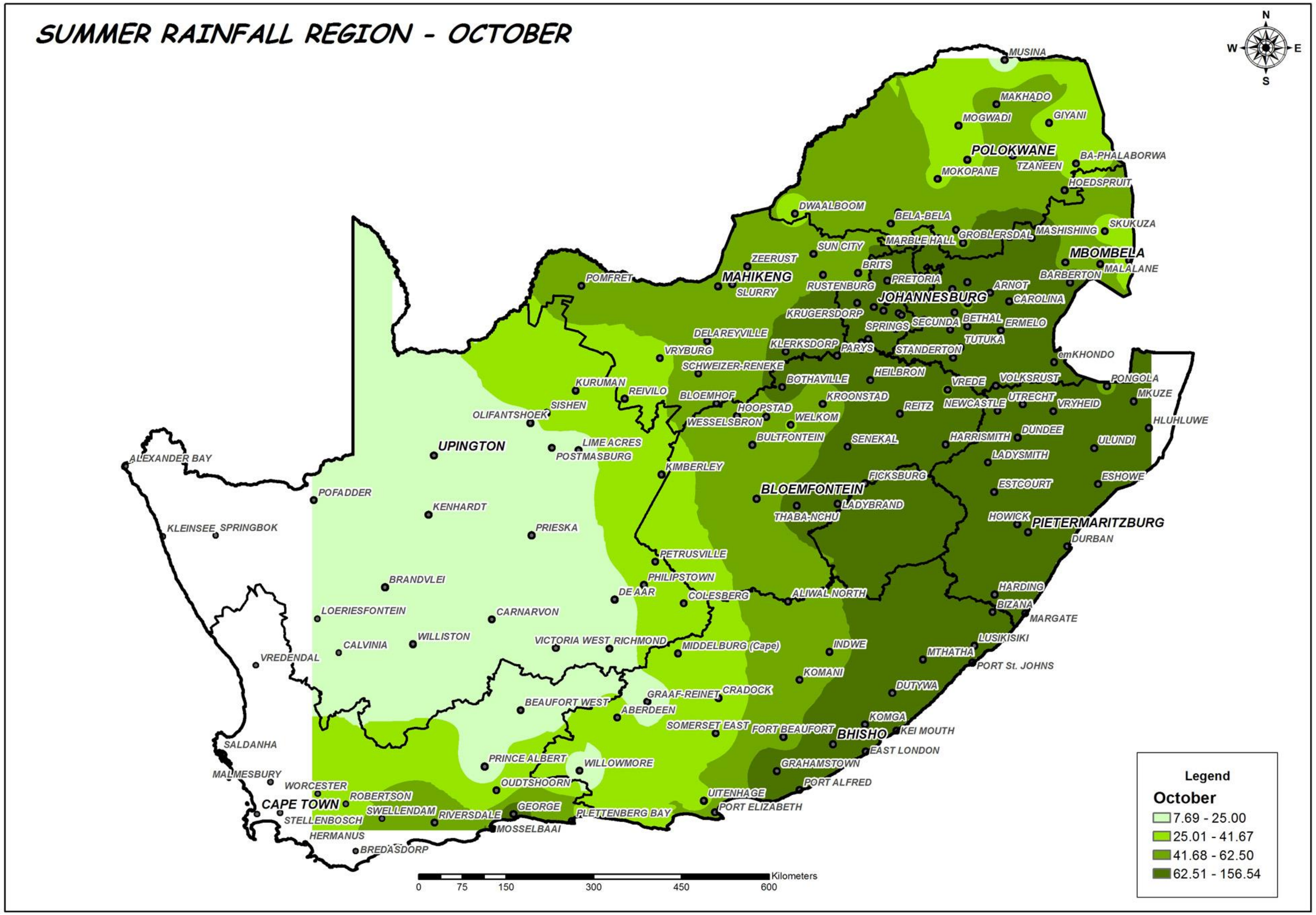
August summer rainfall region linked to monthly average rainfall and hydrozone data.



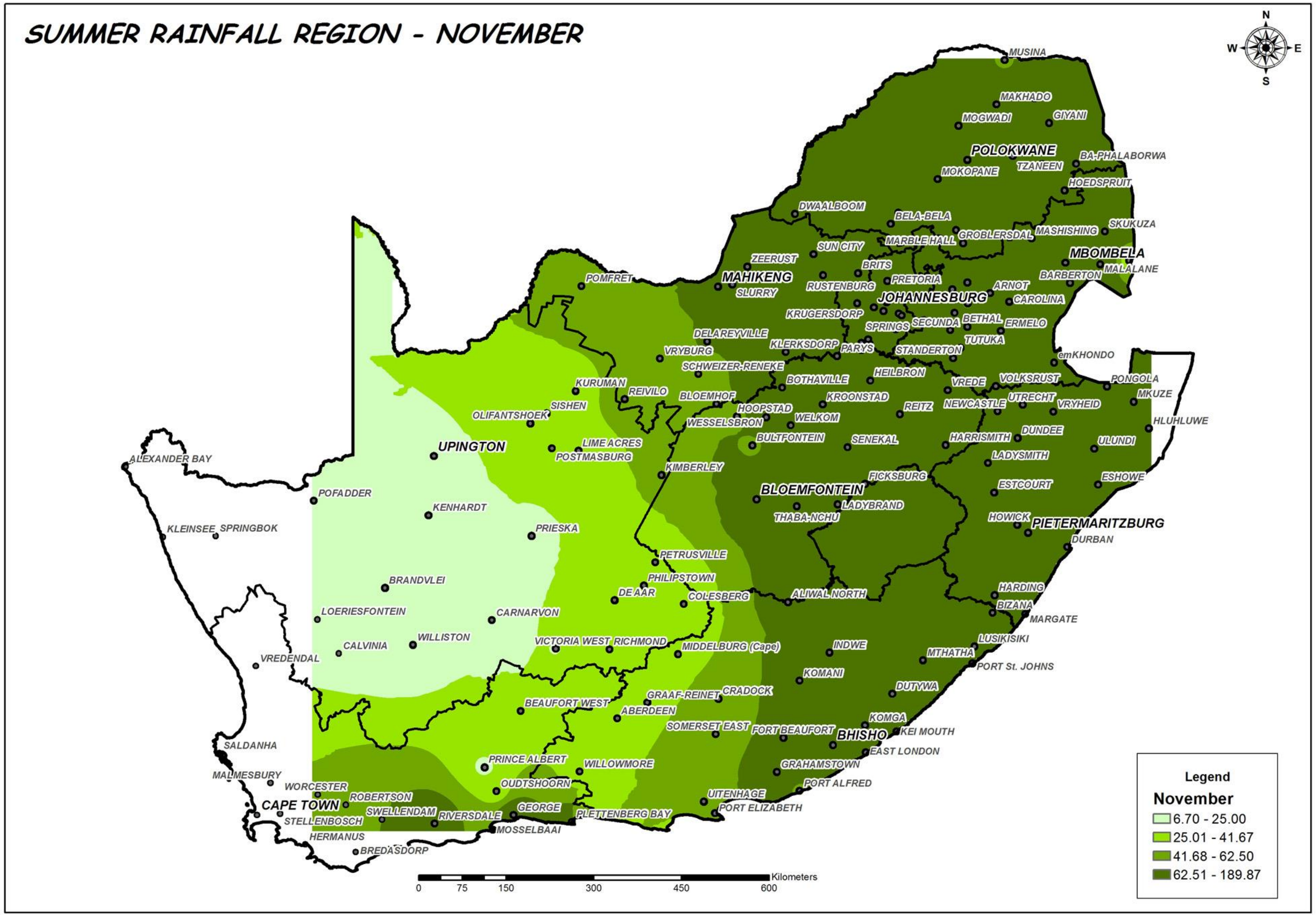
September summer rainfall region linked to monthly average rainfall and hydrozone data.



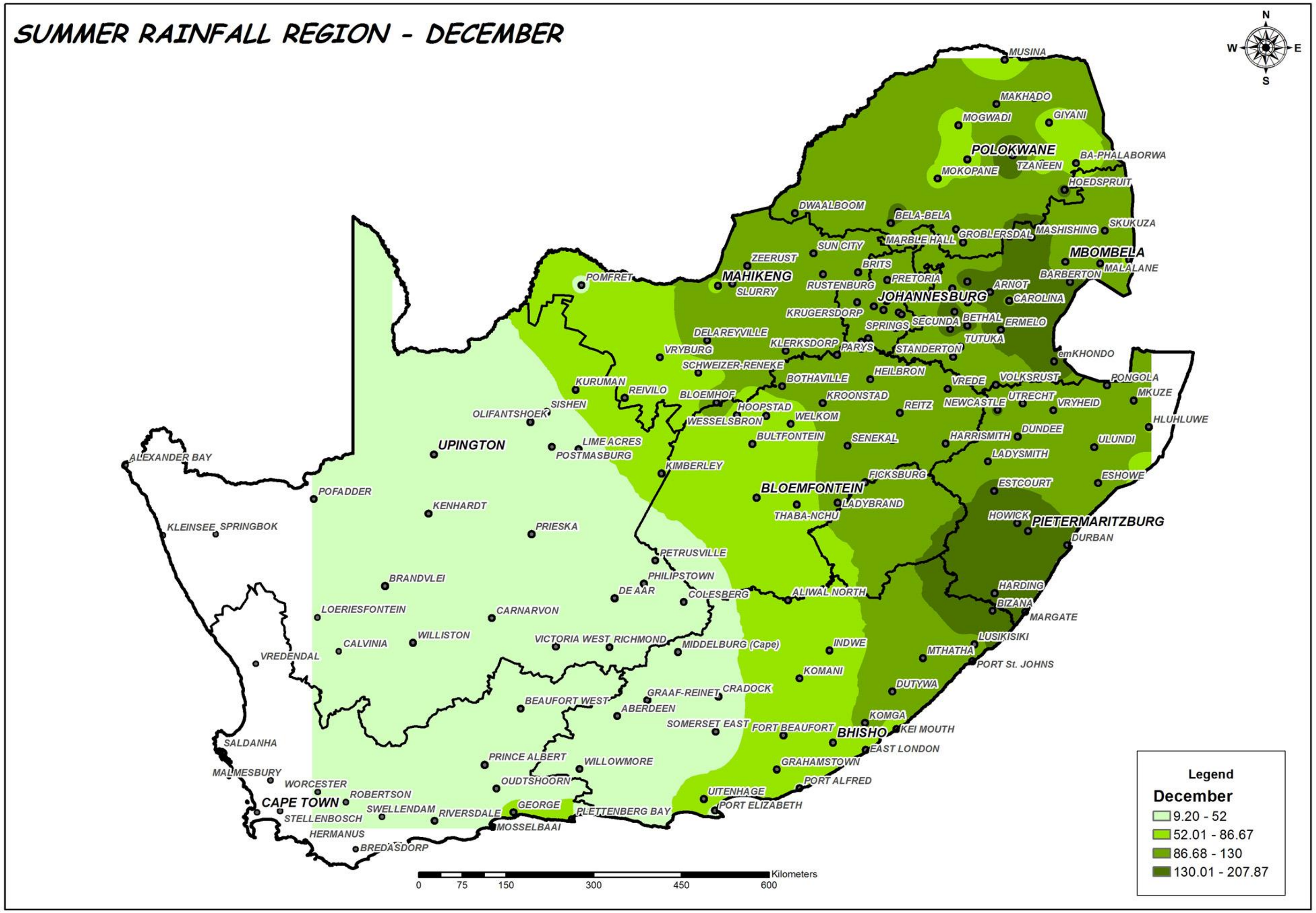
October summer rainfall region linked to monthly average rainfall and hydrozone data.



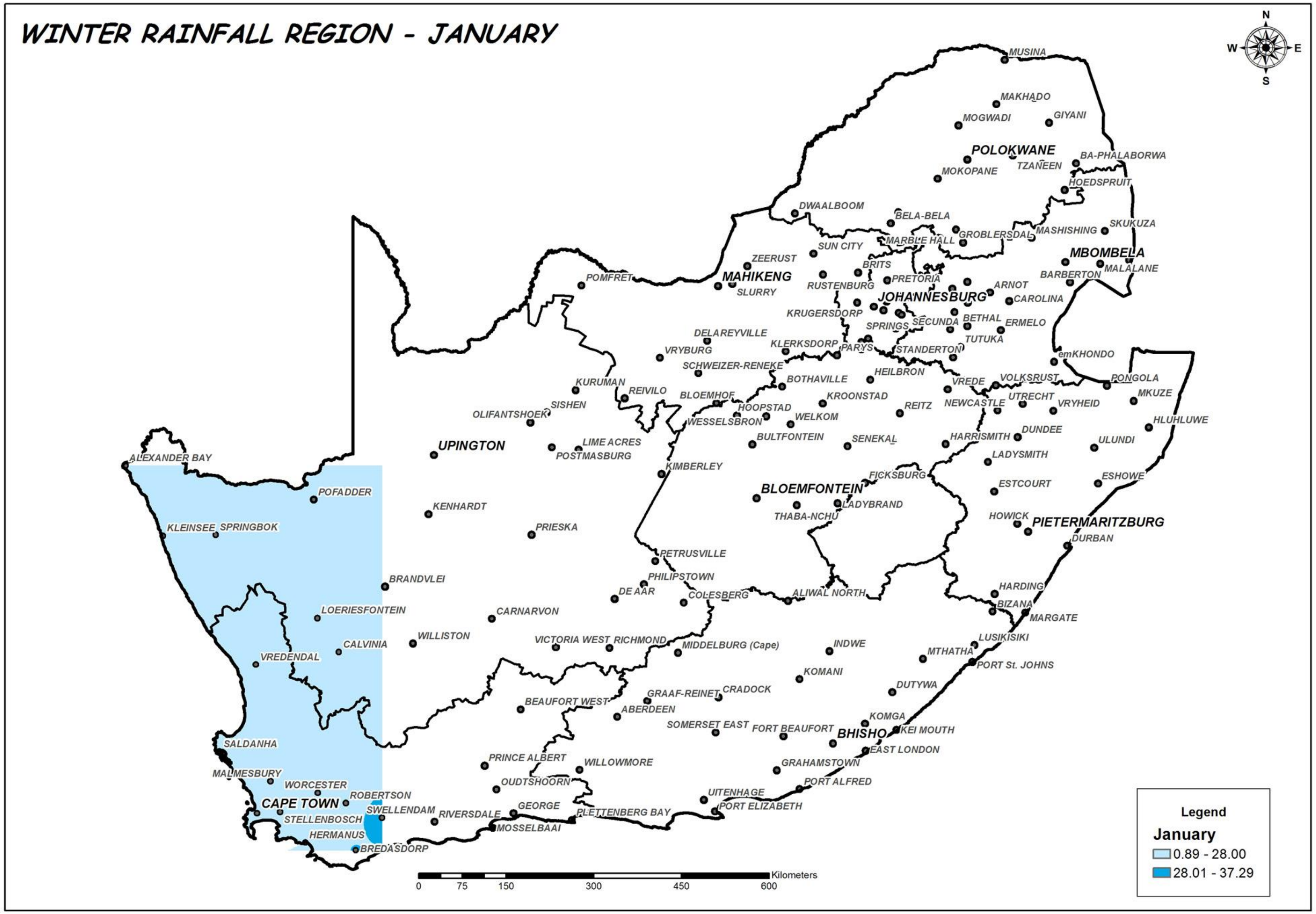
November summer rainfall region linked to monthly average rainfall and hydrozone data.



