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Directorate Water Resources Planning

WATER RESOURCES SITUATION ASSESSMENT STUDY

LOWER VAAL WATER MANAGEMENT AREA

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OVERVIEW

The water resources of South Africa are vital to the health and prosperity of its people, the sustenance of its natural heritage and to its economic development. Water is a national resource that belongs to all the people who should therefore have equal access to it, and although the resource is renewable, it is finite and distributed unevenly both spatially and temporally. The water also occurs in many forms that are all part of a unitary and inter-dependent cycle.

The National Government has overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial and sustainable use, the redistribution of water and international water matters. The protection of the quality of water resources is also necessary to ensure sustainability of the nation's water resources in the interests of all water users. This requires integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level where all persons can have representative participation.

This report is based on a desktop or reconnaissance level assessment of the available water resources and quality and also patterns of water requirements that existed during 1995 in the Lower Vaal Water Management Area, which occupies portions of the North-West, Northern Cape and the Free State Provinces. The report does not address the water requirements beyond 1995 but does provide estimates of the utilisable potential of the water resources after so-called full development of these resources, as this can be envisaged at present. A separate national study has been conducted to consider future scenarios of land use and water requirements and the effects of water conservation and demand measures on these requirements and to identify alternative water resource developments and water transfers that will reconcile these requirements with the supplies.

The main purpose of this report is to highlight the principal water related issues, to identify existing water shortages, to provide information that is necessary to formulate future strategies such as the national water resources strategy and catchment management strategies and to stimulate initial actions to ensure the best overall sustainable utilisation of the water, with minimal waste and harm to the aquatic ecosystems.

The National Water Act (No. 36 of 1998), requires that a national water resources strategy (NWRS) be established that sets out the policies, strategies, objectives, plans, guidelines and procedures and the institutional arrangements for the protection, use, development, conservation, management and control of water resources for the country as a whole, and establish and define the boundaries of water management areas taking into account catchment boundaries, socio-economic development patterns, efficiency considerations and communal interests. This strategy is binding on all authorities and institutions exercising powers or performing duties under the National Water Act.

The national water resources strategy will, inter alia, provide for at least the requirements of the Reserve, international rights and obligations, actions required to meet projected future water needs and water use of strategic importance. Furthermore, it will contain estimates of present and future water requirements, set out principles relating to water conservation and demand management, give the total quantity of water available within each water management area, state the surpluses or deficits, provide for inter-catchment water transfers required to balance the supply with the requirements and state the objectives in respect of water quality to be achieved through the classification system to be provided for the water resources.

A catchment management agency established in terms of the National Water Act (No. 36 of 1998), must progressively develop a catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of water resources within its water management area. Such a strategy must not be in conflict with the national water resources strategy, must take into account the class of water resource and resource quality objectives, the requirements of the Reserve and any applicable international obligations, the geology, land use, climate, vegetation and waterworks within its water management area. The strategy shall contain water allocation plans, take account of any relevant national or regional plans prepared in terms of any other law; enable public participation and take into account the needs and expectations of existing and potential water users. This report provides the initial baseline data that can be used by the catchment management agency to develop its catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of the water resources in its area of responsibility.

The national water resources strategy will be reviewed and published at five-yearly intervals, with Addenda being issued in the interim, when required. The strategy will give guidance to the Department of Water Affairs and Forestry in respect of the protection, use, development, conservation, management and control of water resources and will also serve as a very important means of communication with all the stakeholders. The overall responsibility for the compilation of the national water resources strategy rests with the Directorate: Strategic Planning of the Department of Water Affairs and Forestry, while the Directorate: Water Resources Planning is responsible for:

- Identification of water resources to meet particular requirements
- Identification of international rights and obligations
- Identification of water use of strategic importance
- Calculating water balances
- Developing plans to reconcile water requirements and resources.

A number of inter-related studies have therefore been included by the Directorate: Water Resources Planning of the Department of Water Affairs and Forestry in the national future scenario study that will supply the information required for formulating the strategies, as given above.

The main objective of this water resources situation assessment has been to determine the water requirements of all the user sectors (including those of the riverine and estuarine ecosystems) and the ability of the available water resources to supply these requirements. However, other aspects such as water quality, legal and institutional aspects, macro-economics, existing infrastructure and international requirements have also been addressed. This report outlines the 1995 water resources situation, using information obtained from previous study reports to identify the main water related issues of concern. The large body of information available in the Department of Water Affairs and Forestry and from other sources has also been collated and presented in this assessment. This has been collected on a catchment basis at the quaternary catchment level of resolution. The levels of confidence that can be attached to the data on land use, water requirements and surface water and groundwater resources have however, been found to vary considerably because of the desktop nature of the study. This has therefore also provided a basis for identifying where improvements need to be made to the data in future and to prioritise such studies. It is also important to note that where information on land and water use and sensitive ecosystems is not given, this could be due to the fact that it does not exist or because it has not been documented in a format or source that is readily accessible.

The larger inter-related studies that have supported this water resources situation assessment have been the following:

Development of a computerised database

Data collected in this water resources situation assessment has been used to populate the database of the Chief Directorate: Planning of the Department of Water Affairs and Forestry. The database design has mainly been based on the requirements of a water balance model that has been developed to compare the water requirements with the available water resources.

Demographic study

An important part in the development of the national water resources strategy is the future scenarios. Since water use is mainly driven by the requirements of the various socio-economic groupings of the population, a national demographic study was initiated. An important part of the study was an estimate of the base year (1995) population. The study has also associated the population with defined water user categories to facilitate estimating existing and future water requirements. These categories have inter alia been defined on the basis of reports on urban water supplies and questionnaires completed by local authorities.

Macro-economic study

Economic activity and its effects on the spatial distribution of the population and vice versa is an important determinant of water use. With the ever-increasing need for water for domestic use and protection of the water resources, water availability is already becoming a limiting factor in various regions of the country. The economic viability of continuing to supply water for existing sectors, such as irrigation and also of expanding such activities to satisfy socio-economic aspirations will need careful consideration. A national macro-economic study has therefore been undertaken to provide basic economic data for use in the demographic study and to provide macro-economic overviews for each water management area.

Formulation and development of a water situation assessment model

The primary function of the water situation assessment model is to reconcile water supply and water requirements by quantifying the surplus or deficit per catchment area. Water balances are compiled from the quaternary catchment level of resolution of the data, which can then be aggregated to suite any desired predetermined catchment boundaries. The water situation assessment model is nevertheless only a coarse planning tool and does not replace the detailed hydrological studies that are required for basin studies or project investigations.

Water requirements for the ecological component of the Reserve

The National Water Act (No. 36 of 1998) requires that water be provided for the Reserve, which is the quantity and quality of water required to satisfy basic human needs and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant resource. The ecological sensitivity and importance of the rivers in South Africa and the present ecological status class was therefore established at the quaternary catchment level of resolution, using available data and local knowledge. At the same time the results of previous field assessments of the water requirements of the aquatic ecosystems at selected sites in South Africa were used in a separate study to develop a model for estimating the water required for the ecological component of the Reserve for various ecological management classes that correspond to those determined previously for the rivers throughout the country.

SYNOPSIS

1. INTRODUCTION

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required. This information was gathered by various consultants in what is known as the Water Resources Situation Assessment.

Data was collected on a reconnaissance level of detail at quaternary catchment level and detail and captured in an electronic database to reflect the water situation in 1995. Data was sourced mostly from existing reports although some new studies were undertaken to provide information such as demographics, ecological requirement and groundwater availability. The water requirements have been reconciled with the water availability to determine a so-called water balance.

2. PHYSICAL FEATURES

The Lower Vaal Water Management Area **(see Figure 2.1.1)** is situated partly in the North-West Province and partly in the Northern Cape Province with a small fraction of the areas also lying within the Free State province.

By far the most significant river in this WMA is the Vaal River, which flows through the south-eastern portion of the WMA, from Bloemhof Dam to the confluence with the Orange River. The only other river of any significance from a water resources point of view is the Harts River, which drains the north-eastern portion of the WMA. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in this area, these rivers are not significant.

The **mean annual temperature** ranges between 18.3ºC in the east to 17.4ºC in the west. There is a large seasonal variation in temperature with average temperature in January of 24ºC and 10ºC in July. Rainfall is strongly seasonal with most rain occurring in summer. The overall range of the Mean Annual precipitation for the entire study area is 100 mm in the West to 600 mm in the East.

A large portion of the central and north-east corner of Lower Vaal WMA is underlayen by the Transvaal Supergroup which is associated with ample groundwater. The Ventersdorp and Olifantshoek supergroups, which cover the remainder of the WMA are associated with mineral deposits, especially Manganese, which is mined extensively.

3. DEVELOPMENT STATUS

The total population of the Lower Vaal WMA is approximately 1 280 000, of which an estimated 570 000 live in urban centres and the remaining 710 000 are classified as rural. The majority of this population is found in the east of the WMA where the water resources of the Vaal and Harts River have allowed the development of large-scale irrigation schemes.

The most significant towns in the WMA are Kimberley in the South, which lies only partially within the WMA, Lichtenburg in the north-east and Kuruman in the centre. Other significant towns are Schweizer Reineke, Jan Kempdorp, Pampierstad, Christiana, Warrenton, Riverton, Warrenton, Delportshoop, Olifantshoek annd Postmasburg.

The most significant land use in the WMA is irrigation which takes place in the lower reaches of the Harts river along the banks of the Vaal River. Dry land crops, mostly maize, are also grown in the eastern part of the WMA. The rest of the WMA is used for stock grazing. There is no afforestation within the WMA.

Land use within the WMA is shown in **Table 1**.