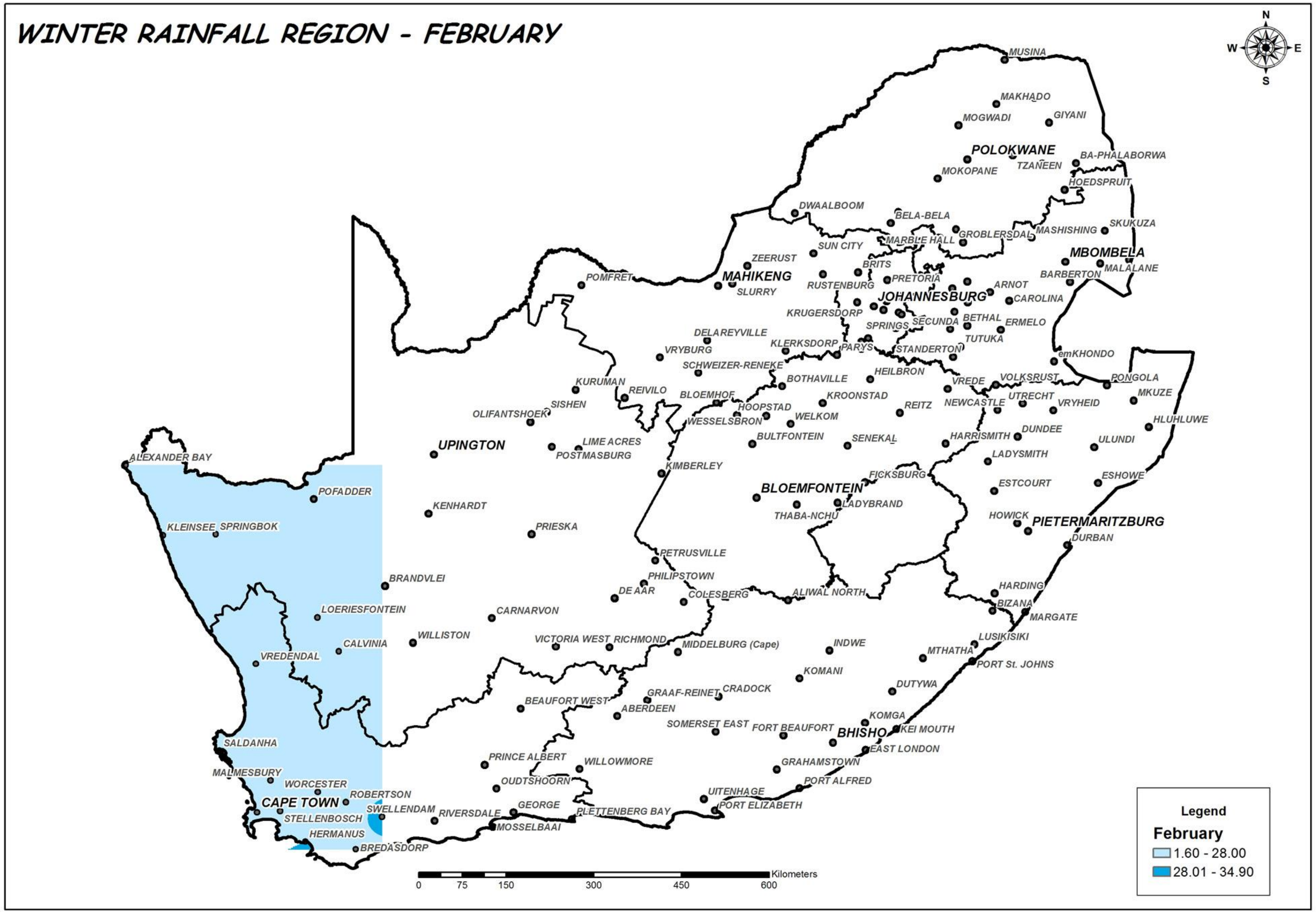
December summer rainfall region linked to monthly average rainfall and hydrozone data.



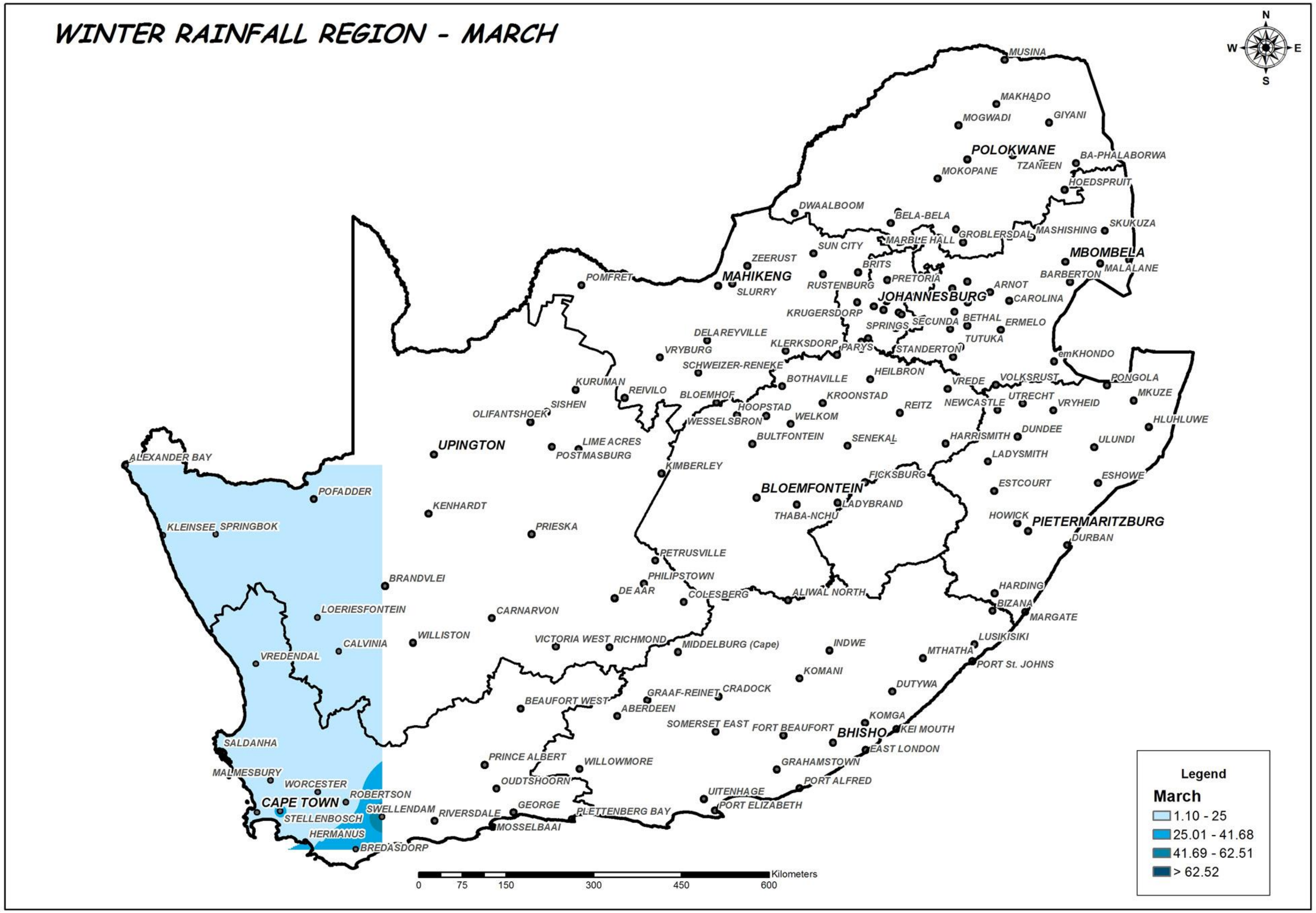
January winter rainfall region linked to monthly average rainfall and hydrozone data.



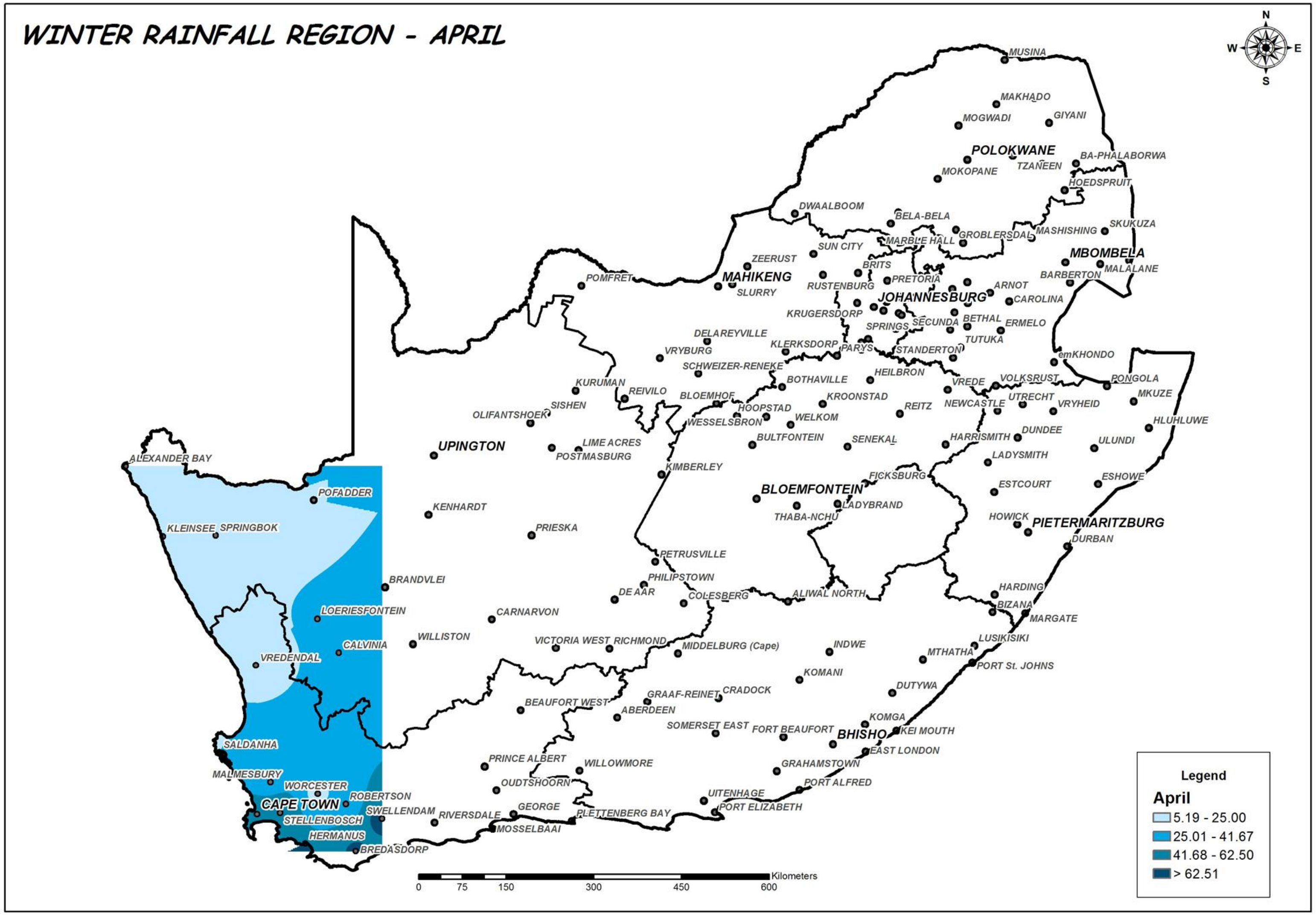
February winter rainfall region linked to monthly average rainfall and hydrozone data.



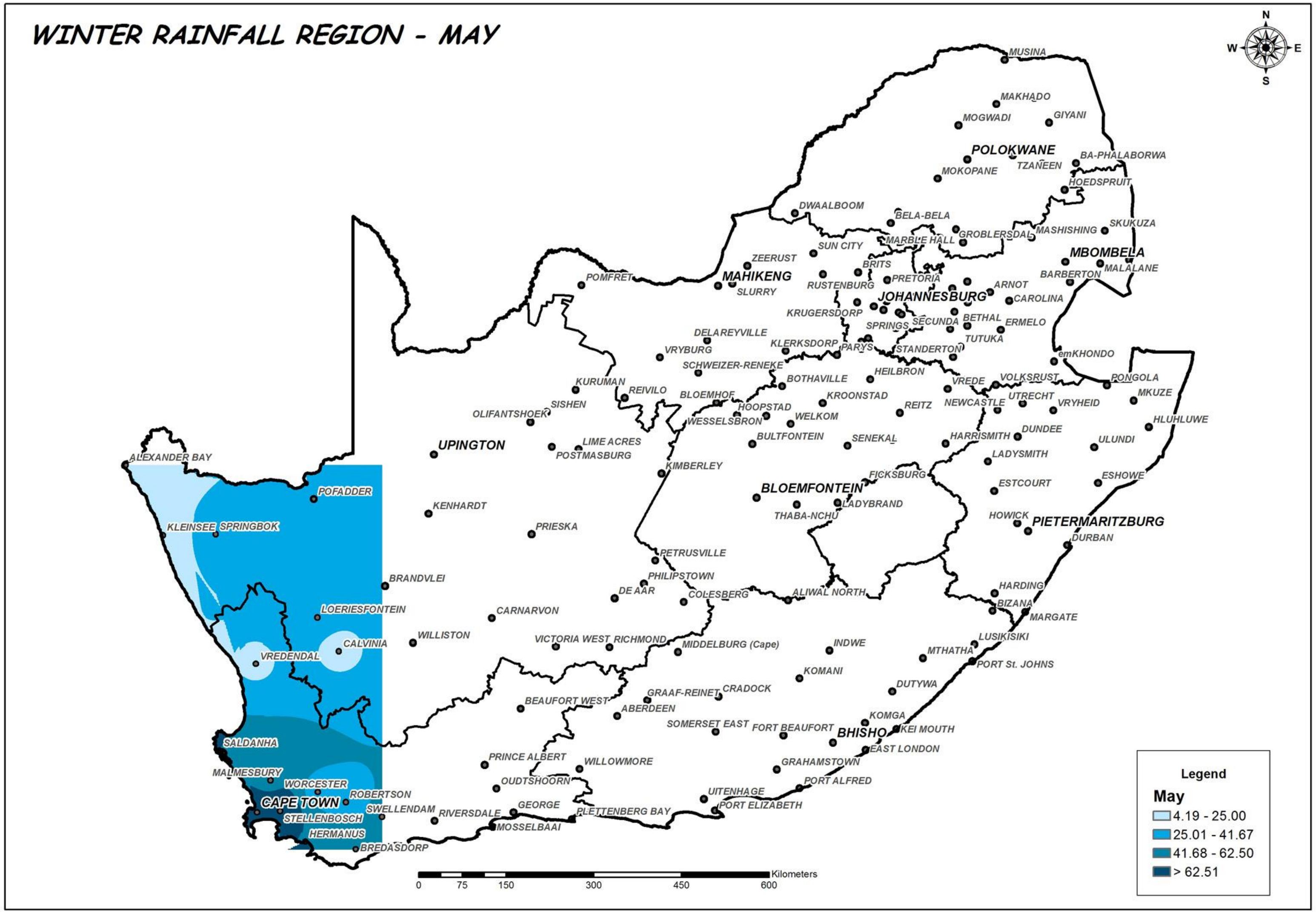
March winter rainfall region linked to monthly average rainfall and hydrozone data.



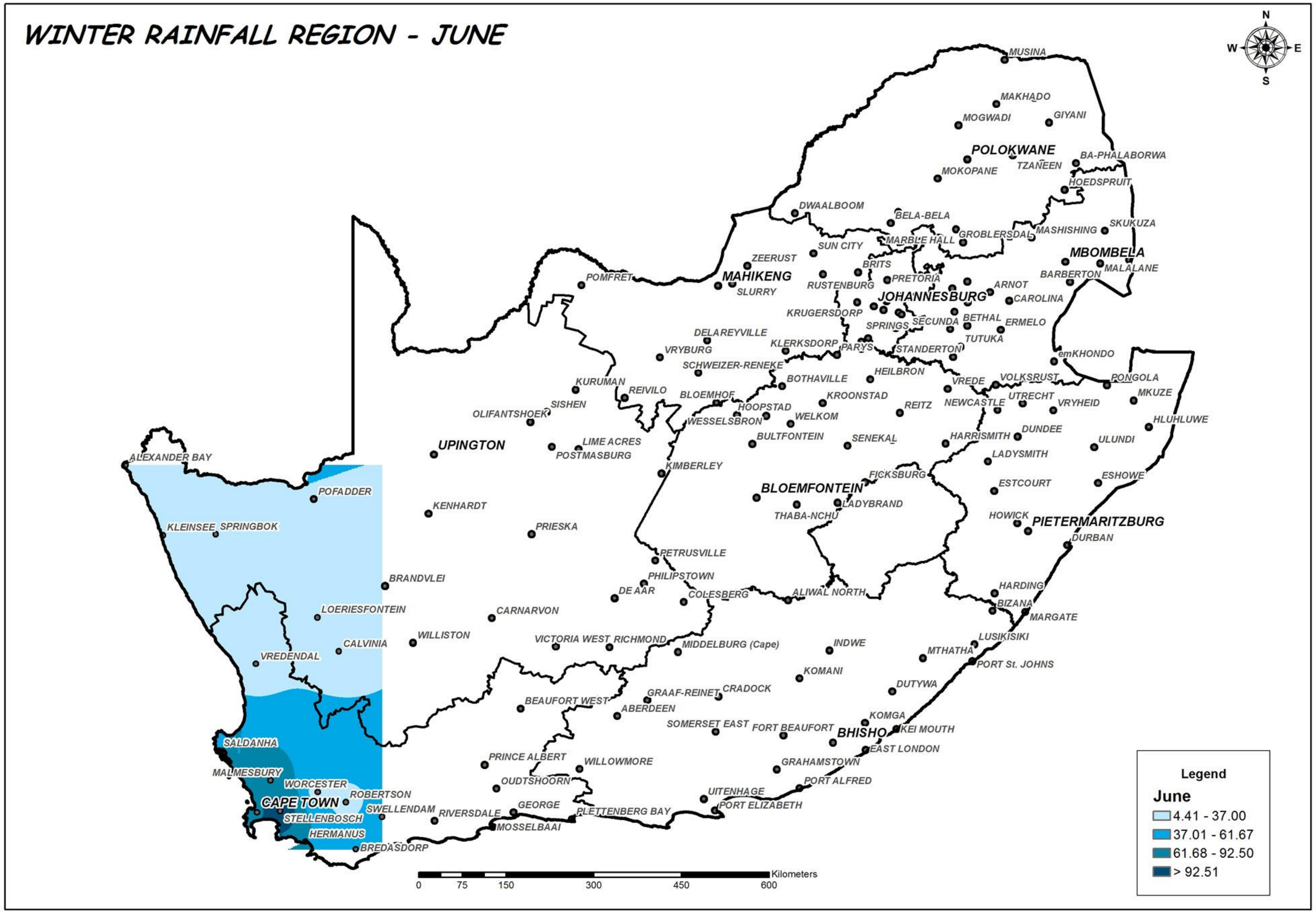
April winter rainfall region linked to monthly average rainfall and hydrozone data.