Table 1: Land Use By Drainage Areas

CATCHMENT		IRRIGATION (km^2)	URBAN AREAS	ALIEN VEGETATION	POPULATION
Quaternary catchment	**Key area**				
D41B-M, D73A-E	Molopo River	0.0	30.2	384.4	441 197
C32A-D	Dry Hartz	35.7	21.0	25.5	122 660
C31A-F	Harts	1.0	19.0	12.5	232 100
C33A-C	Vaalhartz	336.9	36.0	0.3	140 810
C91A-E, C92A-B	Vaal D/S Bloemhof	118.2	171.0	27.9	345 830
TOTAL		**491.8**	**277.2**	**450.6**	**1 282 597**

4. EXISTING WATER RELATED INFRASTRUCTURE

The water related infrastructure in the Lower Vaal WMA is sparse. This is due to the limited available water resources in the catchment. The larger water related schemes which are in place are linked to either irrigation or abstractions from the Vaal River, the only abundant source of water within the WMA. By far the most significant of these schemes is the transfer of water from the Vaal River to the Vaalharts irrigation scheme. Smaller schemes transfer water from the Vaal to towns and mines in the arid north-west area of the WMA and to Kimberley.

There are a few significant dams in the WMA, namely the SpitskopDam, the Wentzel Dam, the Douglas weir, the Vaalharts weir and the recently constructed Taung Dam. These dams are used mostly for irrigation purposes.

5. WATER REQUIREMENTS

The total water requirement of the Lower Vaal WMA is estimated at 731 million m^3/annum and includes all distribution and conveyance losses **(see Table 2).** The majority of this requirement is from the irrigation sector, with other significant water requirements being urban and rural requirements. Although there are a number of mines in the WMA, the water requirements of these mines is limited.

The impact of water on the available yield varies according to the assurance of supply required by the various user sectors. Strategic users, for example, require a very high level of assurance and their water supply infrastructure is designed for an assurance of supply of 99,5%. Irrigators, on the other hand, are prepared to tolerate a much higher risk of failure, often as low as 70%, in return for a greater total volume of water on average and typically operate at an assurance of 80 to 90%.

It is therefore necessary to convert the actual water use of the various water users to an equivalent water use at a common assurance of supply in order to carry out a meaningful yield balance. The assurance level chosen for comparison purposes is the 1:50 year assurance level, or 98% assurance. The conversion from the assurance of supply of each user to a 1:50 year assurance was done by means of stochastic modelling carried out over the whole country to determine factors for converting water use at a given assurance to a 1:50 year assurance.

Since the largest water user sector in the Lower Vaal WMA is irrigation, water conservation and demand measures should be aimed at this sector. It is estimated that only 51% of the water diverted out of the Vaal River to the Vaalharts scheme reaches the root zone of the irrigated crops. Although much of this loss is unavoidable, there is scope for water conservation on this scheme. This needs to be investigated.

Table 2: Water Requirements Per User Group in 1995

USER GROUP	SUB GROUP	ESTIMATED WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT OR IMPACT AT 1:50 YEAR ASSURANCE (10^6 m^3/a)
Bulk water use (4)	Strategic	0.0	0.0
	Mining	5.3	5.0
	Other	0.8	0.8
Irrigation		615	529
Ecological reserve		481	0
Urban (1)		54	54
Rural (5)		49	52
Neighbouring states		0.0	0.0
Afforestation		0.0	0.0
Alien vegetation		6.0	0.0
Water transfers (3)		0.0	0.0
River losses		94	94.0
TOTAL		**1 305**	**735**

(1) Includes urban domestic, commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, livestock and game.
(3) Only transfers out of the WMA are included.
(4) Includes thermal powerstations, major industries and mines.
(5) Includes domestic use only.
(6) Included in Transfers

6. WATER RESOURCES

Due to the low rainfall in the Lower Vaal WMA, the natural surface water resource of the WMA is very limited **(**see **Table 3).** Accurate estimates of this resource are not available and it is recommended that this be determined more accurately in order to improve the efficiency of the water use within the WMA. The groundwater resource is more substantial, with an estimated 128 million m^3/annum currently being supplied from groundwater. By far the greatest proportion of the water used in the Lower Vaal originates from the Upper and Middle Vaal WMAs, which is released from the Bloemhof Dam.

According to the limited analysis carried out as part of this WRSA study, the water quality in the Vaal River is surprisingly good. However, the water quality in the lower Harts River is marginal due to saline return flows from the Vaalhartz irrigation scheme.

Table 3: Water Resources

CATCHMENT		SURFACE WATER RESOURCES		GROUND WATER RESOURCES	TOTAL REOURCES
Quaternary catchment	Key area	Natural MAR	1:50 Year developed resource		
D41B-M, D73A-E	Molopo River	165.2	0.0	31.1	31.1
C32A-D	Dry Hartz	48.7	27.4	19.9	47.3
C31A-F	Harts	59.0	4.5	12.0	16.5
C33A-C	Vaalhartz	40.2	419	10.3	429.3
C91A-E, C92A-B	Vaal D/S Bloemhof	43.0	42.0	54.3	96.3
TOTAL		356.1	492.9	127.6	620.5

7. WATER BALANCE

The Water Situation Assessment Model (WSAM) was developed with the purpose of providing a reconnaissance level decision support tool. The intention was to use the WSAM to determine the water balance for the WRSA reports and also to use the WSAM reporting tools to produce as many of the tables in the WRSA reports as was practical. However, due to various unresolved developmental problems with the WSAM, another approach was adopted. For this reason, the WSAM is not described in any detail in this report.

In terms of the naturally occurring resource, it is apparent that there is a large deficit within the Lower Vaal WMA. However, this is to expected since there are large water requirements within the WMA, mostly irrigation, and very limited local resources. This large deficit is only apparent when the WMA is considered in isolation. The Lower Vaal WMA is in fact part of the larger Vaal System and water is allocated to users in the Lower Vaal from the Upper Vaal. The planning and operation of the entire Vaal System does take the requirements of the Lower Vaal into account and should continue to do so.

There is currently surplus water available in the Upper and Middle Vaal WMA and this water is released from Bloemhof Dam to meet requirements in the Lower Vaal.

8. COST OF WATER RESOURCES DEVELOPMENT

The surface water resources of the Lower Vaal WMA are considered to be fully developed and there is little or no scope for the construction of new dams or the raising of existing dams. However, there appears to large potential for increased groundwater use, especially in the eastern and central portion of the WMA. Any increases in water requirements in the future would therefor need to supplied from either the Vaal System or from groundwater.

The growth in the water requirements are not expected to be large and increased domestic requirements can probably be met from groundwater in most cases. The cost of developing the groundwater resources to their full potential is estimated at R850 million in terms of 1995 costs.

9. CONCLUSION AND RECOMMENDATIONS

The Lower Vaal WMA, when considered in isolation, is in deficit with the water requirements exceeding the local resources by almost 500 million m^3/annum. However, this is to be expected since there are large water requirements within the WMA, mostly irrigation, and very limited local resources. This large deficit is only apparent when the WMA is considered in isolation. Provided the Lower Vaal WMA is operated as part of the larger Vaal System, as is currently the case, the bulk of the requirements of the Lower Vaal WMA can be met from the Middle and Upper Vaal WMA.

There is large groundwater use in this WMA with large potential to increase the use of this resource. Groundwater is used for irrigation, mining and domestic use.

Water losses within the Lower Vaal are exceptionally high, both in absolute terms and as a percentage of total water consumption. Although there is no urgency in addressing the problem since there is currently sufficient water available to the Lower Vaal WMA, a reduction in these losses could delay the implementation of a future scheme to augment the water supply to the Vaal System. It is recommended that a water conservation study be initiated to investigate methods of reducing conveyance losses as well as reducing losses by means of improved irrigation application techniques. Evaporation and systems losses downstream of Bloemhof Dam also need to be investigated with a view to reducing these large losses.

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GLOSSARY OF TERMS

AEMC	Attainable Ecological Management Class (A-D). A class indicating the management objectives of an area which could be attained within 5 years. Values range from Class A (largely natural) to Class D (largely modified).
ANASTOMOSED	A river made up of multiple channels with stable islands, usually with a bedrock substrate.
BIOTA	A collective term for all the organisms (plants, animals, fungi. bacteria) in an ecosystem.
CONDENSED AREA	The area considered in the alien vegetation component whereby alien vegetation which sparsely occurs in a large area, is redefined as a smaller area with a maximum concentration/density
CAIRN	Mound of rough stones as a monument or landmark.
DEMC	Default Ecological Management Class (A-D). A class indicating the ecological importance and sensitivity of an area, as it is likely to have been under natural (undeveloped) conditions, and the risks of disturbance that should be tolerated. Values range from Class A (highly sensitive, no risks allowed) to Class D (resilient systems, large risk allowed).
DESC	Default Ecological Status Class.
DIURNAL	During the day.

ENVIRONMENTALLY SENSITIVE AREA	A fragile ecosystem which will be maintained only by conscious attempts to protect it [Concise Oxford Dictionary (COD) of Geography].
ECOSYSTEM HEALTH	An ecosystem is considered healthy if it is active and maintains its organisation and autonomy over time, and is resilient to stress. Ecosystem health is closely related to the idea of sustainability.
ECOLOGICAL IMPORTANCE	A measure of the extent to which a particular species, population or process contributes towards the healthy functioning of an ecosystem. Important aspects include habitat diversity, biodiversity, the presence of unique, rare or endangered biota or landscapes, connectivity, sensitivity and resilience. The functioning of the ecosystem refers to natural processes. (a measure of a river for conservation, including natural, socio-economic and cultural aspects).
EDAPHIC	1. Pertaining to the influence of soil on organisms. 2. Resulting from or influenced by factors inherent in soil rather than by climatic factors.
EISC	Ecological importance and sensitivity class.
EPHEMERAL RIVERS	Rivers where no flow occurs for long periods of time.

ENDANGERED	Species in danger of extinction and whose survival is unlikely if the causal factors bringing about its endangered status continue operating. Included are species whose numbers have been reduced to a critically low level or whose habitat has been so drastically diminished and/or degraded that they are deemed to be in immediate danger of extinction.
ENDEMIC	Occurring within a specified locality; not introduced (Concise Oxford Dictionary of Geography.)
ENDOREIC	Portion of a hydrological catchment that does not contribute towards river flow in its own catchment (local) or to river flow in downstream catchments (global).
HETROGENEOUS	Not uniform. Disparate. Consisting of dissimilar parts or ingredients.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.
LOTIC	Flow water.
PESC	Present Ecological Status Class (A-F). A class indicating the degree to which present conditions of an area have been modified from natural (undeveloped) conditions. Factors that are considered in the classification include the extent of flow modification, inundation, water quality, stream bed condition, riparian condition and proportion of exotic biota. Values range from Class A (largely natural) to Class F (critically modified).

PETROGLYPH	A carving or inscription on a rock.
RARE	Species with small or restricted populations, which are not at present endangered or vulnerable, but which are at risk. These species are usually localised within restricted geographical areas or habitats, or are thinly scattered over a more extensive range. These may be species, which are seldom recorded but may be more common than supposed, although there is evidence that their numbers are low.
RED DATA BOOK	A book that lists species that are threatened with extinction. The concept was initiated by the International Union for the Conservation of Nature, and has since become adopted by many countries. The "Red" stands for "Danger". The categories reflect the status of the species only within the area under review, and it is sometimes the case that species, which are threatened in one region may have secure populations in other areas.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act 108 of 1997) for people, who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource as indicated in NWA, 1998.

RESILIENCE	The ability of an ecosystem to maintain structure and patterns of behaviour in the face of disturbance (Holling 1986, in Costanza et al 1992), or the ability to recover following disturbance.
RESOURCE QUALITY	The quality of all the aspects of a water resource including: (a) the quantity, pattern, timing, water level and assurance of instream flow; (b) the water quality, including the physical, chemical and biological characteristics of the water; (c) the character and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of the aquatic biota.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection.
SPATIO — TEMPORARY ROBUST	Does not change significantly with time in relation to spatial distribution.
STROMATOLITE	A rocky cushion-like growth formed by the growth of lime-sectreting blue-green algae, thought to be abundant 200 million years ago, when blue-green algae were the most advanced form of life on earth.
SWALES	A small earth wall guiding surface runoff away from the stream back onto the fields.

TAXON (plural: TAXA)	General term for a taxonomic group in a formal system of nomenclature, whatever its rank. A taxonomic group refers to the systematic ordering and naming of plants and animals according to their presumed natural relationships. For example, the taxa Simuliidae, Diptera, Insecta and Arthropoda are examples of a family, order, class and phylum respectively.
TROPHIC	Pertaining to nutrition.
VADOSE ZONE	Relating to or resulting from water or solutions that are above the permanent groundwater level.
VULNERABLE	Species believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are species of which all or most of the population are decreasing because of overexploitation, extensive destruction of habitat, or other environmental disturbance. Species with populations which have been seriously depleted and whose ultimate security is not yet assured, and species with populations that are still abundant but are under threat from serious adverse factors throughout their range.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy for the protection, use, development, conservation, management and control of water resources. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required, that is, a national water resources situation assessment providing information on all the individual drainage basins in the country.

The Department of Water Affairs and Forestry (DWAF) has appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database that will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and water availability are being dealt with in a separate study. These scenarios will be taken up in the National Water Resource Strategy and will be reported on separately for each water management area.

As a component of the National Water Resource Strategy, the Minister of Water Affairs and Forestry has established water management areas and determined their boundaries. The National Water Act provides for the delegation of water resource management from central government to the regional or catchment level by establishing catchment management agencies. It is intended that the documents produced in this study as well as in the subsequent scenario studies referred to above should contribute to the establishment of the National Water Resource Strategy. In addition they will provide information for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

In order to facilitate use by future catchment management agencies, the information has been presented in the form of a separate report on each water management area. This report is in respect of the Lower Vaal Water Management Area (WMA), which occupies portions of the North West, Free State and Northern Cape provinces. A provincial water resources situation assessment can be derived by assembling the provincial data from each of those reports that describe the water management areas that occupy the province.

1.2 APPROACH TO THE STUDY

The study was carried out as a desktop investigation using data from reports and electronic databases, or supplied by associated studies, local authorities and DWAF. The study considered conditions as they were in the year 1995 and did not make projections of future conditions. Data at reconnaissance level of detail was collected on land-use, water requirements, water use, water-related infrastructure, water resources and previous investigations of water supply development possibilities. Relevant data was used in a computerised water balance model, developed in a separate study (DWAF, February 2000) to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to consultants appointed to carry out a separate national demographic study, in relation to water requirements.

In that study, data from the 1996 census, and other sources, was used to derive demographic information for the whole country for the year 1995. In addition, the information on urban water use that was supplied by the water resources situation assessment studies, was analysed in the demographic study to derive typical unit water requirements. These were used, in conjunction with the demographic data, to estimate water requirements in 1995 for urban areas for which no recorded data was available.

Both the demographic data and the estimated water requirements in 1995, as supplied for the Lower Vaal Water Management Area by the national demographic study (DWAF, March 2000), are presented in this report. In addition to the separate studies on the water balance model and demography referred to above, separate studies were carried out to provide information on a national basis on:

- Macro-economic aspects
- Legal aspects of water resource management
- Institutional arrangements for water supply
- Effects of alien vegetation on runoff
- Groundwater resources
- Bacteriological contamination of water resources
- Water requirements for irrigation
- Ecological classification of rivers
- Water requirements for ecological component of Reserve
- Effects of afforestation on runoff
- Storage-yield characteristics of rivers

Information from all the above studies, that is relevant to the Lower Vaal WMA, is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect of the Lower Vaal WMArea are presented in the nine chapters that make up the main body of this report. A number of appendices contain statistics for the quaternary hydrological sub-catchments that make up the water management area. (The system used to divide the area into hydrological sub-catchments is explained in **Section 2.1** of the report).

The chapter headings are:

Chapter 1:	Introduction
Chapter 2:	Physical Features
Chapter 3:	Development Status
Chapter 4:	Water Related Infrastructure
Chapter 5:	Water Requirements
Chapter 6:	Water Resources
Chapter 7:	Water Balance
Chapter 8:	Costs of Water Resources Development
Chapter 9:	Conclusions and Recommendations

Chapters 2, 3 and 4 describe climatic and physical features, and land-uses that affect water resources or water supply. Chapter 5 describes the various water user sectors and their requirements. It includes information on water allocations, water conservation and demand management, and water losses and return flows. Chapter 6 describes the groundwater and surface water resources of the water management area, and Chapter 7 compares water requirements with the available resource. In Chapter 8, rough estimates are given of the cost of developing the portion of the total water resource that was not developed by 1995, and the conclusions and recommendations arising from the study are presented in Chapter 9.

CHAPTER 2: PHYSICAL FEATURES

2.1 THE STUDY AREA

The Lower Vaal WMA **(see Figure 2.1.1)** is situated partly in the North-West Province and partly in the Northern Cape Province with a small fraction of the areas also lying within the Free State province. The drainage regions included in the study area are: D41 (excl D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91 and C92 (excl C92C).

Appendix A1 lists all the quaternary catchments within the WMA and gives the breakdown of the WMA into the three provinces in which it lies.

The main rivers in drainage regions D41 and D42 are the Molopo River, the Nossob River and the Kuruman River. The main rivers in these drainage regions that are of interest to this study are the Molopo and Kuruman Rivers in the Far Northern Cape. The Nossob River does not form part of this study and is therefore excluded from the discussion presented here. The Molopo River forms the border between South Africa and Botswana and together with its tributaries it drains much of the northern part of the Lower Vaal WMA. The Molopo River flows from approximately 35 km north-east of Mmabatho all along the border with Botswana to the west where it joins the Nossob River approximately 70 km from the Namibian border.

The Kuruman River together with its tributaries mainly drains the southern part of the Lower Vaal WMA. The Kuruman River originates approximately 35 km south-east of Kuruman and joins its tributaries approximately 120 km north-west of Kuruman.

The main tributaries of the Molopo River found in the Lower Vaal WMA are shown in **Figure 2.1.2.** They are:

- Setlagoli River - joins the Molopo River approximately 90 km north-east of Morokweng
- Phepane River - joins the Molopo River approximately 110 km north-west of Morokweng

The main tributaries of the Kuruman River found in the Lower Vaal WMA are shown in **Figure 2.1.2.** They are:

- Kgokgole and Moshaweng Rivers - joins the Kuruman River approximately 120 km north-west of Kuruman

The Kuruman and Molopo Rivers, which drain the Kalahari and northern Lower Orange regions, do not make a meaningful contribution to the surface water resources.

Drainage regions C31, C32, C33, C91 and C92 are divided into the Harts River catchment and the Vaal River catchment as described below.

The Harts River drains a catchment area of approximately 31 000 km^2 and has one major tributary, the Dry Harts River which joins the Harts River just downstream of Taung.

The stretch of Vaal River considered here is the reach between Bloemhof Dam and the Orange and Vaal River confluence. The total catchment area is almost 22 500 km^2.

For the purpose of assessing water requirements and the available water resources, the water management area has been divided into quaternary catchments and so-called key areas **(see Figure 2.1.3).** These are the basic unit of area used in the Water Research Commission Report: *"The Surface Water Resources of South Africa, 1990"*, which is the main source of the hydrological data used in this study.

In this system, drainage regions throughout the country are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been created to have similar runoffs: the greater the runoff volume the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example D41C, may be interpreted as follows. The letter D denotes Drainage Region D (sometimes referred to as a primary catchment). The number 4 denotes secondary catchment 4 of Drainage Region D. the number 1 shows that the secondary catchment has been sub-divided into tertiary catchments.

The letter C shows that the quaternary catchment is the third in sequence downstream from the head of secondary catchment D4.