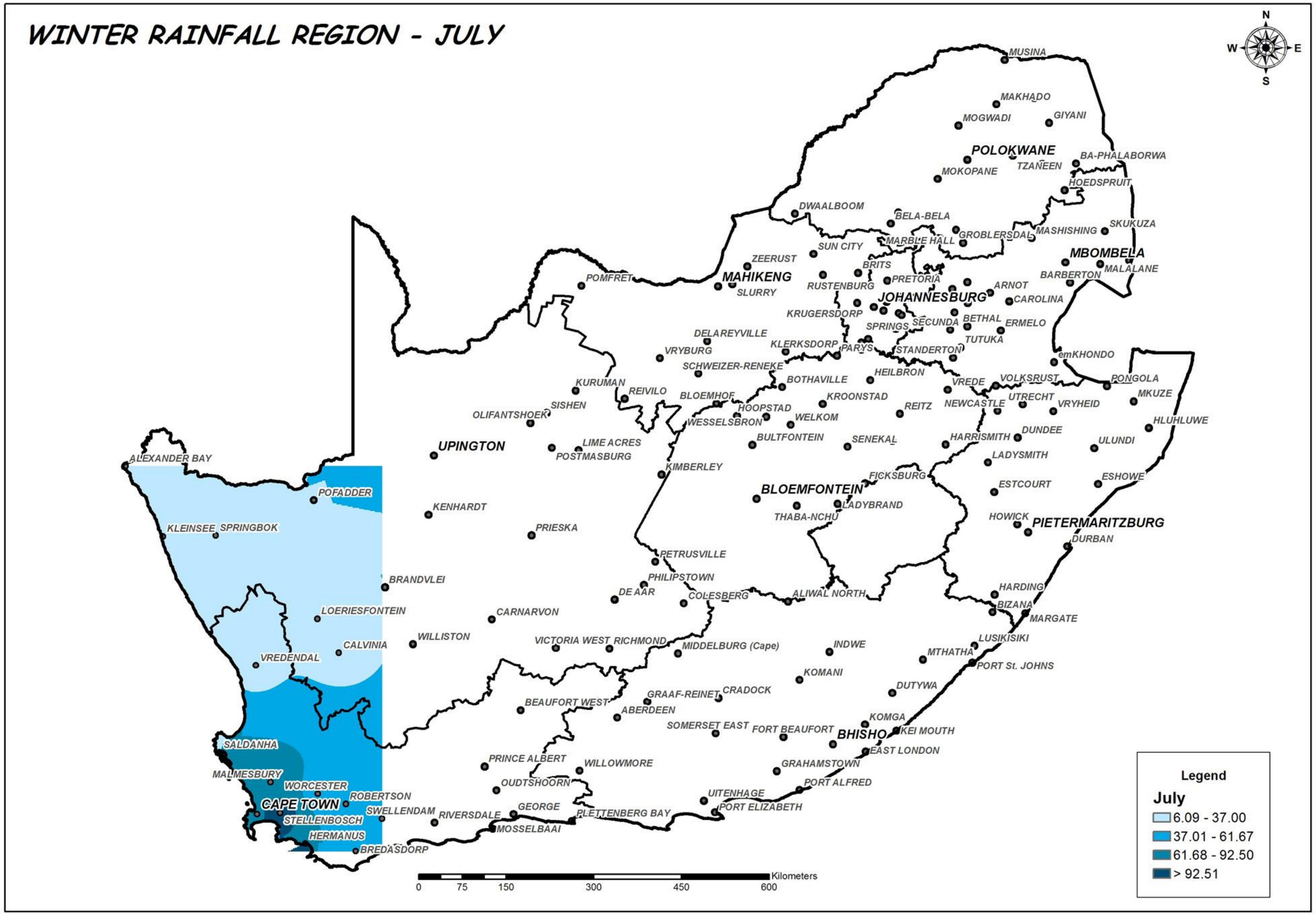
May winter rainfall region linked to monthly average rainfall and hydrozone data.



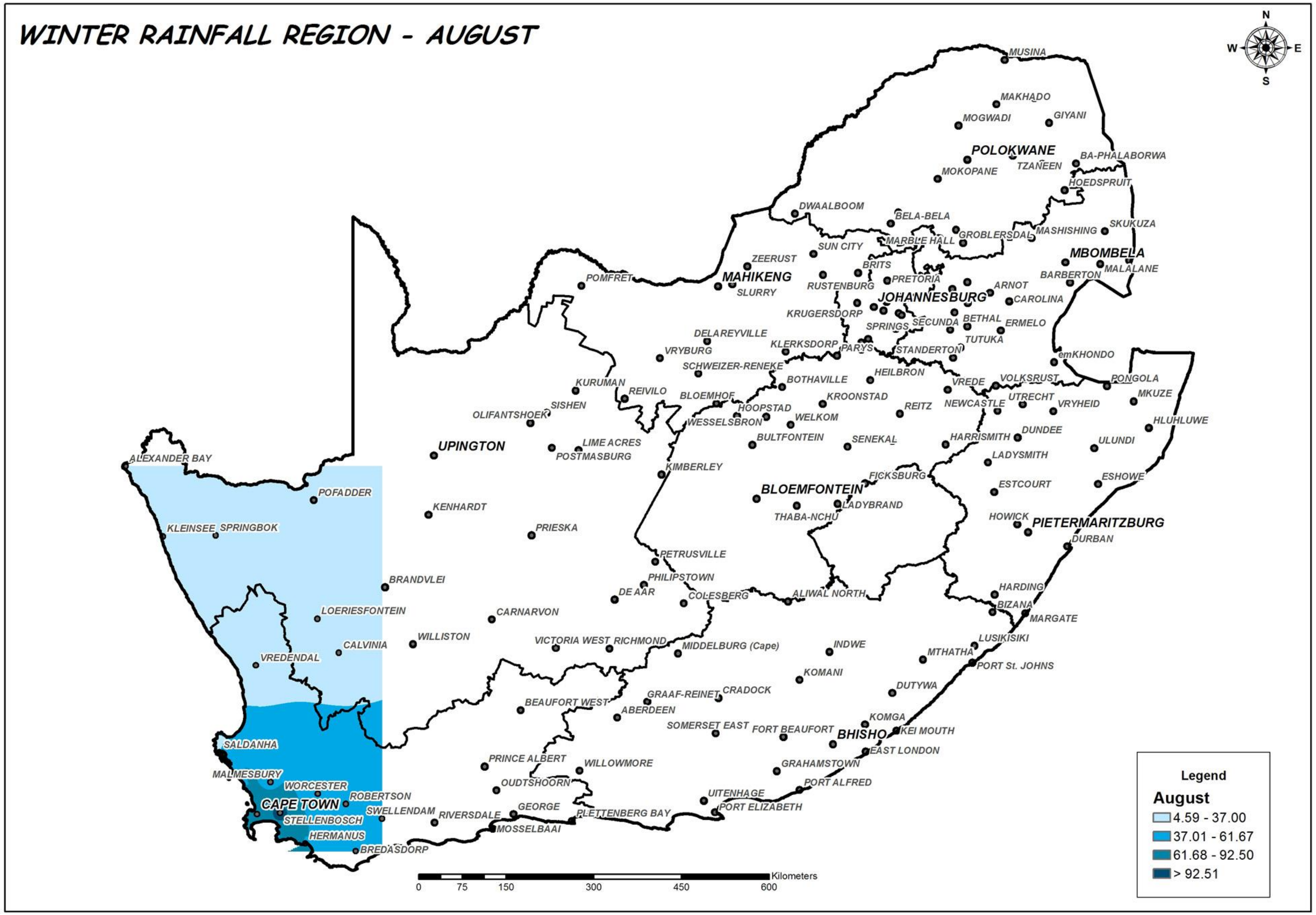
June winter rainfall region linked to monthly average rainfall and hydrozone data.



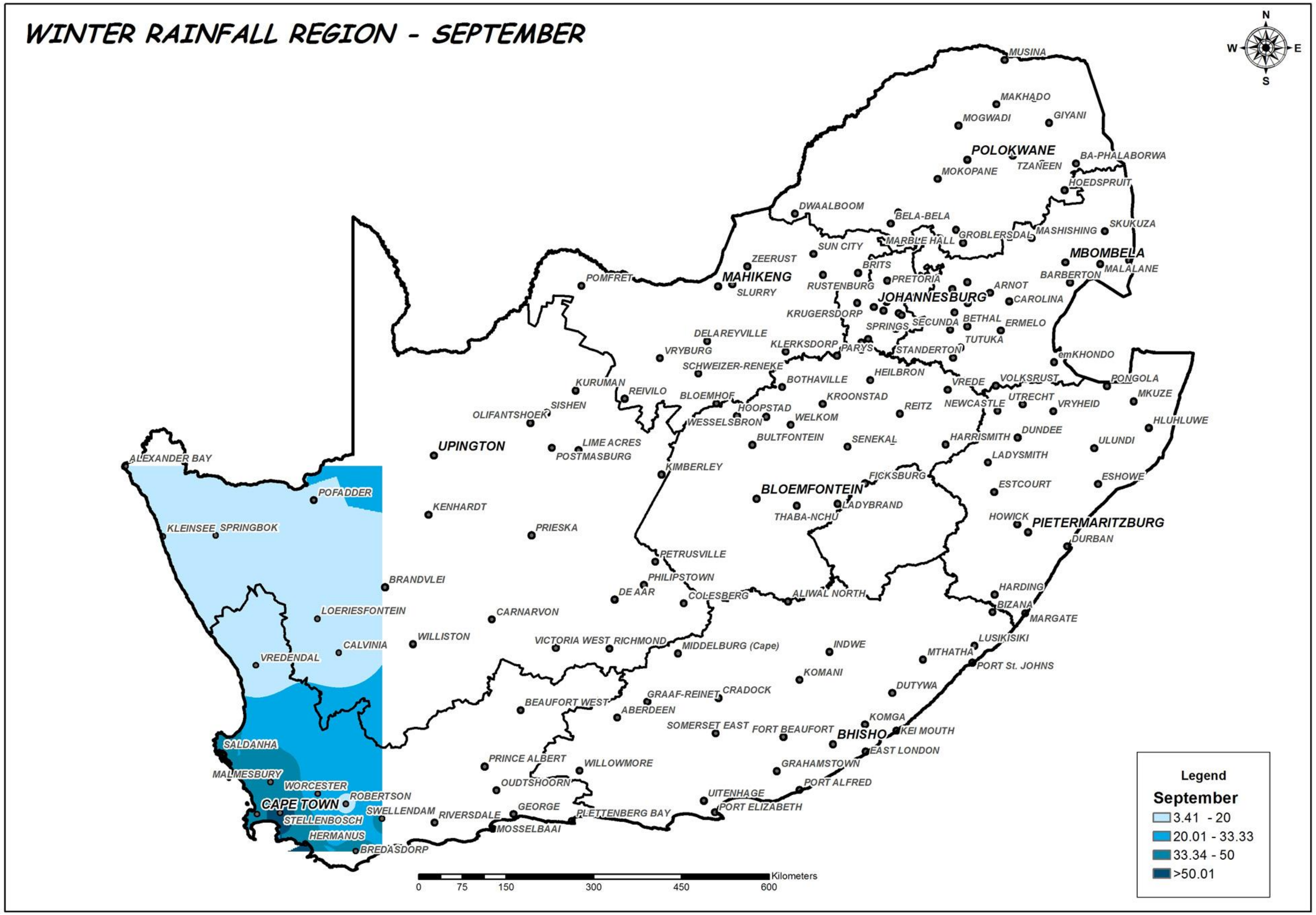
July winter rainfall region linked to monthly average rainfall and hydrozone data.



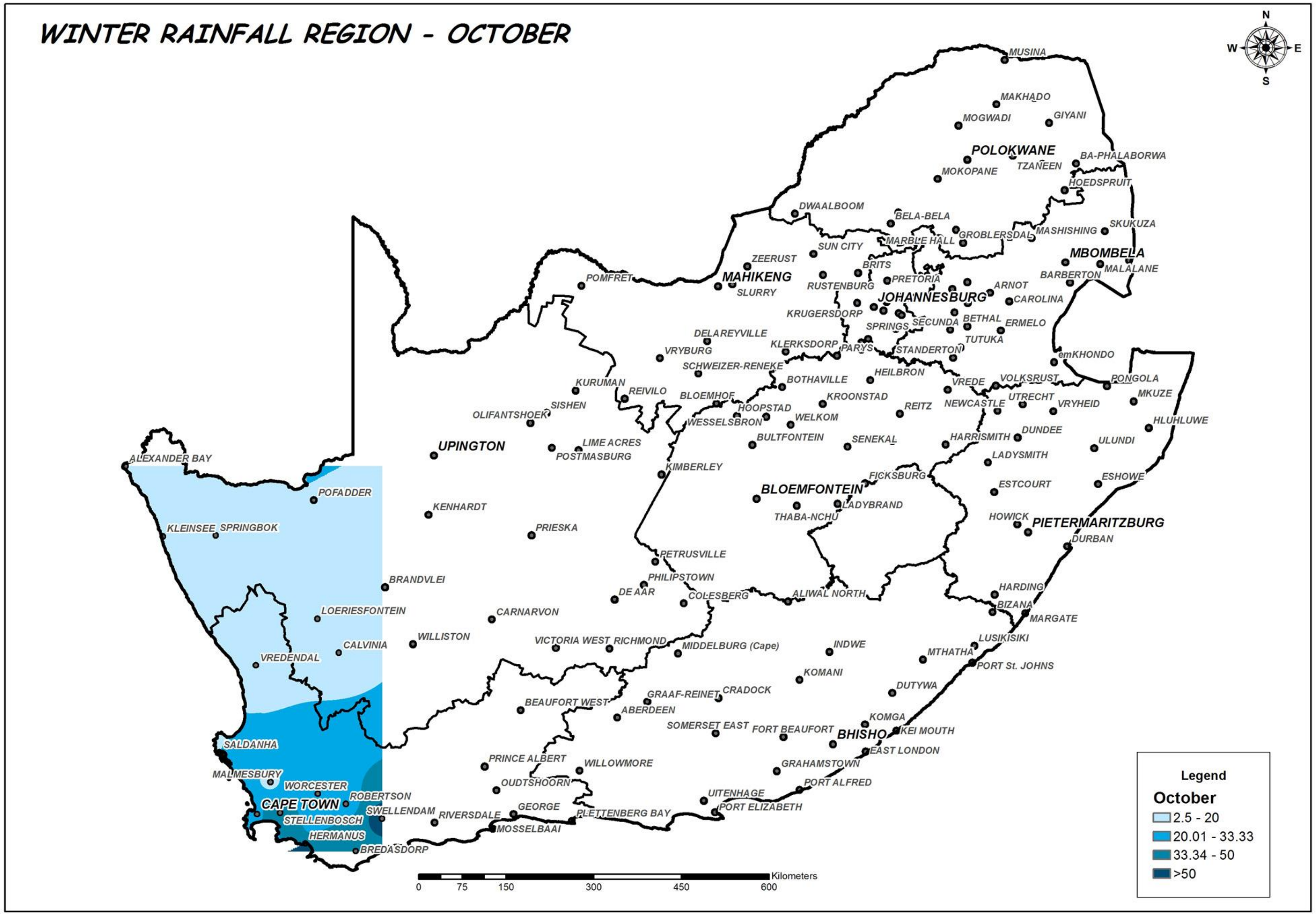
August winter rainfall region linked to monthly average rainfall and hydrozone data.