For the purposes of this report, reporting on water requirements, resources and balances were determined on a so-called key area level of detail and reported on at key points. A key point is any point in the WMA where it was decided it would be convenient to report on the various components making up the water balance and usually coincides with major dams or the boundaries of tertiary and secondary catchments. A key area is the catchment area upstream of the key point and downstream of the immediate upstream key point(s).

The Key points used in this WMA are shown in **Table 2.1** and **Figure 2.1.4.**

Table 2.1: Key Points For Yield Determination

LOCATION OF KEY POINT		
SECONDARY CATCHMENT		QUATERNARY CATCHMENT NO.
NO.	NAME	
D4, D7	Molopo River	D41B-M D73A-E
C3	Dry Hartz Hartz Vaalhartz	C32A-D C31A-F C33A-C
C9	Vaal D/S Bloemhof	C91A-E C92A-B

2.2 CLIMATE

The extent of the studied portion of the Lower Vaal WMA is shown in **Figure 2.2.1.** Climatic conditions are fairly uniform from east to west across the study area.

The **mean annual temperature** ranges between 18.3ºC in the east to 17.4ºC in the west. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. The following table summarises temperature data for the study area for these two months.

Frost occurs throughout the study area in winter, typically over the period mid-May to late August. The average number of frost days per year for the study area ranges from 30 in the eastern parts of the study area (western part of North-West) to 31 in the western parts (eastern part of the Far Northern Cape). The overall range of the number of frost days per year for the entire study area is 1 to 60 days.

Table 2.2.1: Temperature Data

Month	Temperature (ºC)	Average (ºC)	Range (ºC)
January	Mean Temperature	23.8 to 24.7	>22
	Maximum Temperature	32.0	>30
	Minimum Temperature	15.6 to 17.4	14 to 20
	Diurnal Range	14.5 to 16.4	14 to 17
July	Mean Temperature	10.2	6 to 12
	Maximum Temperature	18.0 to 19.6	16 to 22
	Minimum Temperature	0.9 to 2.3	-2 to 4
	Diurnal Range	15.8 to 18.7	>17

Rainfall is strongly seasonal with most rain occurring in the summer period (October to April). The peak rainfall months are December and January. Rainfall occurs generally as convective thunderstorms and is sometimes accompanied by hail. The average hail day frequency for the study area ranges between 1 and 3 per annum (at any single location) and the mean lightning flash density is 2 to 6 per km^2 per annum.

The overall feature of **mean annual rainfall** over the study area is that it decreases fairly uniformly westwards from the western parts of the North-West Province to the eastern parts of the Northern Cape Province. The MAP for the North-West Province as a whole is 481 mm and for the Northern Cape Province as a whole 202 mm. The **average coefficient of variation** (CV) ranges from 31 % to 38 % for the North-West Province and the Northern Cape Province respectively. The overall range of the MAP for the entire study area is 100 mm to 600 mm while the overall range of the CV over the entire study area is 25 % to 40 %.

For the **driest year in five** (80 % exceedance probability) the annual rainfall ranges between 600 mm in the eastern part of the study area and less than 100 mm in the western part of the study area. For the **wettest year in five** (20 % exceedance probability) the annual rainfall ranges between 800 mm and 100 mm in the eastern and western parts of the study area respectively.

In accordance with the rainfall pattern the **relative humidity** is higher in summer than in winter. Humidity is generally highest in February (the daily mean over the study area ranges from 65.7 % in the east to 61.9 % in the west) and lowest in August (the daily mean over the study area ranges from 52.8 % in the east to 57.3 % in the west). The overall range for the month of February for the entire study area is 62 % to 68 % and for the month of August the value drops to less than 56 %.

Average potential mean annual gross evaporation (as measured by A-pan) ranges from 2 646 mm in the North-West Province to 2 690 mm in the Northern Cape Province. The overall range for the entire study area is greater than 2400 mm per annum. The highest A-pan evaporation is in December and ranges from 317 mm in the North-West Province to 360 mm in the Northern Cape Province with the overall range between 300 mm and 380 mm. The lowest evaporation occurs in June and ranges between 110 mm for North-West and 97 mm for the Northern Cape. The overall range for June is greater than 90 mm.

The **mean annual gross irrigation requirement** (based on rainfall and A-pan evaporation) for the study area ranges from 1 947 mm in the North-West Province to 2 225 mm in the Northern Cape Province while the overall range for mean annual gross irrigation is greater than 1 400 mm. The minimum mean monthly requirement is in June and ranges from 102 mm in the North-West Province to 80 mm in the Northern Cape Province. For the entire study area it varies between 60 mm and 125 mm. The maximum mean monthly requirement ranges from November (219 mm) in North-West to January (287 mm) in the Northern Cape. The entire study area's range is in excess of 125 mm (November and January included).

The gross irrigation requirements are based on the assumption of a perennial crop with a uniform crop factor of 0.8. The requirement takes into account effective rainfall plus conveyance losses and spray drift losses (both assumed to be 10 %).

2.3 GEOLOGY

Due to the extremely arid nature of the Lower Vaal WMA, groundwater plays a very important role in the water resources of this WMA. In many areas the only source of water is groundwater since there are no sustainable surface water resources. This section on the Geology has therefore been written with a strong emphasis on the groundwater situation.

A large portion of the central and north-east corner of Lower Vaal WMA is underlayen by the Transvaal Supergroup consisting of the dolomite, chert and subordinate limestone (shown in light blue on **Figure 2.3.1).** This area is characterised by a high potential for groundwater with a 50 to 75% probability and accessibility throughout the dolomitic area. The groundwater level is between 8 to 20 metres deep on average. Water is found mainly in fractures; dissolution features are not prominent.

The abundance of groundwater in these areas has huge implications on the economic development of these regions which have negligible surface water resources.

The Olifantshoek Supergroup lies to the west of this area in the vicinity of Vanzylsrus, Hotazel, Sishen and Postmasburg. Here the Geology presents very low-to-low grade metamorphic rocks of schist, quartzite, lava, subgreywacke and conglomerates. Tillite with sandstone, mudstone and shale is also found in the area. Unlike the central dolomitic area, the geology of the western part of the WMA does not lend itself to groundwater resources. Boreholes tend to be less successful and much deeper, up to 125 metres. Water is also often saline. It is this very limited and unreliable groundwater resource that necessitated the implementation of the Kalahari East and West rural water supply schemes.

To Ventersdorp Supergroup lies to the east and north of the Transvaal Supergroup are areas composed mainly of volcanic rocks, andesite, quartz porphyry, sedimentary rocks, conglomerate and sandstone. This area also represents a low grade metamorphism and water is found in weathered fractures. Probability of a successful borehole yielding >2l/s is 10-20% with and average groundwater level of between 8 to 20 metres deep.

Thus, there is a great variety of geological units in the Lower Vaal WMA and the quoted figures related to groundwater are mainly generalized trends. Specific site investigations are necessary for water potential in any area. Even in dolomite there are very poor zones amongst the good zones, but the best overall potential for sustainable water at shallow depths are in the Transvaal Supergroup rocks of this area, especially in the dolomite.

The main minerals in this area are iron, manganese (associated with the Kalahari Manganese field) and asbestos mines in the south west. This has a major impact on the water situation of the region since there are a number of Manganese mines in the area which are situated in the region where ground ware is extremely limited. This has necessitated schemes such as the Vaal Gamagara to supply water to these mines. The iron ore mine at Sishen is better situated with regard to ground water and although the Vaal Gamagara scheme was developed to supply this mine, it still receives most of its water from groundwater. Alluvial diamonds are associated with the central and east area and Kimberlite diamonds in the west near Kimberley.

In the central and northern areas, the chance for exploitable commodities are low. There are also a few copper, zinc and gold mines throughout the WMA area.

2.4 SOILS

Figure 2.4.1 shows a generalised soils map of the study area using some 16 broad soil groupings. **Figure 2.4.1** was obtained from the publication Surface Water Resources of South Africa (Midgeley, et al), often referred to as the WR90 study. The 16 groupings were derived by the Department of Agricultural Engineering of the University of Natal using a national base map, which was divided into 84 soil zones. These soil zones were then analysed according to features most likely to influence hydrological response, viz. depth, texture and slope. The following table shows the different types of soils found in the Lower Vaal Water Management Area.

Table 2.4.1: Soil types in the Lower Vaal Water Management Area

Depth	Texture	Relief
Shallow	Sandy	Flat
Moderate to deep	Clayey Loam	Flat
Moderate to deep	Sandy Loam	Undulating
Moderate to deep	Sandy Loam	Flat
Moderate to deep	Sandy	Steep
Moderate to deep	Sandy	Flat

It should be noted that the base information for the above work is quite old and that much more detailed and reliable information exists today which can be used for more detailed planning purposes. The interpretation of this data for a particular purpose, such as runoff response or irrigation potential will however involve considerable work and was therefore not deemed warranted for the purpose of this study.

2.5 NATURAL VEGETATION

2.5.1 Introduction

A simplified map of the natural vegetation is shown in **Figure 2.5.1**. Some 20 000 different plant species occur throughout South Africa. These are however not randomly distributed within the region but are organised into distinct communities, largely dependent on the prevailing climatic (especially rainfall) and edaphic (soil) conditions. For the purposes of identifying and managing the heterogenous range of vegetation within South Africa, we need to be able to recognise relatively homogenous vegetation groups or types.

Furthermore, for the recognised groups to be meaningful, it is essential that they are readily apparent and spatio-temporally robust.

Acocks (1988) introduced the concept of “Veld type”, which he defined as : “a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities”. Acocks (1988) identified a total of 70 veld types in South Africa (**see Table 2.5.1**), including 75 variations. These 70 veld types fall into 11 broad categories, ranging from various forest types to sclerophyllous (Fynbos) types (**Table 2.5.1**). These “simplified” Acocks veld type categories are used for the purposes of this report, and accordingly the description of the natural vegetation types occurring within the Water Management Area (WMA) is rather broad.

Table 2.5.1: A List of the Detailed and Simplified Acocks Veld Types (Acocks, 1988)

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Coastal Forest and Thornveld	1	**Coastal Tropical Forest**
Alexandria Forest	2	
Pondoland Coastal Plateau Sourveld	3	
Knysna Forest	4	
‘Ngongoni Veld	5	
Zululand Thornveld	6	
Eastern Province Thornveld	7	
North-eastern Mountain Sourveld	8	**Inland Tropical Forest**
Lowveld Sour Bushveld	9	
Lowveld	10	**Tropical Bush and Savanna**
Arid Lowveld	11	
Springbok Flats Turf Thornveld	12	
Other Turf Thornveld	13	
Arid Sweet Bushveld	14	
Mopani Veld	15	
Kalahari Thornveld	16	
Kalahari Thornveld invaded by Karoo	17	
Mixed Bushveld	18	
Sourish Mixed Bushveld	19	
Sour Bushveld	20	
False Thornveld of Eastern Cape	21	**False Bushveld**
Invasion of Grassveld by Acacia karoo	22	**False Bushveld**
Valley Bushveld	23	**Karoo and Karroid**
Noorsveld	24	
Succulent Mountain Scrub	25	
Karroid Broken Veld	26	
Central Upper Karoo	27	
Western Mountain Karoo	28	
Arid Karoo	29	
Central Lower Karoo	30	**Karoo and Karroid**
Succulent Karoo	31	
Orange River Broken Veld	32	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Namaqualand Broken Veld	33	
Strandveld	34	
False Arid karoo	35	**False Karoo**
False Upper Karoo	36	
False Karroid Broken Veld	37	
False Central Lower Karoo	38	
False Succulent Karoo	39	
False Orange River Broken Karoo	40	
Pan Turf Veld invaded by Karoo	41	
Karroid Merxmuellera Mountain Veld replaced by K	42	
Mountain Renosterveld	43	
Highveld Sourveld and Dohne Sourveld	44	**Temperate and Transitional Forest**
Natal Mist Belt 'Ngongoni Veld	45	
Coastal Renosterveld	46	
Coastal Fynbos	47	
Cymbopogon – Themeda Veld	48	**Pure Grassveld**
Transitional Cymbopogon – Themeda Veld	49	
Dry Cymbopogon – Themeda Veld	50	
Pan Turf Veld	51	
Themeda Veld or Turf Highveld	52	
Patchy Highveld to Cymbopogon – Themeda Veld Transition	53	
Turf Highveld to Highland Sourveld Transition	54	
Bakenveld to Turf Highveld Transition	55	
Highland Sourveld to Cymbopogon – Themeda Veld Transition	56	
North-eastern Sandy Highveld	57	
Themeda – Festuca Alpine Veld	58	
Stormberg Plateau Sweetveld	59	
Karroid Merxmuellera Mountain veld	60	
Bankenveld	61	**False Grassveld**
Bankenveld to Sour Sandveld Transition	62	
Piet Retief Sourveld	63	
Northern Tall Grassveld	64	
Southern Tall Grassveld	65	
Natal Sour Sandveld	66	
Pietersburg Plateau False Grassveld	67	
Eastern Province Grassveld	68	
Fynbos	69	**Sclerophyllous Bush**
False Fynbos	70	**False Sclerophyllous Bush**

2.5.2 Natural Vegetation Types within the Lower Vaal WMA

The Lower Vaal WMA is dominated by Tropical Bush and Savanna with small areas of Pure Grassveld in the east.

2.6 ECOLOGICALLY SENSITIVE SITES

2.6.1 Sensitive Ecosystems

The conservation of living resources is essential for sustaining development by maintaining the essential ecological processes and life support systems, preserving genetic diversity and ensuring that utilisation of species and ecosystems is sustainable. However, for conservation to succeed it should be underpinned by two basic principles, namely the need to plan resource management (including exploitation) on the basis of an accurate inventory, and the need to implement proactive protective measures to ensure that resources do not become exhausted. Accordingly, a vital component of ensuring sustainable conservation practices is the identification of conservation worthy habitats or sensitive ecosystems.

In terms of Section 2 (1) of the Environment Conservation Act (No. 73 of 1989), South Africa's schedule of protected areas was published in the Government Gazette 15726 in May 1994 (Notice 449 of 1994). This classification identifies the following sensitive or protected areas:

> *Scientific and Wilderness Areas, National Parks and Equivalent Reserves, Natural Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes, based on their location and the functions they fulfil.*

South Africa has also recognised the importance of its wetlands as sensitive ecosystems that require conservation, and accordingly has become a signatory to the International Convention on Wetlands of International Importance especially as Waterfowl Habitat or RAMSAR Convention. In terms of this convention, signatories undertake to include wetland conservation considerations in their national land-use planning, and as far as possible to ensure the wise use of wetlands within their territory.

Before moving on to discuss ecosystems of concern to the study area it would be prudent to give some consideration to the definition of aquatic ecosystems, especially with respect to the National Water Act (No. 36 of 1999). In general terms an ecosystem may be defined as a community of organisms and their physical environment interacting as an ecological unit. Hence, aquatic ecosystems encompass the aquatic community and water resources necessary to sustain its ecological integrity. Within the National Water Act the water resource requirements of aquatic ecosystems are recognised and protected by the introduction of the concept of an ecological reserve, viz. the water required to protect the aquatic ecosystem of the water resources. The Reserve refers to both the quantity and quality of the resource. Accordingly, development must take cognisance not only of the sensitivity of the receiving ecosystem but also of the resource requirements or ecological reserve of the aquatic communities it supports.

2.6.2 River Classification

The water resources situation assessment has been performed at the quaternary catchment scale of resolution as described in **Section 2.1.** However, the delineation of these quaternary catchments was not based on ecological principles. In order to provide some ecological basis for the estimates of water requirements to maintain a particular class of river it was decided to base estimates of water requirements on an index of the ecological importance and sensitivity class (EISC) of the rivers in the quaternary catchment of concern. The ecological importance and sensitivity class of the rivers was used to derive the default ecological management class (DEMC), which relates to a default ecological status class (DESC). The default ecological status class and the present ecological status class (PESC) have been used to arrive at a suggested future ecological management class (AEMC) to be considered for the water resources. The default ecological status class would normally be assigned to a water resource on the basis of ecological sensitivity and importance. This methodology is based on the assumption that the ecological importance and sensitivity of a river would generally be closely associated with its default ecological management class and that its current ecological status and potential to recover from past ecological damage will determine the possibility of restoring it to a particular ecological management class.

This section describes the procedures and methods adopted to estimate the various status and management classes of the rivers that will be used to estimate the corresponding quantities of water required for that component of the Reserve that is necessary to protect the aquatic ecosystems according to the designated class. The procedure that has been followed to determine the various classifications is illustrated in **Diagram 2.6.2.1.** The descriptions of the various ecological importance and sensitivity classes (EISC), default ecological management classes (DEMC), default ecological status classes (DESC), present ecological status classes (PESC) and the suggested future ecological management class (AEMC) are given in **Diagram 2.6.2.2.**

Individual assessors familiar with the ecology of a particular area or a comparable area were engaged in discussions and workshops during which a number of biotic and habitat determinants considered important for the determination of ecological importance and sensitivity were quantified or scored. The procedure that was followed was considered to be suitable for the situation where the delineation of the quaternary catchment units was not based on ecological considerations. The approach may however, have a low ecological sensitivity because of the absence of an ecological typing framework. The median of the scores assigned by the assessors was calculated to derive the ecological importance and sensitivity class. The assessors were then required to compare this with their overall estimation of the ecological importance and sensitivity class of the mainstem river of the quaternary catchment of concern near its outlet.

The assessors were required to record and be able to substantiate their assessments to a reasonable degree for possible review in future.

The ecological importance and sensitivity classes were assessed during meetings or a workshop held during 1998. This was followed by a second workshop during 1999 that was primarily concerned with the assessment of the present ecological status class, the potential to improve the ecological status class and the suggested future management class. The second workshop however, also involved an overall review of the ecological importance and sensitivity assessments determined during the original workshop.