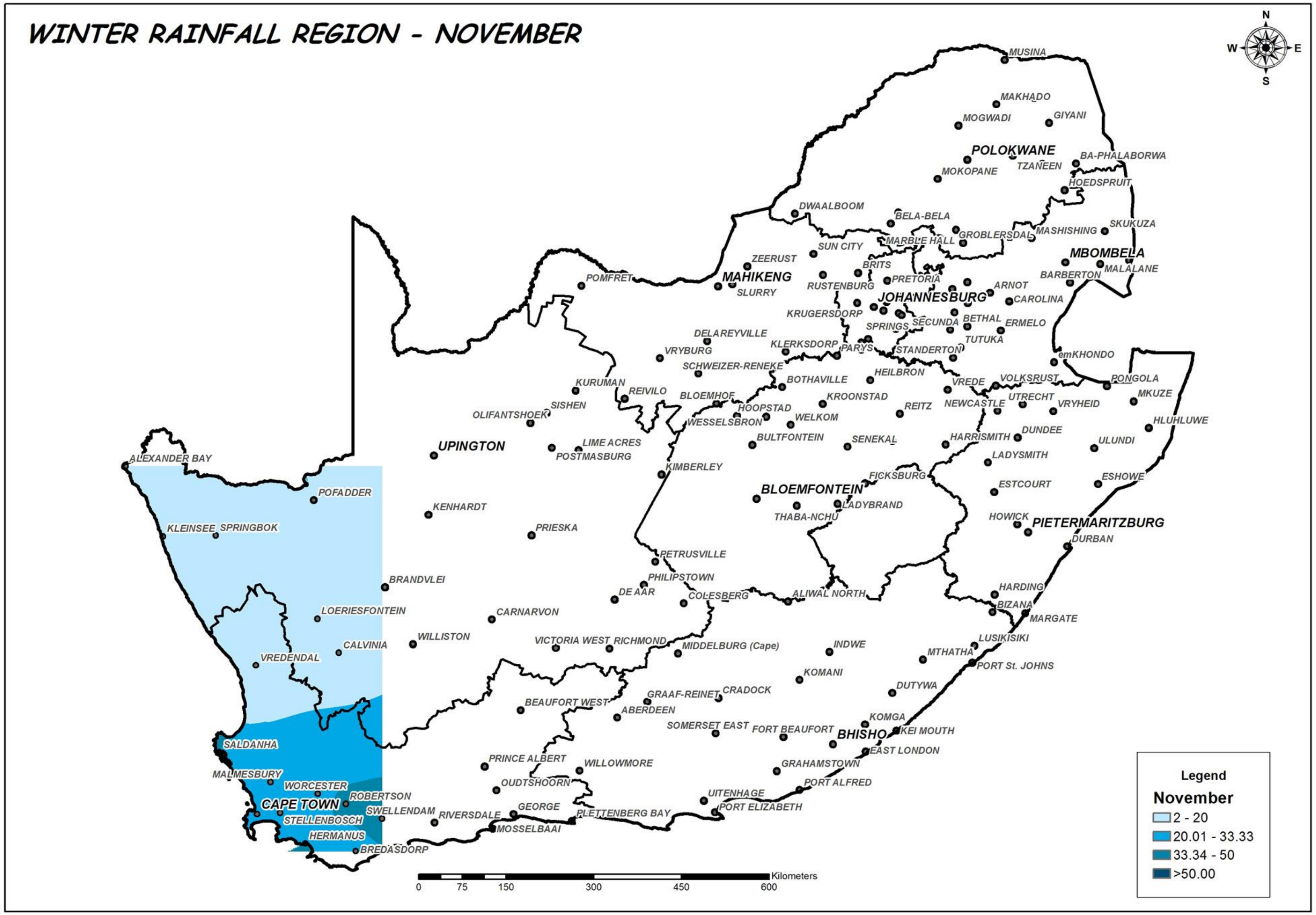
September winter rainfall region linked to monthly average rainfall and hydrozone data.



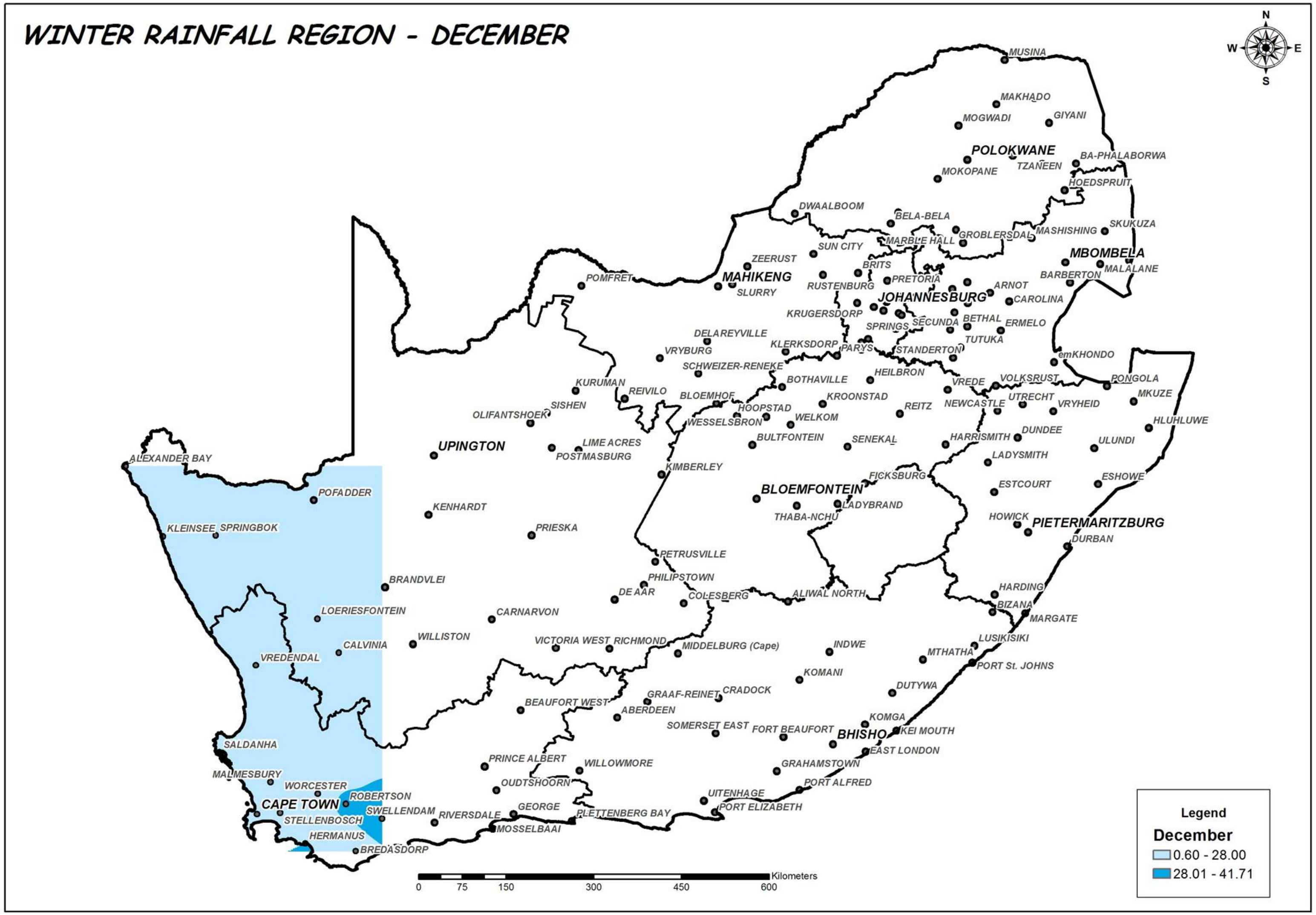
October winter rainfall region linked to monthly average rainfall and hydrozone data.



November winter rainfall region linked to monthly average rainfall and hydrozone data.



December winter rainfall region linked to monthly average rainfall and hydrozone data.



Annexure 11: Complete list of hydrozone references used for the plant data base.

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
Internet - Intnl	Kwantlen Polytechnic University, 2015. *Plant Database*. [online] s.l: s.n. Available at: <https://plantdatabase.kpu.ca/plant/resourcePlantMasterList> [Accessed 21 January 2017].	Dry/No water	No water	
		Low water	Low	
		Moderate water use	Medium	
		High water/Aquatic	High	
Internet - SA	eGardens Online Nursery (Pty) Ltd., n.d.. *Egardens Plants Wizard*. [online] Available at: <http://soulv.co.za/portfolio/egardens-online-nursery> [Accessed 5 February 2017].	Water needs: Low	Low	
		Water needs: medium	Medium	
		Water needs: Lots	High	
Internet - Internl	Salt Lake City Public Utilities, 2013. *Salt Lake City Plant List & Hydrozone Schedule 2013*.	0 - No supplemental water on establishment	No water	
		1- One irrigation application per	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	[online] Salt Lake City. Available at: <http://www.slcdocs.com/utilities/PDF%20Files/2013_SLCPlantList_ver2-1.pdf> [Accessed 4 February 2017].	month 2 -Two irrigation applications per month		
		3 -Three irrigation applications per month	Medium	
		4 Four irrigation applications per month (or once per week)	High	
Internet - SA	Keith Kirstens, n.d.. *Plantinfo*. [online] Available at: <http://plantinfo.co.za/plant> [Accessed 26 January 2016].	Low	Low	
		Moderate watering	Medium	
		High	High	
Internet-SA	Water Use It Wisely, n.d. *Plant List.* [online] Available at: <http://wateruseitwisely.com/100-ways-to-conserve/plant-list/> [Accessed 1 February 2017].	Water: Low	Low	Low Water-Use Zones Low Water-Use Zones are somewhat exposed areas that need some watering, but take advantage of runoff from downspouts, patios, and driveways for most of their water. Using low-volume irrigation systems and effective mulching over the soil and plant roots can oft en turn a Moderate Water-Use Zone into a Low

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
				Water-Use Zone.
Internet-Internl	Arizona Municipal Water Users Association, 2017. *Landscape Plants for the Arizona Desert*. <http://www.amwua.org/plants/> [Accessed 2 February 2017].	Very Low	No water	
		Low	Low	
		Moderate	Medium	
		High	High	
Internet-Internl	SRP, n.d. *Water Efficient Landscape Guide for the Valley.* [Online] Available at: <http://togetherweconservelandscape.com/> [Accessed 2 February 2017].	Very low	No water	
		Low	Low	
		Medium, Low-extra in summer	Medium	
		High, Medium extra in summer	High	
Internet-Internl	Utah Government Services, n.d.. *Water-Wise Plants for Utah*. [Online] Available at:	The plants on the list are (1) water conserving, (2) adapted to Utah's arid climate and cold winters, and (3)	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	<http://www.waterwiseplants.utah.gov/plants.pdf> [Accessed 3 February 2017].	have desirable landscape characteristics which remain desirable under limited water availability. The water wise designation suggests that, on average, the plants only need to be watered approximately once every two weeks after establishment and will still retain their aesthetic characteristics.		
Internet-Internl	Utah State University Cooperative Extension, 2003. *WATER WISE PLANTS FOR UTAH LANDSCAPES.* [online] s.l.: Utah State University. Available at: <http://extension.usu.edu/files/publications/publication/HG-2003-01.pdf> [Accessed 3 February 2017].	The 'water-wise' designation means a plant needs to be watered *at most* once every two weeks ***after establishment*** and will still retain its aesthetic characteristics.	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
Internet-Internl	Talhouk S.N., Fabian M., and Dagher R., 2015. *Landscape Plant Database. Department of Landscape Design & Ecosystem Management*, [online] American University of Beirut: s.n. Available at: <http://landscapeplant.aub.edu.lb> [Accessed 03 Jun 2017].	Low	Low	
		Moderate	Medium	
		High	High	
Internet-SA	Green Building Council of South Africa, 2014. *Green Star SA – Existing Building Performance PILOT POTABLE WATER CALCULATOR GUIDE Revision1*. s.l. [online] Available through Green Building Council of South Africa <https://www.gbcsa.org.za/>	Low water demand plants – 7.5 mm per week	Very Low	
		Medium low water demand plants – 12.5 mm per week	Low	
		Medium water demand plants – 20 mm per week. Medium high water demand plants – 30 mm per week	Medium	
		High Water demand plants-40 mm per week.	High	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	[Accessed 6 April 2015].			
Internet-Internl	Southern Nevada Regional Planning Coalition & Southern Nevada Water Authority, n.d.. *Water Smart Landscape Program plant lists.* [online] s.l.: s.n.. Available at: <https://www.snwa.com/assets/pdf/wsl_plantlist.pdf> [Accessed 7 February 2017].	Water Use: Low, Medium, High (no definition offered) where plants are given 2 options e.g. L-M, the higher water use option was chosen namely M.	Low	
			Medium	
			High	
Internet-Internl	University of California Cooperative Extension California Department of Water Resources, 2000. *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California.* [pdf], [Online] Available at: <ucanr.org/sites/OC/files/132534.pdf> [Accessed 17 March	Very Low	Very Low	WUCOLS (USA) divides plants into 4 categories and some climatic zones have different categories for the same plant. For each of these, the researcher took the highest value for the category for each plant. E.g. if plant had H,M,M,M,L etc. across categories it was rated at high not medium.
		Low	Low	
		Moderate	Medium	
		High	High	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	2013].			
Internet-Internl	Zureikat, L. and Husseini, D., n.d. *Landscape water efficiency guide.* [pdf] Jordan: Center for the Study of the Built Environment(CSBE). Available at: <http://www.mwi.gov.jo/sites/en-us/best%20managment%20practices/landscape%20water%20efficiency%20guide.pdf> [Accessed 28 February 2017].	NO watering once established-Plants are watered by rainfall. Use drought tolerant native vegetation or imported plants from similar regions. Low water use zone. No watering	No water	Researcher classified this as No water zone based on their definition and not the title given.
		Some watering once established-require only occasional watering. Do not require constant watering. Include low-water-use ground covers and shrubs. Once a month	Low	Researcher classified this as Low water zone based on their definition and not the title given.
		Plants that require relatively high amounts of water-high maintained areas, lushest part of the landscape and may require regular watering in the absence of rainfall. Twice a month	Medium	Researcher classified this as medium water zone based on their definition and not the title given.
		Once a week. Require relatively high amounts of water	High	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
Internet-Internl	Keane, T., 1995. *Water-wise Landscaping guide for water management planning*. Utah State University Cooperative: Utah. Available at: <http://digitalcommons.usu.edu/extension_histall> [Accessed 9 February 2017].	• Zone 0 means that little or no irrigation is required. Plants in this zone will be drought tolerant native or naturalized plants. During extended hot spells they may need some irrigation.	Very Low	
		• Zone 1 plants will need a monthly irrigation. During extremely hot or windy weather they may need an additional irrigation.	Low	
		• Zone 2 plants require irrigation once every 2 weeks. They may also require an additional irrigation during hot spells.	Low	
		• Zone 3 plants require weekly watering.	Medium	
		• Zone 4 plants are shallow rooted or water loving. They need irrigation twice per week.	High	
Internet-	Green Building Council of	Very Low water use	Very Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
Internl	Australia, 2012. *Green Star – Potable Water Calculator Guide* [online] Available at: <http://www.gbca.org.au> [Accessed 19 July 2014].	Low water use	Low	
		Moderate water use	Medium	
		High water use	High	
Brochure - SA	Rosendal Farms, 2004. *Rosendal Farms.* s.n.: s.l..	Drought tolerant (illustrated by picture of a camel)	Low	
Book - SA	Simpson, M., 1985. *Annuals for the South African Garden.* Centaur: Cape Town.	Empty watering can -Requires little water and will tolerate long dry periods.	Low	
		Half full watering can - Average watering requirements - normal watering	Medium	
		Full watering can- an extremely thirsty plant; requires a lot of water	High	
Book - Internl	Chatto, B., 1980. *The Dry Garden.* Saga press Inc: New York.	Drought resistant	Low	Note from the author, pg88 "nothing has been watered except at the time of planting". Page 17 author referred to "That year from November '58 to November '59, our rainfall was 14.65 in/370 mm."