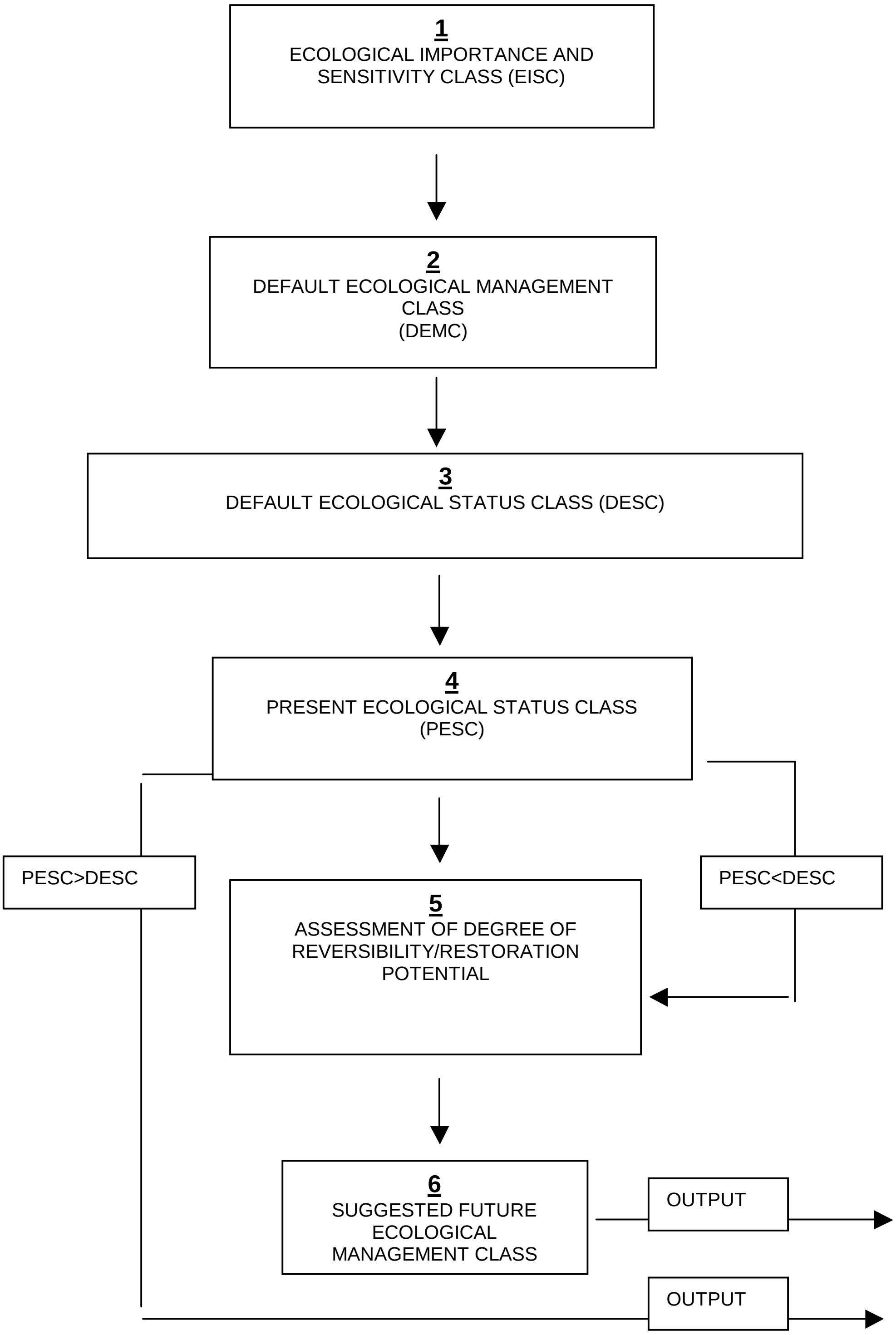


Diagram 2.6.2.1: Procedure followed to determine the river classifications

EISC		DEMC and DESC
Very high →	No human induced hazards →	Class A: Unmodified natural
High →	Small risk allowed →	Class B: Largely natural
Moderate →	Moderate risk allowed →	Class C: Moderately modified
Low/marginal →	Large risk allowed →	Class D: Largely modified

PESC	PESC: SUGGESTED ATTAINABLE IMPROVEMENT Acceptable range of AEMC:
Class A: Unmodified natural	Class A: Unmodified natural
Class B: Largely natural	Class B: Largely natural
Class C: Moderately modified	Class C: Moderately modified
Class D: Largely modified	Class D: Largely modified
Class E: Seriously modified	Class E: Seriously modified
Class F: Critically modified	Class F: Critically modified

→ : indicates relationship.

⟶ : indicates possible direction of desirable change.

Diagram 2.6.2.2: Descriptions of EISC, DEMC DESC, PESC and AEMC.

The procedure that was adopted to classify the rivers was qualified in the following respects:

- Only lotic systems (i.e. streams and rivers and associated habitats such as lotic wetlands) can be classified and the procedure is not meant to be applied to lakes, pans, impoundments or estuaries. Although several of the components considered in this assessment may be generally applicable, the application of the procedure to systems other than rivers and streams was not attempted.

- Where a quaternary catchment contained an estuary, this procedure was only applied to the riverine part of the catchment.

- Only the mainstem river in a quaternary catchment was considered in the assessment and therefore the management class must not be applied to any tributary streams in the quaternary catchment. These tributaries and their associated water requirements do however, become relevant when a water resources situation assessment is conducted at a sub-quaternary level.

- In cases where a dam wall was present at or relatively close to the outlet of a quaternary catchment, the assessments for that quaternary catchment were based on the river upstream of the dam (i.e. upstream of the backwater effect of the dam).

- In cases where degradation has occurred along certain sections of the mainstem of a quaternary catchment, but where there are still substantial less disturbed sections, the classification was based on those less disturbed areas. The intention of this was to ensure that the ecological component of the Reserve would provide for these less disturbed sections as if they were situated at the outlet of the quaternary catchment, where the ecological component of the Reserve will be estimated for the water resources situation assessments.

- The classifications were fundamentally considered from an instream and riparian zone perspective. Although the catchment in itself plays a major role in the condition and functioning of the rivers and streams in the catchment, the purpose of this procedure was not to provide an overall assessment of the condition of each catchment.

- The riparian zone was broadly been regarded as that part of the river bordering on the river channel. Usually characteristic plant species and/or vegetation structure provided an indication of the extent of the riparian zone.

The specific aspects that were considered when classifying the rivers are described below.

Ecological Importance and Sensitivity Class (EISC)

The following ecological aspects were considered for the estimation of the ecological importance and sensitivity class:

The presence of rare and endangered species, unique species (i.e. endemic or isolated populations) and communities, species intolerant to changes in flow regime or water quality and species diversity was taken into account for both the instream and riparian components of the river.

- Habitat diversity was also considered. This included specific habitats and river reaches with a high diversity of habitat types such as pools, riffles, runs, rapids, waterfalls and riparian forests.

- The importance of the particular river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provides a migration route or corridor for species.

- The presence of conservation or relatively natural areas along the river section serving as an indication of ecological importance and sensitivity.

- The ecological sensitivity (or fragility) of the system to environmental changes. Both the biotic and abiotic components were included.

The ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and broader scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its resilience or capability to recover from a disturbance that has occurred.

The present ecological status was not considered when determining the ecological importance and sensitivity per se. The ecological importance and sensitivity that has been established for the water resources situation assessments is a general and unrefined estimate. It is strongly biased towards the potential importance and sensitivity of the mainstem river of the quaternary catchment under close to unimpaired conditions.

Present Ecological Status Class (PESC)

Habitat integrity i.e. ecological integrity, condition and change from the natural condition, was regarded as a broad preliminary indicator of present ecological status for the purpose of the water resources situation assessments.

Each of the above attributes that were used to estimate the present ecological status were scored, from which the mean was calculated. This mean was used to assign a present ecological status class to the mainstem river in the vicinity of the outlet of the quaternary catchment.

Suggested Future Ecological Management Class (AEMC)

The potential to improve the ecological conditions was assessed only in terms of the present flow regime. Degradation of the system purely because of non-flow related changes was ignored.

The practicality of improving an existing modified ecological system to arrive at the suggested future ecological management class was assessed on the basis of the changes that have occurred, by comparing the difference between the present ecological status class and the default ecological status. For the purpose of these water resources situation assessments restoration was accepted to be the "…re-establishment of the structure and function of an ecosystem, including its natural diversity". Generally, structure is the native or natural species diversity of the ecosystem, while function is its productivity in terms of growth of plant biomass as the basis for food webs and the functions of hydrology, trophic structure and transport. Restoration is to reverse the decline of the health of a degraded ecosystem towards its historic structure. In contrast, reclamation and rehabilitation are usually more local and site-specific, while habitat creation refers to the establishment of new habitat, without regard to historical conditions.

The water resources situation assessment is, inter alia, concerned with the quantity of water, and therefore particular emphasis was placed on flow modification. Where the impact on the biota and the habitats of the estimated present flow modification was less than can be inferred from the present ecological status, this was taken into account and specifically highlighted (emphasised or flagged). It is obvious that such a state of affairs needs more specific attention. This situation arose only in a limited number of cases and has been indicated in the assessment of both the present ecological status class and the suggested future ecological management class, but needs more specific attention in future.

2.6.3 Aquatic Ecosystems of Concern to the Study

It is important to recognise that within the context of the current report, sensitive ecosystems refer specifically to ecosystems which are sensitive with respect to possible changes in water quality and quantity.

An indication of the ecological importance of the aquatic ecosystems within the Lower Vaal WMA can be obtained from Figure 2.6.3.2, which indicates the present ecological management class. The Vaal river is largely modified, and the presence of the Douglas Weir and the Bloemhof weir effectively isolates this stretch of river from the rest of the river system. The Harts River varies from moderately to largely modified and is therefore limited ecological significance. Of some significance is Barberspan, which supports a large number of bird species.

The Kuruman and Molopo river systems are classified as largely unmodified. However, since these rivers are all non-perennial, there are not of very limited ecological importance, with the exception of the Kuruman and Polfontein Eyes where endemic fish species are found.

2.6.4 Natural Heritage Sites, Proclaimed Game and Nature Reserves, Wilderness Areas

These areas can be defined as areas of natural beauty and/or ecological importance that have been recognised as valuable, and set aside to be protected or preserved. Within the Lower Vaal WMA there are a large number of such areas, and the most significant of these are shown in **Table 2.6.4.1**

Table: 2.6.4.1: Conservation areas in the Lower Vaal WMA.

Name of conservation area	Quaternary	Province
Molopo Nature Reserve	D41F	North West
Barberspan Nature Reserve	C31D	North West
Wolwespruit Dam Nature Reserve	C25C	North West
Bloemhof Dam Nature Reserve	C25F	North West
Tshwalu Private Desert Reserve	D42C	North West
S A Lombard Nature Reserve	C91A	North West
Rob Ferreira Game Reserve	C91B	North West
Wanebaai	C91B	Northern Cape
Kamfers Dam	C91E	Northern Cape
Vaalbos National Park	C91E/C92A	Northern Cape
Rooipoort	C92A/B	Northern Cape

Barberspan Nature Reserve is positioned 16 km north east of Delareyville. It has been selected as a RAMSAR site, and is a sanctuary for waterfowl.

Tshwalu Private Desert Reserve is situated on the edge of the Kalahari Desert, east of Hotazel. It is the largest privately owned game reserve in South Africa, with a breeding and rehabilitation programme for animal species including the desert black rhino.

Rob Ferriera Game Reserve is situated along the north bank of the Vaal River, to the north east of Christiana. The 2500 ha reserve is on flat, sandy grassveld. Main mammal species include eland, black wildebeest, red hartebeest, zebra, blesbok, gemsbok, springbok, impala and white rhino.

S A Lombard Nature Reserve is located about 17 km north west of Bloemhof. The 3660 ha reserve is characterised by flat grassveld interspersed with clumps of thorn trees. Mammal species include black wildebeest, gemsbok, eland, red hartebeest, blesbok and springbok.

Vaalbos National Park is situated south of the Vaal River between Barkly West and Kimberley. Vegetation in the 22697 ha reserve is a mixture of Karoo, Kalahari and grassveld. Apart from endemic small mammals, established populations of springbok and red hartebeest are present, and species such as buffalo and black rhino have been introduced.

The above reserves and other ecologically sensitive sites are shown in **Figure 2.6.3.2.**

2.7 CULTURAL AND HISTORICAL SITES

Cultural and historical sites can be broadly defined as natural or manmade areas that are associated with human activity and history, and which carry social, cultural, religious, spiritual or historic significance. All palaeontological, archaeological and historical sites and material older than 50 years are protected by the National Monuments Act.

The National Monuments Council has a very limited database of archaeological and palaeontological sites in South Africa. It is the responsibility of the developer to ensure that any area earmarked for development is surveyed for such sites, and appropriate steps are taken to conserve them if they are present. National legislation that provides clarification on the declaration and classification of such areas is the following:

- National Monuments Act (Act 28 of 1969) sections 9c, 10 and 12
- National Parks Act (Act 57 of 1976) section 4

The Wonderwerk Cave is situated on a private farm in the vicinity of Kuruman. It features extensive Bushmen paintings. The Taung Heritage Site marks the site where a skull of an early hominid child was discovered. Other significant cultural and historical sites are listed in **Table 2.7.1.**

Table 2.7.1: Cultural And Historical Sites

Location	Quat.	Description
Warrenton	C91D	Rock engravings in the path of a proposed new canal
Barkly-West	C91E	Canteen Kopje, stone age artefacts, Old Bridge and tollhouse
Kimberley	C91E	Glaciated pavements and rock Art site
Kimberley	C91E	Belgravia, Architectural Aesthetic Area
Kimberley	C91E	Milner Road Conservation Area, The City Hall
Kimberley	C91E	De Beers Boardroom, built by C Rhodes 1886
Kimberley	C91E	Honoured Dead Memorial
Kimberley	C91E	The Sanatorium
Herbert	C92C	Glacial pavements at Bucklands
Douglas	C92C	Driekops Eiland, entopic engravings

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

3.1.1 The Hartz River catchment

By far the largest water user in the Lower Vaal WMA is the irrigation sector. Development of the water infrastructure within this area has therefore been driven largely by this sector.

The Vaalharts irrigation scheme was developed in the mid 1930's and at this time the Vaalharts weir and canal system was constructed to divert water from the Vaal to irrigators along the Vaal River but mostly in the Harts River catchment. Later, in 1971, the Bloemhof Dam was completed to regulate the flow in the Lower Vaal and increase the assurance of supply to the Vaalharts scheme. The Vaalharts canals were upgraded in the early nineties to increase their peak rate of supply from 28.3 m^3/s to 48 m^3/s.

The Wentzel Dam was constructed in 1935 to supply water to Schweizer Reineke and for limited irrigation.

In 1975 the Spitzkop Dam was constructed in order to supply irrigators along the lower Harts. In 1988 the dam wall was partially washed away but reconstructed with a larger spillway in 1989.

The Taung Dam was constructed on the Harts River in 1993 to augment irrigation supplies to the Taung irrigation area and possibly support new irrigation development in the Pudimoe area. The development of additional irrigation did not materialise, however, as it was found to be uneconomical.

3.1.2 The Kuruman/Molopo catchment

Motivated by the development of mines in the arid areas in the north-west of the Lower Vaal WMA, the Vaal Gamagara scheme was constructed in the mid 1960's. This scheme sources its water from the Vaal River and also supplies water to small towns in the area and to farmers for stock-watering and domestic purposes. The scheme is currently underutilised.

The Kalahari West Rural Water Supply Scheme was implemented as an emergency scheme in 1984 to supply water to farmers in a limited area north of Upington for domestic and stockwatering purposes.

Farmers in the Kalahari had previously relied on groundwater but this source was evidently over-exploited and became increasingly unreliable, both in terms of quantity and quality. Prompted by this, the Kalahari East Rural Water Supply Scheme was implemented in the early 1990's to supply water to a much larger area of the Kalahari.

3.1.3 The Lower-Vaal River

The Douglas weir was originally constructed out of masonary in 1896 but replaced by a concrete structure in 1977. The purpose of this weir is to regulate and divert flows from the lower Vaal for irrigation along the southern bank of the Vaal. The Organge-Vaal canal was constructed in 1984 to import good quality Orange River water to the Lower Vaal for irrigation purposes and to improve the water quality in the Douglas Weir.

An abstraction works and pump station was constructed at Riverton on the lower Vaal River to transfer water to Kimberley for urban use.

3.2 DEMOGRAPHY

3.2.1 Introduction

A national study (Schlemmer *et al*, 2001) to develop water use projections to the year 2025 was undertaken for the Department of Water Affairs and Forestry by a team of specialists, in order to support the development of the National Water Resource Strategy. This included the development of baseline 1995 population estimates. The work commenced well before the results of the 1996 census became available, and a number of sources were used to develop the baseline data set. The database developed was subsequently reconciled with the results of the census in areas where the census had provided superior information.

The study focussed on so-called functional urban centres having or likely to have reticulated water supply systems in the future. In a number of instances areas on the fringe of urban centres and classified as rural in the 1996 census were incorporated with the functional urban centres defined in the study, and urban populations identified in this study therefore differed from the urban populations enumerated in the census. The regional weighting of census counts to compensate for undercounts was also identified as a factor distorting some urban populations in smaller centres reported in the census.

3.2.2 Methodology

Functional urban areas were identified within magisterial districts. Estimates were made of the 1995 population in these centres, while the populations outside of these urban areas were grouped together as a so-called rural remainder. The urban populations were further categorised in order to provide a basis for developing estimates of urban water use for the entire country **(see Section 5.3).**

A number of sources and approaches were used to obtain baseline population data for the year 1995. These included projections and estimates made by the following institutions:

- The Development Bank of Southern Africa.
- The Demographic Information Bureau.
- The Bureau for Market Research.
- Local authority estimates, where available.

The data from the above sources were compared with extrapolations and estimates based on the following:

- Household counts from the sampling database held by one of the participating consultants.
- Previous census results from 1970 onwards, including former homeland censuses.
- Estimates obtained from very large surveys such as that of the SAARF.
- The database of villages of the Directorate: Water Services of the Department of Water affairs and Forestry.

Discrepancies were reconciled on the basis of local knowledge and special enquiries directed at local authorities. The results of the 1996 census became available after this had been completed, and was used as an additional check on the database. Where discrepancies were significant these were investigated, and the database was revised where the 1996 census provided improved information.

As an overall check the population distribution database for 1995 that was developed as part of this study was projected for one year on the basis of a ruling population growth rate of 1,9%. An effective population of 42 379 000 persons in 1996 was arrived at in this way, which is only 1% above the 1996 census population of 41 945 000 persons.

A reasonable estimate of the distribution of the rural population was made, using the census results for the rural population as a guideline, to develop a spatially distributed database.

3.2.3 Historical Population Growth Rate

In order to analyse historical growth trends census data was obtained for 1960, 1970, 1980 and 1991. Although, due to the changes in magisterial boundaries over the years, it was sometimes difficult to obtain comparable figures it is evident that the historical growth rate has decreased. The average growth rate between 1960 and 1970 was approximately 6% per annum, and between 1980 and 1991 it had decreased to 2% per annum. It is evident too that many of the more rural areas are now experiencing a lower growth rate, as a result of migration to the larger urban areas. Employment opportunities in the rural areas are decreasing as mechanisation of farming and mining occurs, and the people are forced to move to the cities in order to obtain work.

3.2.4 Population Size and Distribution in 1995

The total population of the Lower Vaal WMA is approximately 1 292 000, of which about 718 000 live in urban centres. The largest concentration of urban population is in Kimberley, with an estimated population of 204 00. Although Kimberley does not lie entirely within the Lower Vaal WMA, for the purposes of this water situation assessment study, the population is assumed to be in the Lower Vaal. This is a realistic assumption because Kimberley's water supply is sourced from the Lower Vaal.

There are some surprisingly large rural populations in the Lower Vaal, especially in the areas west of Mafikeng, around Kuruman, Pampierstad and Lichtenberg. It is assumed that these communities are supplied from ground water.

The population distribution is shown in **Table 3.2.4.1**. and **Figure 3.2.4.1.**

TABLE 3.2.4.1: POPULATION IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	POPULATION IN 1995		
No	Descrpition	No	Description	Quaternary catchments	Description	URBAN	RURAL	TOTAL
Z		Z		ZB-ZF	Botswana Quats	0	9,500	9,500
TOTAL IN BOTSWANA						0	9,500	0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	79,250	361,947	441,197
	TOTAL IN D CATCHMENT					79,250	361,947	441,197
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	44,500	78,160	122,660
				C31A-F	Harts	111,100	121,000	232,100
				C33A-C	Vaalhartz	51,700	89,110	140,810
		Sub-total				207,300	288,270	495,570
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	286,900	58,930	345,830
		Sub-total				286,900	58,930	345,830
	TOTAL IN C CATCHMENT					494,200	347,200	841,400
TOTAL IN RSA						573,450	709,147	1,282,597
TOTAL IN NORTH WEST						201,228	574,492	775,720
TOTAL IN NORTHERN CAPE						324,956	110,666	435,622
TOTAL IN FREE STATE						47,267	23,989	71,256
TOTAL						573,450	718,647	1,282,597

3.3 MACRO-ECONOMICS

3.3.1 Introduction

The purpose of this section is to provide an economic overview of the salient features of the Lower Vaal WMA in terms of the following aspects:

- The present economic development of the Lower Vaal WMA on a sectoral basis, taking into account the context of economic development in South Africa.
- The comparative advantages of the Lower Vaal WMA.