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
				Researcher therefore placed these plants in the Low category (as per RW definition)
Book - SA	Pienaar, K., 1991. *Gardening with Indigenous Plants*. Struik Timmins Publishers: Cape Town.	Little water	Low	
		Average water	Medium	
		Lots of water	High	
Book - SA	Poynton, R.J., 1984. *Characteristics and uses of selected Trees and Shrubs cultivated in South Africa.* Directorate of Forestry Republic of South Africa: s.l.	XXX -Very resistant: able to survive without watering, once well established, in the arid interior regions, Drought hardy.	No	
		XX-Moderately resistant: suitable for planting in the semi-arid interior regions of the central, N, NE Cape dryland of Natal midlands, W-OFS, etc. Suitable for drier areas as long as sufficient soil moisture.	Low	
		X-Somewhat susceptible: unable to survive in the semi arid regions	Medium	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		except in presence of abundant seepage water. Drought hardy (but not frost sensitive) at Humansdorp, Ladysmith, Bethlehem and in Pretoria -Witwatersrand area.		
		No X-Susceptible; undependable in subhumid regions except on selected sites where supplementary soil moisture is available. Drought hardy (but not frost sensitive) at George, Cedara, Van Reenen and Piet Retief.	High	
Book - Internl	Eslick, C. (Ed)., 1999c. *Growers guide to Annuals.* North Sydney: Murdock Books.	Allow to dry out somewhat between waterings.	Low	
		Occasional deep watering once established.	Low	
		Keep fairly dry throughout the growing season.	Low	
		Deep regular soakings in dry weather.	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		Water regularly but do not allow soil to dry out/water regularly throughout growing period.	Medium	
		Water regularly/ Heavy watering less often	Medium	
		Water heavily every 7-10 days	Medium	
		Water heavily once or twice a week	High	
		Water heavily once a week and maybe more if hot	High	
		Never let plants be short of water	High	
		Needs regular copious supplies of water.	High	
		Keep soil moist at all times	High	
Book - Internl	Eslick, C. (Ed)., 1999b. *A Growers Guide to Perennials.* North Sydney: Murdock Books.	Drought tolerant but responds well to occasional deep watering	Low	
		Water in dry spells of hot dry weather/Tolerates dry conditions well.	Low	
		Give only occasional deep watering	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		Deep watering every week or two//Needs ample water supply in summer and spring, but tolerates dry periods.	Medium	
		Deep weekly watering (for flowering)	Medium	
		Need regular watering in summer and spring	Medium	
		Needs plenty of water throughout summer & spring or it will die/ Regular deep watering in spring & summer	High	
		Water heavily every week	High	
		Regular deep watering	High	
		Keep soil just moist throughout the warmer months.	High	
		Needs ample water supply in summer and spring	High	
Book - Internl	Allaway, Z. (Ed)., 2013. *The Royal Horticultural Society What Plant Where*	Empty water droplet - Prefers well drained soil	Low	
		Half full water droplet -Prefers moist	Medium	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	Encyclopaedia. Dorling Kindersley Limited: London.	soil		
		Full water droplet-Prefers wet soil	High	
Book - Internl	Perry, F. (Ed)., 1982. *The Macdonald Encyclopaedia of Plants & Flowers.* Macdonald & Co: London.	Quarter full watering can - Sparingly	Low	
		Half full watering can -Sufficiently	Medium	
		Full watering can-Generously	High	
Book - Internl	Lord, T., 2010. *Plant Combinations for Your Landscape*. Creative Homeowner: Upper Saddle River. 1-368pp	One drop indicates dry conditions	Low	Raindrop symbols show the plants preferred soil water content. (author often indicated plant could be 1-2 or 2-3 drop, researcher selected the lowest version)
		Two drops indicates soil that is always moist, never water logged or dry	Medium	
		Three drops indicates plenty of moisture year round	High	
Book - Internl	Denver Water., 1998. *Xeriscape Plant Guide*, Fulcrum Publishing, Colorado. 2-176pp.	Low/Dry	Low	
		Moderate/Somewhat dry/ best with occasional deep soaking	Medium	
		Moist	High	
Book - SA	Sheat, W.G., 1993. *The A-Z of Gardening in South Africa.* Struik Publishers: Cape Town.	Quarter full watering can - requires little water and will tolerate long dry periods.	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		Half full watering can - average water requires normal watering.	Medium	
		Full watering can - an extremely thirsty plant; requires a lot of water	High	
Book - Internl	Brandies, M.M., 1994. *Xeriscaping for Florida Homes*. Great Outdoors: St.Petersburg.	Very drought tolerant: Will survive without supplemental irrigation after establishment.	Very Low	
		Moderately drought tolerant: Will require supplemental irrigation during extreme dry periods to maintain attractive appearance.	Low	
Book - SA	Joffe, P., 2003. *Easy Guide to Indigenous Shrubs*. Briza Publications: Pretoria.	Quarter full watering can - Requires little water	Low	
		Half full watering can - Requires moderate water	Medium	
		Full watering can- requires lots of water	High	
Book - Internl	Eslick, C. ed., 1999a. *Growers guide to Bulbs*. Ultimo: Murdock Books.	Allow to dry out somewhat between waterings	Low	
		Occasional deep watering once	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		established		
		Keep fairly dry throughout the growing season.	Low	
		Deep regular soakings in dry weather	Low	
		Water regularly but do not allow soil to dry out/water regularly throughout growing period	Medium	
		Water regularly/ Heavy watering less often	Medium	
		Water heavily every 7-10 days	Medium	
		Water heavily once or twice a week	High	
		Water heavily once a week and maybe more if hot	High	
		Never let plants be short of water	High	
		Needs regular copious supplies of water.	High	
		Keep soil moist at all times	High	
Book - SA	Johnson, D., Johnson, S. and Nichols, G., 2002. *Gardening*	(Picture - Cloud with little rain) Grows best in area with low rainfall.	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	with Indigenous Shrubs. Struik: Cape Town.	(Picture - Cloud with half rain) Grows best in area with moderate rainfall.	Medium	
		(Picture- Cloud with rain) Grows best in area with high rainfall.	High	
Book - SA	Pienaar, K., 1985. *Grow South African Plants.* Struik: Cape Town.	(Empty watering can) Little water	Low	
		(Half full watering can) Average water	Medium	
		(Full watering can) Lots of water	High	
Book - SA	Pienaar, K., 2000. *The South African What Flower is That?* Struik: Cape Town.	(Empty watering can) Little water	Low	
		(Half full watering can) Average water	Medium	
		(Full watering can) Lots of water	High	
Book - Internl	Hodges, J., 2008. *The water-wise garden How you grow healthy plants using less water.* Viking: Camberwell.	Minimal water conditions	Low	
Book - SA	Kirsten, K., 1992. *Keith Kirsten's complete garden Manual for South Africa.* Human & Rousseau (Pty) Ltd:	Plants for dry conditions	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	Cape Town.			
Book - Internl	Maclay, G. (Ed)., 1984. *Illustrated Encyclopedia of Gardening in South Africa.* Readers Digest: Cape Town.	Plants for hot dry areas.	Low	
Book - Internl	Dunmire, J.R. (Ed)., 1972. *Sunset Western Garden Book*. Lane Magazine & Book Company: California.	Dry places	Low	
		Wet places	High	
Book - SA	Van Jaarsveld, E., 2000. *Wonderful Waterwise Gardening*. Tafelburg publishers: Cape Town.	Succulent Karoo garden - rainfall of less than 300 mm.	No water	The plants in this book where divided according to their water use as outlined in the initial part of the book and linked back to the RW definition on the amount of water a plant should have. Also in each category all aquatic plants (submerged or floating) were all given a rating of 3 regardless of the area/zone. In some cases plant was listed as low but also as medium water use. In these cases the
		Strandveld Garden - rainfall 300-500 mm	Low	
		Thicket garden - Rainfall less than 500 mm/a	Low	
		Karoo garden - Rainfall of less than 600 mm/a	Low	
		Fynbos garden - Rainfall of higher than 500 mm/a	Medium	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		Bushveld garden - Rainfall of between 400 – 800 mm/a	Medium	plant was allocated the higher water use category.
		Highveld garden - Rainfall 500-1000 mm/a	Medium	
		Forest Garden - Rainfall greater than 1000 mm/a	High	
Book - Internl	Houghton Mifflin Company 1990. *Taylors Guide to Water-Saving Gardening*. Tokyo: Houghton Mifflin Company.	Extremely drought tolerant - Needs less than 14 inches of water per year	Low	**Converted to mm** (355.6) and referenced back to RW lists.
		Very drought tolerant Needs about 16 inches of water per year.	Low	**Converted to mm** (406.4) and referenced back to RW lists.
		Moderately drought - Needs about 18 inches of water per year.	Low	**Converted to mm** (457.2) and referenced back to RW lists.
		Fairly drought tolerant - needs about 20 inches of water per year.	Medium	**Converted to mm** (508) and referenced back to RW lists.
		Slightly drought tolerant - Needs about 22 inches of water per year.	Medium	**Converted to mm** (558.8) and referenced back to RW lists.
Book - Internl	Green, C., 1999. *Gardening Without Water Creating beautiful gardens using only rainwater*. Search Press	Drought resistant plants	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	Limited: Kent.			
Book - SA	Joffe, P., 2001. *Creative gardening with Indigenous Plants: A South African Guide.* Brizia Publications: Pretoria.	Empty watering can - Requires little water	Low	
		Half full watering can - Requires moderate water	Medium	
		Full watering can - lots of water	High	
Book - Internl	Stewart, K., and Alexander, M. (Eds)., 2010. *Waterwise Gardening: How to create and maintain a beautiful garden without wasting a drop.* Ultimo: Reader's Digest (Australia) Pty Limited.	NO water/Low water apply within specific climate zones for the plant.	Low	No water zone. "Plants in this zone survive with no supplementary watering once established. This area will only need to be watered during prolonged periods of drought". All plants are listed as requiring either L/M or H water use irrespective of climate zone and hence all Low plants here were kept as Low for the study.
		Additional plants were also listed as Water Wise plants and these were also listed at Low water use plants.	Low	
Book - SA	Barnhoorn, C., 2013. *The Bulb Book: A South African Gardener's Guide.* Sunbird	A little amount of water. Water sparingly during growth period.	Low	Where only the genus was listed only plants in the database that were listed as specific species or hydrids were then given

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	Publishers: Cape Town.6-202pp.	Medium amount of water.Regular watering during growth period.	Medium	the applicable rating. They were specific to indicated that for certain bulbs watering must only be during the growing period (therefore landscapers will need to know this and apply this in the maintenance and design aspects) The watering listed is only for the active growing period which differs for summer, winter and evergreen bulbs.
		Lot amount of water	High	
Book - Internl	Winger, D., (Ed)., 1998. *Xeriscape Color Guide: 100 Water-Wise Plants for landscapes.* Denver Water & Fulcrum Publishing: Colorado.	Low - Watering is required infrequently and only during extended dry periods in the summer	Low	They indicate in some cases that the plant could adapt to either high or low water use. I took the highest rating between what they indicated the plant requires and what it could adapt to use, as I felt that this is what could happen in a landscape.
		Moderate - watering required regularly but not frequently	Medium	
		Higher - water must be applied regularly and frequently	High	
Booklet - SA	Rand Water, n.d., *Water Wise Planting: Group Plants according to their water needs.* [pdf] Available at: <http://www.waterwise.co.za>	Receive less than 300 mm rainfall per annum. Water on in severe cases.	No water	All Wholesale Nurseries that contributed to the mail that the researcher sent out asking for feedback on their sales lists, used this definition.
		Receive annual rainfall of between 300-500 mm rainfall. water every 6-8	Low	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
	[Accessed 24 April 2017].	weeks		
		Receive between 500-750 mm rainfall a year. If they show signs of distress in dry times water. Water once a month in winter.	Medium	
		Receive over 900 mm of annual rainfall. Water once a week in general, and twice or three times a week during very hot dry spells	High	
Booklet – SA	Rand Water Environmental Management Services Department, n.d., *Water Wise Watering*. [pdf] Available at: <http://www.waterwise.co.za/export/sites/water-wise/gardening/water-your-garden/downloads/Water_Wise_Watering.pdf> [Accessed 20 April 2017].	No watering required unless in extreme cases	No water	All Wholesale Nurseries that contributed to the mail that the researcher sent out asking for feedback on their sales lists, used this definition.
		Summer-12 mm(50%)/week Spring/Autumn-7 mm(25%)/week Winter-12 mm every second week (including lawns but not at all if dormant)	Low	
		Summer-15 mm(60%)/week Spring/Autumn-12 mm(50%)/week Winter-7 mm (25%)/week	Medium	

Source	Reference	Definition provided by the source data	Matched hydrozone allocated for use in this study VL/L/M/H	Notes
		Summer-25 mm(100%)/week Spring/Autumn-15 mm(60%)/week Winter-12 mm (50%)/week	High	
Wholesaler- SA	Beckwith, S., 2015. *E mail on plant data base feedback*. [E mail] (Personal communication 22 April 2015).	• 1 drop zone = plants that need to be watered once a week.	Medium	Changed their zones to more suite zones of others and RW
		• 2 drop zone = plants that need to be watered twice a week.	High	
		• 3 drop zone = plants that need to be watered more than twice a week.	High	
Wholesaler - SA	Vrone Nursery.			Note from Vrone Nursery after listing their plants as H/M/L etc. "The above information is based on experience, without scientific testing, and will obviously vary depending on climate, soil type, amount of composting and mulching, size of the plants, and so on. Many plants will survive on less water, but not thrive, and with ornamental plants, the idea is to have them looking their best for maximum enjoyment of the garden."

Annexure 12: Plant type and plant factor listed by various authors for either months or average.

Plant type and plant factors listed by various sources.																	
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
3	General Lawns, Golf Rough & Fairway - *Warm-season Turfgrass*	0.1	0.3	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.3	0.1					
1	Warm season - High (Golf course)														0,65			
2	Warm-season grass	0.55	0.54	0.76	0.72	0.79	0.68	0.71	0.71	0.62	0.54	0.58	0.55		0,60			Species include Bermuda grass, Zoysia grass, and St. Augustine grass.
1	Warm Season grass													0,90		0,90		
4	Warn-season																	

Plant type and plant factors listed by various sources.																		
Source (see list below)	Plant Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	High water	Average water	Low water	Very Low	Notes
	turf grass																	
1	Warm season - Acceptable (Park)														0,76			
5	Turf - Warm season e.g. Buffalo, Couch, Kikuyu, Zoysia.													0,70		0,25		
6	Warm Season grass													0,80		0,40		
5	Turf - Moderate growth, just acceptable													0,40		0,25		
5	Turf - Strong growth													0,55		0,45		
5	Turf - Vigorous growth													0,70		0,55		

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
3	Sports Fields; Golf Greens & Tees - *Warm-season Turfgrass*	0.4	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.5	0.4					
3	Overseeded General Lawns & Golf Fairways	0.8	0.8	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.8	.08	0.8					
3	Overseeded Golf Greens & Tees	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8					
9	Lawns														1,00			
3	General Lawns, Golf Rough & Fairway - *Cool-season Turfgrass*	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8					
1	Cool season -														0,72			

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
	High (Golf course)																	
2	Cool-season grass	0.61	0.64	0.75	1.04	0.95	0.88	0.94	0.86	0.74	0.75	0.69	0.6		0,80			Species include Tall fescue, Ryegrass, Bentgrass, and Kentucky bluegrass.
1	Cool-season grass													1,00		0,85		
4	Cool-season turf grass														0,80			
1	Cool season - Acceptable Park														0,65			
5	Turf - Cool season e.g.. Bentgrass, Bluegrass, Tall Fescue,													0,85		0,65		

Plant type and plant factors listed by various sources.																	
Source (see list below)	Plant Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	High water	Average water	Low water	Very Low	Notes
	Ryegrass																	
5	Turf - Cool season Moderate growth, just acceptable													0,70		0,65		
5	Turf - Cool season Strong growth													0,75		0,70		
5	Turf - Cool season Vigorous growth													0,85		0,80		
3	Sports Fields, Golf Greens & Tees - *Cool-*	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
	season Turfgrass																	
3	Annual Flowers	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8					
6	Annual Flowers													0,80		0,70		
3	Groundcovers	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6					
4	Groundcover													0,90	0,50	0,20		
5	Ground Covers													0,60		0,30		
6	Ground Covers													0,70		0,05		
3	Trees	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6					
4	Trees													0,90	0,50	0,20		
5	Trees													0,80		0,30		

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
9	Trees														0,00			
6	Trees													0,70		0,05		
3	Shrubs	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6					
4	Shrubs													0,70	0,50	0,20		
5	Shrubs													0,70		0,30		
6	Shrubs													0,70		0,05		
3	Herbaceous Perennials	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7					
6	Herbaceous Perennials													0,80		0,70		
3	Native Plants for America	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3					
9	Native plants -														0,40			

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
	for India																	
3	Vegetable Gardens	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					
5	Vegetables													0,90		0,40		
3	Home Orchard *Deciduous*	0.1	0.3	0.6	0.7	0.8	1.0	1.0	1.0	1.0	0.8	0.3	0.1					
3	Home Orchard *Evergreen*	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8					
4	Mixture of trees, shrubs & groundcover													0,90	0,50	0,50		
9	Newly planted plants														0,70			
7	General plant factor													0,80	0,50	0,20	0,10	

Plant type and plant factors listed by various sources.																	
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
8	General plant factor													0,80	0,50	0,20	0,10	In order to determine an average rating for comparison basis the mid-range for each factor in this reference was chosen. The full range values are displayed below.
10	General plant factor													0,80	0,50	0,20	0,10	In order to determine an average rating for comparison basis the mid-range for each factor in this reference was chosen. The full range values are

Plant type and plant factors listed by various sources.																		
Source (see list below)	**Plant Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**High water**	**Average water**	**Low water**	**Very Low**	**Notes**
																		displayed below.
												Average		0,77	0,59	0,41	0,10	

Reference list of sources of data:	
1	Brown, P.W., n.d. *Azmet Evapotranspiration Estimates: A Tool For Improving Water Management Of Turfgrass*. [online] University of Arizona. Available at <http://ag.arizona.edu/azmet/et1.htm> [Accessed 6 January 2014].
2	Pittenger, D. and Shaw, D., 2004 What We Know About Landscape Water Requirements. Co-Hort, 6.1(Spring), 1-3pp.
3	Pittenger, D., 2014. *A Report to the Barton Springs/Edwards aquifer conservation trust: Methodology for estimating landscape irrigation demand, Review and recommendations.* [online] s.l.: s.n.. Available at: <bseacd.org/uploads/BSEACD_Irr_**Demand**_Meth_Rprt_2014_Final_140424.pdf> [Accessed 22 February 2017].
4	McCabe, J. 2005. *Landscape Irrigation Scheduling and Water Management*. [pdf] s.l.: The Irrigation Association. Available at: <http://www.weatherset.com/Explain/IA_2005.pdf> [4 November 2017].
5	Connellan, G., 2002. *Efficient irrigation:A reference manual for turf and landscape.* [pdf] Melbourne:University of Melbourne. Available at: <http://southeastwater.com.au/SiteCollectionDocuments/Business/Local-government/Attachment6EfficientIrrigationForTurfAndLandscape.pdf> [Accessed 25 January 2015].

Reference list of sources of data:	
6	University of California, 2016. *Using ANSI/ASABE S623 & SLIDE to Estimate Landscape Water Requirements*. [online] Available at: <http://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/SLIDE__Simplified_Irrigation_Demand_Estimation/> [Accessed 7 March 2017].
7	Riverside County Transportation and Land Management Agency. 2009. *Comprehensive Landscape Guidelines and Standards*. [online] Riverside County Transportation and Land Management Agency. Available at: <http://rctlma.org/Portals/7/documents/landscaping_guidelines/Comprehensive_Landscape_Guidelines_and_Standards.pdf>. [Accessed 4 July 2016].
8	University of California Cooperative Extension California Department of Water Resources, 2000, *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California*[pdf], *Available at:* <ucanr.org/sites/OC/files/132534.pdf> [Accessed *17* March 2013].
9	Ministry of New and Renewable Energy, Government of India, and The Energy and Resources Institute, 2008. *National Rating System -The Green Rating for Integrated habitat Assessment.* [pdf] New Delhi: T E R I Press. Available at: <http://grihaindia.org/> [Accessed 9 June 2017].
10	Costello, L.R. and Jones, K.S., 2014. *Water Use Classification of Landscape Species: WUCOLS IV 2014*. [online] s.l.: University of California. Available at: <ucanr.edu/sites/WUCOLS/Download_WUCOLS_IV_List/?sharebar=share> [Accessed 10 January 2013].

Annexure 13: Hydrozone linked plant database for South Africa.

Refer to separate excel sheet with final plant database (one disk).

Annexure 14: List of wholesale and other growers, that provided hydrozone data linked to plant species.

List of suppliers:
Andy Titterton Wholesale Nursery – Walkerville -Gauteng
Arnellia Farms - Hopefield Western Cape
Ballstraathof – Roodepoort - Gauteng
Coprosma Nursery – Krugersdorp - Gauteng
ECO Balance Landscapers – Ballito - Gauteng
Elands Nursery - Uitenhage - Eastern Cape
Green Reflections CC – Donkerhoek - Gauteng
HADECO (PTY) LTD – Roodepoort - Gauteng
Malanseuns – Rosslyn - Gauteng
Mayford seeds – Lanseria - Gauteng
Montana Nurseries – Nelspruit - Mpumalanga
Samgro Wholesale Nursery – Wellington - Western Cape
Sebenza Nursery South Coast – Margate - Kwazulu Natal (KZN)
Sittigs Nursery: Garden Fun – Hartebeespoort - North West
Super Garden Centre – Sandton - Gauteng
Vrone Nursery – Roodepoort - Gauteng
Wildflower Nursery – Hartebeespoort - North West

Annexure 15: Incorrect plant names versus correct plant names.

EXAMPLES OF INCORRENT PLANT NAMES USED	EXAMPLES OF CORRECTED PLANT NAME OR OTHER ACTION
Aspidistrus "variegated"	*Aspidistra* "variegated"
Aspidistrus "Green"	Plant was removed from database as it was unclear what plant was actually meant.
Anthirrhinum	*Antirrhinum*
Aster novi-belgii 'Mystery Lady® Jessica® var. 'Dasjes'	*Symphyotrichum novi*-belgii 'Mystery Lady® Jessica® var. 'Dasjes'
Babylon Eye Rose	*Rosa* Babylon Eye Rose
Balanites mauyhamii	*Balanites maughamii*
Brachycome	*Brachyscome*
Calocephalus brownie	*Leucophyta brownii*
Capurinea aurea	*Calpurna aurea*
Carya illinoinensis	*Carya illinoensis*
Cordelia africana	*Cordyla africana*
Coreopsis sollana Golden Sphere	*Coreopsis solanna* Golden Sphere
Crassula streyii	*Crassula streyi*
Cyperus articulates	*Cyperus articulates*
Davallia trichomanioides	*Davallia trichomanoides*
Dianthus heddeweggii	*Dianthus heddewegii*
Durantha yellow	Removed as it was unclear which plant this

EXAMPLES OF INCORRENT PLANT NAMES USED	EXAMPLES OF CORRECTED PLANT NAME OR OTHER ACTION
	was.
Dyschoriste fisheri	*Dyschoriste fischeri*
Chondropetalum tectorum	*Elegia tectorum*
Euphorbia splendens	*Euphorbia milii splendens*
Haplocarpa scaposa	*Haplocarpha scaposa*
Markamia acuminate	*Markhamia acuminate*
Protorhus longofolia	*Protorhus longifolia*
Syncolestemon densiflorus	*Syncolostemon densiflorus*
Erethia rigida	*Ehretia rigida*
Leonotis leonurus "white" /Leonotis 'white lion'	*Leonotis leonurus* "Alba"
Lyssimachia 'green'	*Lysimachia nummularia*
Plumbago auriculata "Blue"	*Plumbago auriculata*
Prunus domestica	*Prunus x domestica*
Bulbinella fructescens "Orange"	*Bulbine frutescens*
Rosemary *officinalis* "Barbeque"	*Rosmarinus officinalis* "Barbeque"
Eugenia paniculata	*Syzygium paniculatum*
Dierama medium	No such plant and as a result plant removed from database
Cupressocyparis leylandii 'Gold crest'	Does not exist it could be *Cupressocyparis leylandi* 'Gold Rider' or *x Cupressocyparis*

EXAMPLES OF INCORRENT PLANT NAMES USED	EXAMPLES OF CORRECTED PLANT NAME OR OTHER ACTION
	leylandi 'Castlewellan Gold' or *Cupressus macrocarpa* 'Gold crest'. Due to working just from list and not actual plant identification this was actually removed in total.
Platycladus orientalis 'skyrocket'	Incorrectly named. Could be a range of plants and therefore deleted.

Annexure 16: Site A.

	Amenity Landscape site water use assessment model												
	Main Element /questions	**Element/questions**	**Sub-element**	**Site Name & ID: Site -A**									
			Sub aresa of site →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)	Yes/no	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings.	Yes/no/partial	N	N	N	N	N	N	N	N	N	N
3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings.	Yes/no/partial	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Microclimate - solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation).	Yes/no/partial	P	P	P	P	P	P	P	P	P	P
5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun	Yes/no/partial	N	N	N	N	N	N	N	N	N	N
6	Mulch (choose only one)	Is bare soil on site covered by mulch (organic ie can it decompose).	Yes/no/partial	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath).	Yes/no/partial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site	Yes/no/partial	T	T	T	T	T	T	T	T	T	M
		Landscape style/type - **Transformed**.	Yes/no/partial										
		Landscape style/type - **mix** of natural and transformed.	Yes/No										
9	Gradient/slope (choose one only)	Gradient/slope of site- **<10°** (flat-low)	Yes/no/partial	<10	<10	<10	>10	>10	<10	<10	<10	<10	<10
		Gradient/slope of site- **11°-30°** (medium)	Yes/no/partial										
10	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site - **Sand**	Yes/No/NA	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam
		Using the basic soil test what is the predominant soil type on site - **Clay**	Yes/No/NA										
		Using the basic soil test what is the predominant soil type on site - **Loam**	Yes/No/NA										
		Rocky or stoney soil	Yes/No/NA										
11	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**	Yes/No/NA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**	Yes/No/NA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	Soil type-modified	Have water retention granules/polymers been added to soil on site.	Yes/No/Partial	N	N	N	N	N	N	N	N	N	N
13	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned?	North	N	W	N	S	S	S	S	S	S	S
			South										
			East										
			West										
			Not applicable										
14	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat	Free flowing areas/roads	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Traffic islands										
			Traffic islands -standing areas (robots etc)										
			Type of landscape design used for this portion of the site - single trees surrounded by paving/hard surface (**eg parking lot)**										
			Not applicable										
15	Micro-climate wind , inclusive of wind tunnels (choose one only)		1. High wind	Med	Med	Med	Med	Med	Med	Med	Med	Med	Med
			2. Medium wind										
			3. Low wind										
			A. Constant wind										
			B. Sporadic wind										
16	Rainfall	Area/zone	Automatically included										
17	Landscape age (choose one only) If user does not know use professional judgment to decide.	**1.** Age of majority of landscape being assessed - < 3yrs		1	1	1	1	1	1	1	1	1	1
		2. Age of majority of landscape being assessed - > 3yrs -14yrs											
		3. Age of majority of landscape being assessed - > 15yrs											

	Amenity Landscape site water use assessment model												
	Main Element /questions	**Element/questions**	**Sub-element**	**Site Name & ID: Site -A**									
			Sub aresa of site →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
18	Plant density (choose only one)	Dense, includes multiple layers of plants (less H2O) > 80% cover	Yes/no	N	N	N	N	N	N	N	N	N	N
		Normal - 50%-80% cover	Yes/no										
		Sparse < 50% cover (more H2O)	Yes/no										
19	Plant canopy (choose only one)	Do >70% of plants on site/zone create own canopy	Yes/No	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%
		% of site shaded by trees	Sparse(more H2O) < 50% cover										
		% of site shaded by trees	Normal - 50%-80% cover										
		% of site shaded by trees	Dense (less H2O) > 80% cover										
20	Plant zone (choose only one) **Watering amounts must match the RW water Wise definition.**	High	(Over 750mm/a) **or** (25mm/wk,-summer, 15mm/wk-spring/Atum, winter 12mm/wk)	Med	Med	Med	Med	Med	Med	Med	Med	Med	Med
		Medium	(500-750mm/a) **or** (15mm/wk-summer, 12mm/wk-Spring/Autm, winter 7mm/wk)										
		Low	(300mm-500mm/a) **or** (12mm/week-summer, 7mm/week-spr+Autm, winter 12mm every 2nd week)										
		No water	(<300mm) **or** (no water unless extreme)										
21	Irrigation efficiency (Type)	• Drip • Micro spray		Stream	Stream	Stream	Stream	Stream	Gear	Gear	Gear	Gear	Gear
		• Rotary/ Gear/Stream sprinklers • Cone/Fixed Sprayer • Hand or other											
22	Irrigation - watering time (Choose only one)	Water only between 14h00 and 10h00 (late pm , night & early am)	Yes/No	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2
		Water only between 18h00 and 06hoo	Yes/No										
		Watering between 10h00 & 14h00 due to site/client requirements.	Yes/no/partial										
23	Irrigation - rain sensor	Is a rain sensor attached to the irrigation system.	Yes/No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
24	Irrigation - system (Choose only one)	1. Is the irrigation system automated	Yes/no	1	1	1	1	1	1	1	1	1	1
		2. Is the irrigation system manual	Yes/No										
25	Irrigation - system- soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No	N	N	N	N	N	N	N	N	N	N
26	Irrigation - system- changed to season	Is the irrigation system set to change according to seasonal rain expectations eg summer vs winter.	Yes/No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
27	Irrigation controller	Is a smart controller installed	Yes no	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
28	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements.(can only be yes for both, otherwise no)	Yes/no	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
29	Site Maintenance (Chooes only one)	1. Conducted at least weekly	Yes/no	1	1	1	1	1	1	1	1	1	1
		2. Conducted at least monthly	Yes/no										
		3.Conducted at least 6 monthly	Yes/no										
		4. No maintenance	Yes/no										
30	ETO	Potential evapotranspiration											
31	Irrigation & rain for du Plessis & Jacobs.	Flow rate per irrigation zone	Figure										
		Time per irrigation event	Time minutes	45min	45min	45min	45min	45min	20min	20min	20min	20min	20min
		Events per week	Number	2	2	2	2	2	2	2	2	2	2
		Measured precipitation	Amount in mm										
32	Size of the Zone monitored		Area in M^2 round off.										

	Amenity Landscape site water use assessment model												
	Main Element /questions	**Element/questions**	**Sub-element**	**Site Name & ID: Site -A**									
			Sub aresa of site →	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)	Yes/no	Y	Y	Y	Y						
2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings.	Yes/no/partial	N	N	N	N						
3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings.	Yes/no/partial	Y	Y	Y	Y						
4	Microclimate - solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation).	Yes/no/partial	P	P	P	P						
5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun	Yes/no/partial	N	N	N	N						
6	Mulch (choose only one)	Is bare soil on site covered by mulch (organic ie can it decompose).	Yes/no/partial	Y	Y	Y	Y						
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath).	Yes/no/partial	N/A	N/A	N/A	N/A						
8	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site	Yes/no/partial										
		Landscape style/type - **Transformed**.	Yes/no/partial	T	T	T	T						
		Landscape style/type - **mix** of natural and transformed.	Yes/No										
9	Gradient/slope (choose one only)	Gradient/slope of site- **<10°** (flat-low)	Yes/no/partial	<10	<10	<10	<10						
		Gradient/slope of site- **11°-30°** (medium)	Yes/no/partial										
10	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site - **Sand**	Yes/No/NA										
		Using the basic soil test what is the predominant soil type on site - **Clay**	Yes/No/NA	Loam	Loam	Loam	Loam						
		Using the basic soil test what is the predominant soil type on site - **Loam**	Yes/No/NA										
		Rocky or stoney soil	Yes/No/NA										
11	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**	Yes/No/NA	N/A	N/A	N/A	N/A						
		Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**	Yes/No/NA	N/A	N/A	N/A	N/A						
12	Soil type-modified	Have water retention granules/polymers been addded to soil on site.	Yes/No/Partial	N	N	N	N						
13	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned?	North										
			South										
			East										
			West										
			Not applicable	N	N	N	N						
14	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat	Free flowing areas/roads										
			Traffic islands										
			Traffic islands -standing areas (robots etc)										
			Type of landscape design used for this portion of the site - single trees surrounded by paving/hard surface (**eg parking lot)**	Tree pave	Tree pave	Tree pave	Tree pave						
			Not applicable										
15	Micro-climate wind , inclusive of wind tunnels (choose one only)		1. High wind										
			2. Medium wind										
			3. Low wind	Med	Med	Med	Med						
			A. Constant wind										
			B. Sporadic wind										
16	Rainfall	Area/zone	Automatically included										
17	Landscape age (choose one only) If user does not know use professional judgment to decide.	**1.** Age of majority of landscape being assessed - < 3yrs											
		2. Age of majority of landscape being assessed - > 3yrs -14yrs		1	1	1	1						
		3. Age of majority of landscape being assessed - > 15yrs											

	Amenity Landscape site water use assessment model												
	Main Element /questions	**Element/questions**	**Sub-element**	**Site Name & ID: Site -A**									
			Sub aresa of site →	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
18	Plant density (choose only one)	Dense, includes multiple layers of plants (less H2O) > 80% cover	Yes/no	N	N	N	N						
		Normal - 50%-80% cover	Yes/no										
		Sparse < 50% cover (more H2O)	Yes/no										
19	Plant canopy (choose only one)	Do >70% of plants on site create own canopy	Yes/No	>70%	>70%	>70%	>70%						
		% of site shaded by trees	Sparse(more H2O) < 50% cover										
		% of site shaded by trees	Normal - 50%-80% cover										
		% of site shaded by trees	Dense (less H2O) > 80% cover										
20	Plant zone (choose only one) **Watering amounts must match the RW water Wise definition.**	High		Med	Med	Med	Med						
		Medium											
		Low											
		No water											
21	Irrigation efficiency (Type)	• Drip • Micro spray		Drip	Drip	Stream	Drip						
		• Rotary/ Gear/Stream sprinklers • Cone/Fixed Sprayer • Hand or other											
22	Irrigation - watering time (Choose only one)	Water only between 14h00 and 10h00 (late pm , night & early am)	Yes/No	10 to 2	10 to 2	10 to 2	10 to 2						
		Water only between 18h00 and 06hoo	Yes/No										
		Watering between 10h00 & 14h00 due to site/client requirements.	Yes/no/partial										
23	Irrigation - rain sensor	Is a rain sensor attached to the irrigation system.	Yes/No	Y	Y	Y	Y						
24	Irrigation - system (Choose only one)	1. Is the irrigation system automated	Yes/no	1	1	1	1						
		2. Is the irrigation system manual	Yes/No										
25	Irrigation - system- soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No	N	N	N	N						
26	Irrigation - system- changed to season	Is the irrigation system set to change according to seasonal rain expectations eg summer vs winter.	Yes/No	Y	Y	Y	Y						
27	Irrigation controller	Is a smart controller installed	Yes no	Y	Y	Y	Y						
28	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements.(can only be yes for both, otherwise no)	Yes/no	Y	Y	Y	Y						
29	Site Maintenance (Chooes only one)	1. Conducted at least weekly	Yes/no	1	1	1	1						
		2. Conducted at least monthly	Yes/no										
		3.Conducted at least 6 monthly	Yes/no										
		4. No maintenance	Yes/no										
30	ETO	Potential evapotranspiration											
31	Irrigation & rain for du Plessis & Jacobs.	Flow rate per irrigation zone	Figure										
		Time per irrigation event	Time minutes	60min	60min	45min	60min						
		Events per week	Number	2	2	2	2						
		Measured precipitation	Amount in mm										
32	Size of the Zone monitored		Area in M^2 round off.										

Annexure 17: Site B.

	Amenity Landscape site water use assessment model													
	Main Element/questions	**Element/questions**	**Sub-element**		**Site Name & ID: Site -B**									
			Sub aresa of site →		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)	Yes/no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings.	Yes/no/partial		N	N	N	N	N	N	Y	Y	N	N
3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings.	Yes/no/partial		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Microclimate - solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation).	Yes/no/partial		P	P	P	P	P	P	P	P	P	P
5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun	Yes/no/partial		N	N	N	N	N	N	N	N	N	N
6	Mulch (choose only one)	Is bare soil on site covered by mulch (organic ie can it decompose).	Yes/no/partial		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath).	Yes/no/partial		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site	Yes/no/partial		T	T	T	T	T	T	T	T	T	T
		Landscape style/type - **Transformed**.	Yes/no/partial											
		Landscape style/type - **mix** of natural and transformed.	Yes/No											
9	Gradient/slope (choose one only)	Gradient/slope of site- **<10°** (flat-low)	Yes/no/partial		<10	<10	<10	<10	<10	11°-30°	11°-30°	<10	<10	<10
		Gradient/slope of site- **11°-30°** (medium)	Yes/no/partial											
10	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site - **Sand**	Yes/No/NA		Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam
		Using the basic soil test what is the predominant soil type on site - **Clay**	Yes/No/NA											
		Using the basic soil test what is the predominant soil type on site - **Loam**	Yes/No/NA											
		Rocky or stoney soil	Yes/No/NA											
11	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	Soil type-modified	Have water retention granules/polymers been added to soil on site.	Yes/No/Partial		N	N	N	N	N	N	N	N	N	N
13	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned?	North		N	W	S	S	S	S	E	E	N	N
			South											
			East											
			West											
			Not applicable											
14	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat	Free flowing areas/roads		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Tree in paving
			Traffic islands											
			Traffic islands -standing areas (robots etc)											
			Type of landscape design used for this portion of the site - single trees surrounded by paving/hard surface (**eg parking lot)**											
			Not applicable											
15	Micro-climate wind , inclusive of wind tunnels (choose one only)		1. High wind		Med	Med	Med	Med	Med	Med	Med	Med	Med	Med
			2. Medium wind											
			3. Low wind											
			A. Constant wind											
			B. Sporadic wind											
16	Rainfall	Area/zone	Automatically included											
17	Landscape age (choose one only) If user does not know use professional judgment to decide.	**1.** Age of majority of landscape being assessed - < 3yrs			1	1	1	1	1	1	1	1	1	1
		2. Age of majority of landscape being assessed - > 3yrs -14yrs												
		3. Age of majority of landscape being assessed - > 15yrs												

	Amenity Landscape site water use assessment model													
	Main Element/questions	Element/questions	Sub-element		Site Name & ID: Site -B									
			Sub areas of site →		1	2	3	4	5	6	7	8	9	10
18	Plant density (choose only one)	Dense, includes multiple layers of plants (less H2O) > 80% cover	Yes/no		N	N	N	N	N	N	N	N	N	N
		Normal - 50%-80% cover	Yes/no											
		Sparse < 50% cover (more H2O)	Yes/no											
19	Plant canopy (choose only one)	Do >70% of plants on site/zone create own canopy	Yes/No		>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%
		% of site shaded by trees	Sparse(more H2O) < 50% cover											
		% of site shaded by trees	Normal - 50%-80% cover											
		% of site shaded by trees	Dense (less H2O) > 80% cover											
20	Plant zone (choose only one) **Watering amounts must match the RW water Wise definition.**	High	(Over 750mm/a) **or** (25mm/wk,-summer, 15mm/wk-spring/Atum, winter 12mm/wk)		Med	Med	Med	Med	Med	Med	Med	Med	Med	Med
		Medium	(500-750mm/a) **or** (15mm/wk-summer, 12mm/wk-Spring/Autm, winter 7mm/wk)											
		Low	(300mm-500mm/a) **or** (12mm/week-summer, 7mm/week-spr+Autm, winter 12mm every 2nd week)											
		No water	(<300mm) **or** (no water unless extreme)											
21	Scheduling coefficient, based on irrigation type & spacing/ operating pressure.	Drip			Gear	Gear & Cone	Stream	?	Stream & Cone	Stream & Cone	Stream	Stream	Stream & Cone	Stream & Cone
		Any other sprinkler type except drip												
22	Irrigation - watering time (Choose only one)	Water only between 14h00 and 10h00 (late pm , night & early am)	Yes/No		10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2
		Water only between 18h00 and 06hoo	Yes/No											
		Watering between 10h00 & 14h00 due to site/client requirements.	Yes/no/partial											
23	Irrigation - rain sensor	Is a rain sensor attached to the irrigation system.	Yes/No		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
24	Irrigation - system (Choose only one)	1. Is the irrigation system automated	Yes/no		1	1	1	1	1	1	1	1	1	1
		2. Is the irrigation system manual	Yes/No											
25	Irrigation - system-soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No		N	N	N	N	N	N	N	N	N	N
26	Irrigation - system-changed to season	Is the irrigation system set to change according to seasonal rain expectations eg summer vs winter.	Yes/No		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
27	Irrigation controller	Is a smart controller installed	Yes no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
28	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements.(can only be yes for both, otherwise no)	Yes/no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
29	Site Maintenance (Chooes only one)	1. Conducted at least weekly	Yes/no		1	1	1	1	1	1	1	1	1	1
		2. Conducted at least monthly	Yes/no											
		3.Conducted at least 6 monthly	Yes/no											
		4. No maintenance	Yes/no											
30	ETO	Potential evapotranspiration												
31	Irrigation & rain for du Plessis & Jacobs.	Flow rate per irrigation zone	Figure	Fig										
		Time per irrigation event	Time minutes	Fig	20min	20min	45min	45min	20min	20min	45min	45min	20min	20min
		Events per week	Number	Fig	2	2	2	2	2	2	2	2	2	2
		Measured precipitation	Amount in mm	Fig										
32	Size of the Zone monitored		Area in M^2 round off.											

Annexure 18: Site C.

	Amenity Landscape site water use assessment model													
	Main Element/questions	**Element/questions**	**Sub-element**		**Site Name & ID: Site -C**									
			Sub aresa of site →		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)	Yes/no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings.	Yes/no/partial		N	N	N	Y	Y	N	Y	Y	N	N
3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings.	Yes/no/partial		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Microclimate - solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation).	Yes/no/partial		P	P	P	P	P	P	P	P	P	P
5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun	Yes/no/partial		N	N	N	N	N	N	N	N	N	N
6	Mulch (choose only one)	Is bare soil on site covered by mulch (organic ie can it decompose).	Yes/no/partial		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath).	Yes/no/partial		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site	Yes/no/partial		T	T	T	T	T	T	T	T	T	M
		Landscape style/type - **Transformed**.	Yes/no/partial											
		Landscape style/type - **mix** of natural and transformed.	Yes/No											
9	Gradient/slope (choose one only)	Gradient/slope of site- **<10°** (flat-low)	Yes/no/partial		<10	<10	<10	<10	<10	<10	<10	>10	<10	>10
		Gradient/slope of site- **11°-30°** (medium)	Yes/no/partial											
10	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site - **Sand**	Yes/No/NA		Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam
		Using the basic soil test what is the predominant soil type on site - **Clay**	Yes/No/NA											
		Using the basic soil test what is the predominant soil type on site - **Loam**	Yes/No/NA											
		Rocky or stoney soil	Yes/No/NA											
11	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	Soil type-modified	Have water retention granules/polymers been added to soil on site.	Yes/No/Partial		N	N	N	N	N	N	N	N	N	N
13	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned?	North		N	N	N	E	E	N	S	S	S	S
			South											
			East											
			West											
			Not applicable											
14	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat	Free flowing areas/roads		N/A	Tree pave	N/A	N/A	N/A	N/A	N/A	N/A	Tree pave	N/A
			Traffic islands											
			Traffic islands -standing areas (robots etc)											
			Type of landscape design used for this portion of the site - single trees surrounded by paving/hard surface (**eg parking lot)**											
			Not applicable											
15	Micro-climate wind , inclusive of wind tunnels (choose one only)		1. High wind		Med	Med	Med	Med	Med	Med	Med	Med	Med	Med
			2. Medium wind											
			3. Low wind											
			A. Constant wind											
			B. Sporadic wind											
16	Rainfall	Area/zone	Automatically included											
17	Landscape age (choose one only) If user does not know use professional judgment to decide.	**1.** Age of majority of landscape being assessed - < 3yrs			1	1	1	1	1	1	1	1	1	1
		2. Age of majority of landscape being assessed - > 3yrs -14yrs												
		3. Age of majority of landscape being assessed - > 15yrs												

	Amenity Landscape site water use assessment model													
	Main Element/questions	**Element/questions**	**Sub-element**		**Site Name & ID: Site -C**									
			Sub aresa of site →		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
18	Plant density (choose only one)	Dense, includes multiple layers of plants (less H2O) > 80% cover	Yes/no		N	N	N	N	N	N	N	N	N	N
		Normal - 50%-80% cover	Yes/no											
		Sparse < 50% cover (more H2O)	Yes/no											
19	Plant canopy (choose only one)	Do >70% of plants on site/zone create own canopy	Yes/No		>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%	>70%
		% of site shaded by trees	Sparse(more H2O) < 50% cover											
		% of site shaded by trees	Normal - 50%-80% cover											
		% of site shaded by trees	Dense (less H2O) > 80% cover											
20	Plant zone (choose only one) **Watering amounts must match the RW water Wise definition.**	High	(Over 750mm/a) **or** (25mm/wk,-summer, 15mm/wk-spring/Atum, winter 12mm/wk)		High	Med	High	High	High	High	High	High	Med	High
		Medium	(500-750mm/a) **or** (15mm/wk-summer, 12mm/wk-Spring/Autm, winter 7mm/wk)											
		Low	(300mm-500mm/a) **or** (12mm/week-summer, 7mm/week-spr+Autm, winter 12mm every 2nd week)											
		No water	(<300mm) **or** (no water unless extreme)											
21	Scheduling coefficient, based on irrigation type & spacing/ operating pressure.	Drip			Stream	Cone	Cone	Coner	Coner & Stream	Stream	Stream	Stream	Cone & Drip	Stream
		Any other sprinkler type except drip												
22	Irrigation - watering time (Choose only one)	Water only between 14h00 and 10h00 (late pm , night & early am)	Yes/No		10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2	10 to 2
		Water only between 18h00 and 06hoo	Yes/No											
		Watering between 10h00 & 14h00 due to site/client requirements.	Yes/no/partial											
23	Irrigation - rain sensor	Is a rain sensor attached to the irrigation system.	Yes/No		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
24	Irrigation - system (Choose only one)	1. Is the irrigation system automated	Yes/no		1	1	1	1	1	1	1	1	1	1
		2. Is the irrigation system manual	Yes/No											
25	Irrigation - system- soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No		N	N	N	N	N	N	N	N	N	N
26	Irrigation - system- changed to season	Is the irrigation system set to change according to seasonal rain expectations eg summer vs winter.	Yes/No		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
27	Irrigation controller	Is a smart controller installed	Yes no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
28	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements.(can only be yes for both, otherwise no)	Yes/no		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
29	Site Maintenance (Chooes only one)	1. Conducted at least weekly	Yes/no		1	1	1	1	1	1	1	1	1	1
		2. Conducted at least monthly	Yes/no											
		3.Conducted at least 6 monthly	Yes/no											
		4. No maintenance	Yes/no											
30	ETO	Potential evapotranspiration												
31	Irrigation & rain for du Plessis & Jacobs.	Flow rate per irrigation zone	Figure	Fig										
		Time per irrigation event	Time minutes	Fig	45min	45min	45min	45min	45min	20min	20min	20min	20min	20min
		Events per week	Number	Fig	2	2	2	2	2	2	2	2	2	2
		Measured precipitation	Amount in mm	Fig										
32	Size of the Zone monitored		Area in M^2 round off.											

	Amenity Landscape site water use assessment model													
	Main Element/questions	**Element/questions**	**Sub-element**		**Site Name & ID: Site -C**									
		→	**Sub aresa of site →**		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)	Yes/no		Y	Y	Y	Y	Y					
2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings.	Yes/no/partial		N	N	N	N	N					
3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings.	Yes/no/partial		Y	Y	Y	Y	Y					
4	Microclimate - solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation).	Yes/no/partial		P	P	P	P	P					
5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun	Yes/no/partial		N	N	N	N	N					
6	Mulch (choose only one)	Is bare soil on site covered by mulch (organic ie can it decompose).	Yes/no/partial		Y	Y	Y	Y	Y					
		Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath).	Yes/no/partial		N/A	N/A	N/A	N/A	N/A					
8	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site	Yes/no/partial		T	T	T	T	T					
		Landscape style/type - **Transformed**.	Yes/no/partial											
		Landscape style/type - **mix** of natural and transformed.	Yes/No											
9	Gradient/slope (choose one only)	Gradient/slope of site- **<10º** (flat-low)	Yes/no/partial		>10	>10	<10	<10	<10					
		Gradient/slope of site- **11º-30º** (medium)	Yes/no/partial											
10	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site - **Sand**	Yes/No/NA		Loam	Loam	Loam	Loam	Loam					
		Using the basic soil test what is the predominant soil type on site - **Clay**	Yes/No/NA											
		Using the basic soil test what is the predominant soil type on site - **Loam**	Yes/No/NA											
		Rocky or stoney soil	Yes/No/NA											
11	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A					
		Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**	Yes/No/NA		N/A	N/A	N/A	N/A	N/A					
12	Soil type-modified	Have water retention granules/polymers been added to soil on site.	Yes/No/Partial		N	N	N	N	N					
13	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned?	North		S	S	W	W	N					
			South											
			East											
			West											
			Not applicable											
14	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat	Free flowing areas/roads		N/A	N/A	N/A	Tree pave	N/A					
			Traffic islands											
			Traffic islands -standing areas (robots etc)											
			Type of landscape design used for this portion of the site - single trees surrounded by paving/hard surface (**eg parking lot)**											
			Not applicable											
15	Micro-climate wind , inclusive of wind tunnels (choose one only)		1. High wind		Med	Med	Med	Med	Med					
			2. Medium wind											
			3. Low wind											
			A. Constant wind											
			B. Sporadic wind											
16	Rainfall	Area/zone	Automatically included											
17	Landscape age (choose one only) If user does not know use professional judgment to decide.	**1.** Age of majority of landscape being assessed - < 3yrs			1	1	1	1	1					
		2. Age of majority of landscape being assessed - > 3yrs -14yrs												
		3. Age of majority of landscape being assessed - > 15yrs												

	Amenity Landscape site water use assessment model													
	Main Element/questions	**Element/questions**	**Sub-element**		**Site Name & ID: Site -C**									
		→	**Sub aresa of site →**		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
18	Plant density (choose only one)	Dense, includes multiple layers of plants (less H2O) > 80% cover	Yes/no		N	N	N	N	N					
		Normal - 50%-80% cover	Yes/no											
		Sparse < 50% cover (more H2O)	Yes/no											
19	Plant canopy (choose only one)	Do >70% of plants on site create own canopy	Yes/No		>70%	>70%	>70%	>70%	>70%					
		% of site shaded by trees	Sparse(more H2O) < 50% cover											
		% of site shaded by trees	Normal - 50%-80% cover											
		% of site shaded by trees	Dense (less H2O) > 80% cover											
20	Plant zone (choose only one) **Watering amounts must match the RW water Wise definition.**	High			High	high	High	Med	High					
		Medium												
		Low												
		No water												
21	Scheduling coefficient, based on irrigation type & spacing/ operating pressure.	Drip			Stream	Stream	Stream	Stream	Stream					
		Any other sprinkler type except drip												
22	Irrigation - watering time (Choose only one)	Water only between 14h00 and 10h00 (late pm , night & early am)	Yes/No		10 to 2	10 to 2	10 to 2	10 to 2	10 to 2					
		Water only between 18h00 and 06hoo	Yes/No											
		Watering between 10h00 & 14h00 due to site/client requirements.	Yes/no/partial											
23	Irrigation - rain sensor	Is a rain sensor attached to the irrigation system.	Yes/No		Y	Y	Y	Y	Y					
24	Irrigation - system (Choose only one)	1. Is the irrigation system automated	Yes/no		1	1	1	1	1					
		2. Is the irrigation system manual	Yes/No											
25	Irrigation - system-soil moisture sensor	Is irrigation system connected to a soil moisture sensor?	Yes/No		N	N	N	N	N					
26	Irrigation - system-changed to season	Is the irrigation system set to change according to seasonal rain expectations eg summer vs winter.	Yes/No		Y	Y	Y	Y	Y					
27	Irrigation controller	Is a smart controller installed	Yes no		Y	Y	Y	Y	Y					
28	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements.(can only be yes for both, otherwise no)	Yes/no		Y	Y	Y	Y	Y					
29	Site Maintenance (Chooes only one)	1. Conducted at least weekly	Yes/no		1	1	1	1	1					
		2. Conducted at least monthly	Yes/no											
		3.Conducted at least 6 monthly	Yes/no											
		4. No maintenance	Yes/no											
30	ETO	Potential evapotranspiration												
31	Irrigation & rain for du Plessis & Jacobs.	Flow rate per irrigation zone	Figure	Fig										
		Time per irrigation event	Time minutes	Fig	60min	45min	45min	60min						
		Events per week	Number	Fig	2	2	2	2						
		Measured precipitation	Amount in mm	Fig										
32	Size of the Zone monitored		Area in M^2 round off.											

Annexure 19: Detailed water application based on 12 month intervals for site A.

	Block A - Irrigation (KL/month)																								Water restrict amount for 11 months	Pre Water restrict amnt/mont	Pre Water restrict amnt/L/m2/m
	Nov-15	**Dec-15**	**Jan-16**	**Feb-16**	**Mar-16**	**Apr-16**	**May-16**	**Jun-16**	**Jul-16**	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**			
ALWUM monthly	284,3	284,3	284,3	284,3	284,3	284,3	284,3	284,3	284,3	284,3	284,3	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19	213,19			
Interval 1	567,3	695,4	54,2	1048,9	127,3	638,9	720,4	625,7	134,0	162,3	135,7	196,0													4910,04	446,37	134,89
Interval 2		695,4	54,2	1048,9	127,3	638,9	720,4	625,7	134,0	162,3	135,7	196,0	207,5														
Interval 3			54,2	1048,9	127,3	638,9	720,4	625,7	134,0	162,3	135,7	196,0	207,5	178,7													
Interval 4				1048,9	127,3	638,9	720,4	625,7	134,0	162,3	135,7	196,0	207,5	178,7	178,7												
Interval 5					127,3	638,9	720,4	625,7	134,0	162,3	135,7	196,0	207,5	178,7	178,7	228,4											
Interval 6						638,9	720,4	625,7	134,0	162,3	135,7	196,0	207,5	178,7	178,7	228,4	252,8										
Interval 7							720,4	625,7	134,0	162,3	135,7	196,0	207,5	178,7	178,7	228,4	252,8	183,8									
Interval 8								625,7	134,0	162,3	135,7	196,0	207,5	178,7	178,7	228,4	252,8	183,8	54,2						Water restrict amount for 13 months	Water restrict amnt/mont	Water restrict amnt/L/m2/month
Interval 9									134,0	162,3	135,7	196,0	207,5	178,7	178,7	228,4	252,8	183,8	54,2	60,4							
Interval 10										162,3	135,7	196,0	207,5	178,7	178,7	228,4	252,8	183,8	54,2	60,4	10,0						
Interval 11											135,7	196,0	207,5	178,7	178,7	228,4	252,8	183,8	54,2	60,4	10,0	167,0					
Interval 12												196,0	207,5	178,7	178,7	228,4	252,8	183,8	54,2	60,4	10,0	167,0	270,0		2164,59	166,51	50,32
Interval 13													207,5	178,7	178,7	228,4	252,8	183,8	54,2	60,4	10,0	167,0	270,0	177,2			
Amount KL/month/M^2	0,17	0,21	0,02	0,32	0,04	0,19	0,22	0,19	0,04	0,05	0,04	0,06	0,06	0,05	0,05	0,07	0,08	0,06	0,02	0,02	0,00	0,05	0,08	0,05			

Annexure 20: Detailed water application based on 12 month intervals for site B.

	Block B - Irrigation (KL/month)																					Water restrict amount for 11 months	Pre Water restrict amnt/month	Pre Water restrict amnt L/m2/mon
	Feb-16	**Mar-16**	**Apr-16**	**May-16**	**Jun-16**	**Jul-16**	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**			
ALWUM monthly	367,7	367,7	367,7	367,7	367,7	367,7	367,7	367,7	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5	275,5			
Interval 1	577,0	998,0	730,0	613,6	87,6	89,8	65,3	255,7	251,0	251,0	881,0	362,0										3417,00	427,13	108,45
Interval 2		998,0	730,0	613,6	87,6	89,8	65,3	255,7	251,0	251,0	881,0	362,0	329,4											
Interval 3			730,0	613,6	87,6	89,8	65,3	255,7	251,0	251,0	881,0	362,0	329,4	461,6										
Interval 4				613,6	87,6	89,8	65,3	255,7	251,0	251,0	881,0	362,0	329,4	461,6	397,4									
Interval 5					87,6	89,8	65,3	255,7	251,0	251,0	881,0	31,9	329,4	461,6	397,4	420,4						Water	Water	Water
Interval 6						89,8	65,3	255,7	251,0	251,0	881,0	362,0	329,4	461,6	397,4	420,4	209,2					restrict	restrict	restrict
Interval 7							65,3	255,7	251,0	251,0	881,0	362,0	329,4	461,6	397,4	420,4	209,2	31,9				amount for	amnt/mon	amnt
Interval 8								255,7	251,0	251,0	881,0	362,0	329,4	461,6	397,4	420,4	209,2	31,9	199,1			13 months	th	L/m2/mon
Interval 9									251,0	251,0	881,0	362,0	329,4	461,6	397,4	420,4	209,2	31,9	199,1	593,0		4487,00	345,15	87,64
Interval 10										251,0	881,0	362,0	329,4	461,6	397,4	420,4	209,2	31,9	199,1	593,0	100,0			
Amount KL/month/	0,17	0,30	0,22	0,19	0,03	0,03	0,02	0,08	0,08	0,08	0,27	0,11	0,10	0,14	0,12	0,13	0,06	0,01	0,06	0,18	0,03			

Annexure 21: Detailed water application based on 12 month intervals for site C.

	Block C - Irrigation (KL/month)																	Water restrict amount for 11 months	Pre Water restrict amnt/month	Pre Water restrict amnt L/m2/month
	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17			
ALWUM monthly	270,8	270,8	270,8	270,8	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1	203,1			
Interval 1	331,0	300,0	450,0	73,0	65,4	64,6	55,6	55,7	77,5	55,6	113,3	177,4						2573,4	643,345467	212,8415353
Interval 2		300,0	450,0	73,0	65,4	64,6	55,6	55,7	77,5	55,6	113,3	177,4	171,6					Water restrict amount for 13 months	Water restrict amnt/month	Water restrict amnt L/m2/month
Interval 3			450,0	73,0	65,4	64,6	55,6	55,7	77,5	55,6	113,3	177,4	171,6	3086,8						
Interval 4				73,0	65,4	64,6	55,6	55,7	77,5	55,6	113,3	177,4	171,6	3086,8	142,6					
Interval 5					65,4	64,6	55,6	55,7	77,5	55,6	113,3	177,4	171,6	3086,8	142,6	164,0				
Interval 6						64,6	55,6	55,7	77,5	55,6	113,3	177,4	171,6	3086,8	142,6	164,0	457,0	4687,0	360,541385	119,2798983
Amount KL/mo	0,11	0,10	0,15	0,02	0,02	0,02	0,02	0,02	0,03	0,02	0,04	0,06	0,05	0,93	0,04	0,05	0,14			

Annexure 22: Examples of literature confirmation when compared to results are achieved in the ALWUMSA scenario tests.

Result	Linkage to literature or theory
ALWUMSA scenario considering no rain sensor used on site produced results that were higher (more water required) than ALWUMSA onsite where a rain sensor was present.	Using measured rainfall (e.g. rain-shut off) to shut off an irrigation system can increase efficiency of irrigation (Pannkuk, and Wolfskill, 2015). The use of rain switch and rain pause are able to reduce irrigation by 41% (Rutland and Dukes, 2012).
ALWUMSA scenario considering sandy soil on site produced results that were higher (more water required) than ALWUMSA onsite where loam soil was observed.	Sandy soil drain and dry out rapidly, while fine clays soils drain more slowly, thus holding water longer (Keane, 1995).
ALWUMSA scenario considering no mulch on site produced results that were higher (more water required) than ALWUMSA onsite where mulch was observed.	By applying of mulch as part of regular landscaping and maintenance dramatically decreases evaporative water losses, increases yield and increases water use efficiency of the plants. (Tolk, Howell and Evett, 1995; Pauker, 2001; Thompson and Sorvig, 2008; Rico, Navarro and Gōmez, 2016).
ALWUMSA scenario considering implementing drip irrigation on the entire site, produced results that were lower (less water required) than ALWUMSA onsite where drip was only used in a small percentage of the zones.	Compared to older aboveground systems, drip saved up to 90 percent of water used; despite important recent improvements in spray technology, drip continues to outperform spray by 30 to 65 percent. (Thompson and Sorvig, 2008).
ALWUMSA scenario considering watering between 18h00 and 06h00 on the entire site, produced results that were lower (less water required) than ALWUMSA onsite where watering was set from 10h00 to 14h00.	Watering daily between 20h00 and 08h00 reduced evaporation and water use (Sun, Kopp and Kjelgren, 2012).
ALWUMSA scenario considering between high wind for the entire site, produced results that were higher (more	Sites that are exposed to wind or are situated in wind tunnels should be allocated a higher microclimate rating which translates into an

Result	Linkage to literature or theory
water required) than ALWUMSA onsite where a rating of medium wind was given.	increased water requirement for the site (Costello & Jones, 2000).
ALWUMSA scenario considering no seasonal change to the irrigation system for the site, produced results that were higher (more water required) than ALWUMSA onsite where the irrigation system was changed seasonally.	Seasonal adjustment of irrigation systems is essential to save water (Ash, 1998; Kjelgren, Rupp, and Kilgren, 2000; Water Use It Wisely, 2005; Symes et al., 2008)
ALWUMSA scenario considering the addition of water retention granules for the site, produced results that were lower (less water required) than ALWUMSA onsite where no water retention granules had been used.	The use of moisture retaining materials/soil water retention agents/hydrogels that absorb hundreds of times their weight in water, minimize the need for irrigation (Zureikat & Husseini, n.d.; Weinstein, 1999; Ghebru, Du Toit and Steyn, 2013).
ALWUMSA scenario considering the incorrect spacing of irrigation sprinklers and sprayers for the site, produced results that were higher (more water required) than ALWUMSA onsite where correct spacing was allocated due to be the system being designed by a professional irrigation designer.	Incorrect spacing of irrigation sprinklers and sprayers results in an increase in water requirements of the site. (Solomon, 1998: Connellan, 2002; St. Hilaire et al., 2008; Hartin, Oki, Fujino and Faber, 2015)

Annexure 23: Categorisation of elements and questions included into ALWUMSA.

Main element category	Element number	Main element/questions	Element/questions
Amenity Landscape design and maintenance aspects	1	Design by trained professionals	Is landscape designed by an accredited professional (correctly)? Yes/No/Partial or NA
	2	Microclimate -rain	Is the landscape screened from the predominant rainside by buildings? Yes/No/Partial or NA
	3	Microclimate - temperature	Is site impacted by increased temperature of surrounding buildings? Yes/No/Partial or NA
	4	Microclimate -solar radiation	Is site impacted by increased reflection of surrounding buildings (solar radiation)? Yes/No/Partial or NA
	5	Microclimate - sun/shade	Is there a canopy or building protecting/shading the soil & plants from sun? Yes/No/Partial or NA
	5	Landscape design type/style (choose one option only)	Landscape style/type - **Natural** site
			Landscape style/type - **Transformed**.
			Landscape style/type - **mix** of natural and transformed.
	6	Orientation (choose only one)	What is the (predominant) main aspect of the area on the site concerned? North, South, East, West, Not applicable
	7	Micro-climate car fumes & heat (choose only 1)	Is the site a traffic island impacted by car fumes & heat?
	8	Micro-climate wind, inclusive of wind tunnels (choose one	1. High wind
			2. Medium wind
			3. Low wind

Main element category	Element number	Main element/questions	Element/questions
		only)	4. Constant wind
			5. Sporadic wind
			6. No wind
	9	Site Maintenance, including irrigation system (Choose only one)	Conducted at least weekly
			Conducted at least monthly
			Conducted at least 6 monthly
			No maintenance
Pedology aspects	10	Gradient/slope (choose one only)	Gradient/slope of site- **<10^0** (flat-low)
			Gradient/slope of site- **11^0-30^0** (medium)
	11	Soil type unmodified (choose one only)	Using the basic soil test what is the predominant soil type on site – **Sand?**
			Using the basic soil test what is the predominant soil type on site – **Clay?**
			Using the basic soil test what is the predominant soil type on site – **Loam?**
			Using the basic soil test what is the predominant soil type on site - **Rocky or stoney** soil?
			Not applicable
	12	Soil type-modified, "Planter boxes - **ONLY**"(Choose one only)	Using the basic soil test what is the predominant soil type on site - **100% pure bark type mix**?
			Using the basic soil test what is the predominant soil type on site - **< 100% pure bark type mix**?
			Not applicable
	13	Soil type-modified	Have water retention granules/polymers been added to soil on site? Yes/No/Not Applicable
Plant factors	14	Mulch (choose only	Is bare soil on site covered by mulch

Main element category	Element number	Main element/questions	Element/questions
		one)	(organic i.e. can it decompose)? Yes/No/Partial
			Is bare soil on site covered by mulch (Rocks with bidum or similar fabric underneath)? Yes/No/Partial
	15	Landscape age (choose one only) If user does not know use professional judgment to decide.	Age of majority of landscape being assessed - < 3yrs.
			Age of majority of landscape being assessed - > 3yrs -14yrs.
			Age of majority of landscape being assessed - > 15yrs.
	16	Plant density (choose only one)	Dense (less H^2O) > 80% cover
			Normal - 50%-80% cover
			Sparse < 50% cover (more H^2O)
	17	Plant canopy (choose only one)	Do >70% of plants on site/zone create **own canopy?**
			% of site **shaded by trees (Sparse(more H^2O) < 50% cover)**
			% of site **shaded by trees (Normal - 50%-80% cover)**
			% of site **shaded by trees (Dense (less H^2O) > 80% cover)**
	18	Plant hydrozone (choose only one)	High (0.9 to 0.7)
			Medium (0.6 to 0.4)
			Low (0.3 to 0.1)
			No water (0.05 to 0.01)
Irrigation factor	19	Irrigation efficiency (Type) (Choose only one the most suitable or the least efficient in the zone)	• Drip (95% efficient) • Micro spray (90% efficient)
			• Rotary/ Gear/Stream sprinklers (80% efficient) • Cone/Fixed Sprayer (75% efficient) • Hand or other (50% efficient)

Main element category	Element number	Main element/questions	Element/questions
	20	Irrigation - watering time (Choose only one the most suitable)	Water only between 14h00 to 10h00 (late pm, night & early am)?
			Water only between 18h00 and 06h00(night only)?
			Watering between 10h00 to 14h00 due to site/client requirements?
	21	Irrigation - rain sensor	Is a rain sensor attached to irrigation system? Yes/No
	22	Irrigation - system (Choose only one)	Is irrigation system automated? Yes/No
	23		(No, implies it is manual)
	24	Irrigation - system-soil moisture sensor	Is irrigation system connected to a soil moisture sensor? Yes/No
	25	Irrigation - system-changed to season	Is the irrigation system set to change according to seasonal rain expectations e.g. summer vs. winter? Yes/No
	26	Irrigation controller	Is a smart controller installed? Yes/No
	27	Irrigation spacing & operating pressure	Are sprinklers spaced head to head & operated at correct pressure, as per manufacturer requirements. (**can only be yes for both, otherwise no**)?
Rainfall (effective rainfall)	28	Rainfall (Monthly average)	Area/zone - Automatically included
ETo (Evapotranspiration)	29	ETo	Potential evapotranspiration. Choose the town from the closest town on the list.
Size	30	Size of the Zone monitored	Area in m^2 round off.

Annexure 24: AWLUMSA Data.

Refer to excel sheet with final amenity landscape water use model South Africa (AWLUMSA) for Block A, B and C.