Selected graphs are included to illustrate the text and additional supporting information is given in **Appendix B.1.**

3.3.2 Data Sources

The information presented has been derived from a database of macroeconomic indicators that was prepared by Urban-Econ: Development Economists from a number of sources, including the Development Bank of Southern Africa. **Appendix B2** contextualises each WMA economy in terms of its significance to the national economy, as derived from the national economic database. Only gross geographic product (GGP) and labour data are analysed. A brief description of the database of macro-economic indicators and associated economic information system is given in **Appendix B3.**

Gross geographic product is the total value of all final goods and services produced within the economy in a geographic area for a given period. GGP is the most commonly used measure of total domestic activity in an area and is also the basis for the national account. Changes in the local economy can therefore be expressed as an increase in GGP. Base GGP data for 1972, 1975, 1978, 1981, 1984, 1988, 1991, 1993 and 1994 were obtained from Statistics South Africa. Data for unknown years between 1972 and 1994 were interpolated applying a compound growth formula. The interpolated data was balanced with national account figures. Data for 1995 to 1997 is based on weighted least squares estimates of the long-term trend, taking into account the change in electricity consumed. The projected data was balanced with national account figures. The major limitation of GGP figures is that activities in the informal sector are largely unmeasured.

The labour distribution provides information on the sectoral distribution of formal economic activities, as do the GGP figures, but in addition, information is provided on the extent of informal activities, as well as dependency. Dependency may be assessed from unemployment figures, as well as by determining the proportion of the total population that is economically active. *Total economically active* population consists of those employed in the formal and informal sectors, and the unemployed. *Formally employed* includes employers, employees and self-employed who are registered taxpayers. *Unemployment figures* include people who are actively looking for work, but are not in any type of paid employment, either formal or informal. *Active in informal sector* includes people who are employers, employees or self-employed in unregistered economic activities, i.e. businesses not registered as such. The labour data was obtained directly from the Development Bank of Southern Africa (DBSA). The DBSA has utilised the 1980 and 1991 population censuses as the basis but has also updated the figures utilising the 1995 October Household Surveys of Statistics South Africa (CSS statistical release P0317 for South Africa as a whole and P3017.1 to P0317.9 for the nine provinces).

The GGP and labour statistics are disaggregated into the following major economic sectors:

- Agriculture
- Mining
- Manufacturing
- Electricity
- Construction
- Trade
- Transportation
- Finance
- Government and Social Services (Community Services).

Separate GDP figures for government and social services are available. However, in the labour market these figures are combined into the community services sector. The nature and composition of each sector are described in **Appendix B.3.**

3.3.3 Methodology

As economic data is mainly available on a magisterial district basis it was necessary to convert the existing data to WMA's as the respective boundaries do not correlate.

Each sector of the economy was dealt with in an appropriate way to reflect a reasonable approximation of the spatial distribution of production and labour:

Agriculture

The digitised geographic layer of WMAs was merged with the Magisterial District (MD) boundaries, and the surface area for each of the newly generated polygons was determined. The proportion of the surface area of each of the MD, which falls within each WMA, was calculated, and that proportion was used to allocate the part of a GGP figure that falls on each side of a WMA-boundary.

Trade and Community Services

To take account of the subdivision of local authority areas by MD or WMA boundaries, the number of enumerator areas (EAs) falling within each subdivision of a local authority area, as a proportion of the total number of EAs in a local authority area, was determined. This proportion was applied to the latest population figure (1996 census) of each local authority area. As EAs are of approximately equal population size, these proportions were used to calculate the approximate population for that part of a local authority area which falls within each MD, as they are subdivided by WMA boundaries. The population of each MD segment, as a proportion of the total MD population, was used to calculate the proportion of a

GGP figure which should be allocated to each segment of a MD, so that theses figures could be totalled up within the WMA boundaries.

Other Sectors

Historical factors such as the relocation of certain segments of the population to non-productive areas, and the immigration of mainly Mozambicans, especially to Mpumalanga and the Northern Province, had to be taken into account when allocating the GGP figure to the WMAs. Subsequently, for all the sectors apart from those discussed above, only the caucasian population was used to perform the calculations as described above. Economic activities in these sectors are less dependent on population *per se*, but are dependent on the same factors which affect the kind of population distribution that is not distorted by government intervention or other external factors. The caucasian population has typically not been influenced by the latter factors, and its distribution is therefore a better guide for determining the distribution of economic activities in these sectors.

3.3.4 Status of Economic Development

The GGP of the Lower Vaal WMA was R9,8bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

- Kimberley 29,6%
- Postmasburg 14,8%
- Lichtenburg 9,6%
- Kuruman 8,9%
- Vryburg 8,3%.

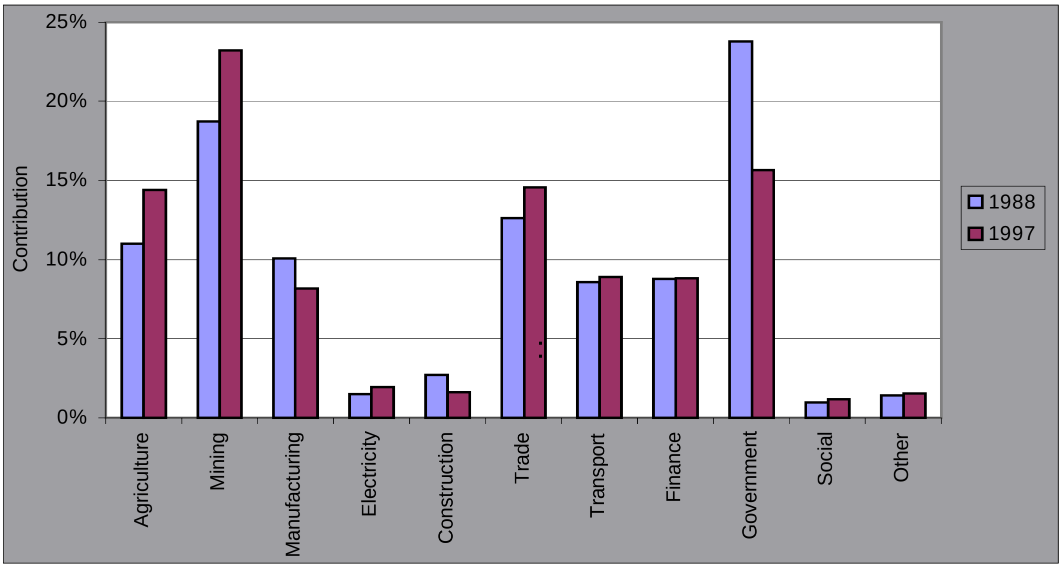
Economic Profile

The composition of the Lower Vaal WMA economy is shown in **Diagram 3.3.1.** The most important economic activities of this economy are:

- Mining 23,2%
- Government 15,7%
- Trade 14,5%
- Agriculture 14,4%

The main agricultural activities identified include livestock and dryland cropping. Livestock include beef and dairy cattle, goats, non-wooled sheep, pigs and ostriches. Crops grown are mainly maize, but also sunflower, cotton, groundnuts and vegetables.

Diagram 3.3.1: Contribution by Sector to the Economy of the Lower Vaal Water Management Area, 1988 and 1997 (%)



The mining activities in this WMA include Kimberlite diamonds, iron ore, manganese and other minerals such as limestone, dolomite and amphibole asbestos. Kimberlite diamonds are mined at the Finsch Mine at Lime Acres, one of the most important diamond producing mines of the De Beers Company. Kimberley is also an important diamond mining area, which is known for its high quality diamonds. The Sishen Mine, currently the major supplier of iron ore in the country, is located in the Lower Vaal WMA. This mine has a mineable depth of 30 metres and was opened in 1953 as part of Iscor's expansion strategy. In 1997, it produced approximately 2 400 million ton iron ore per year. An increase in mining and transportation activities can be expected with the construction of the Sishen railway line that will link Sishen with the Coega initiative near Port Elizabeth. Other important mining areas includes Kudumane (iron, manganese and asbestos etc), Ganyesa (diamonds, mica group clay and salt) and Taung (diamonds, limestone, dolomite and salt).

Since manufacturing production is far less than mining production it can be deduced that only a small percentage of benefication is done locally. This implies that a large percentage of raw mining products are exported to other areas for benefication. Lichtenburg is the largest manufacturing town in the WMA, where manufacturing includes cement and cheese factories. Kimberley is the second largest manufacturing town, but its output is half that of Lichtenburg.

The trade sector is concentrated in wholesale of primary products and related services to the community. Main products of trade in this WMA are ostrich-related products and diamonds (for export) as well a food retail related products.

The importance of the government sector can be attributed to restructuring activities that took place after 1994 when Kimberley became the capital of the Northern Cape.

Economic Growth

The average annual growth in production by sector is shown in **Diagram 3.3.2.** It is evident that growth has predominantly taken place in primary sector activities. The following sectors recorded the highest average annual growth rates between 1987 and 1997:

- Agriculture : 2,3%
- Mining : 1,7%
- Electricity : 2,3%

The growth in the agricultural sector can be attributed to the wide diversity of products found in this area, making the area less vulnerable to fluctuations in the market. The international demand for ostrich related products also contributed to this growth.

Growth in the mining sector is largely the result of successful operations of mines in WMA and the fact that some of the main diamond and iron ore mines are located in this area.

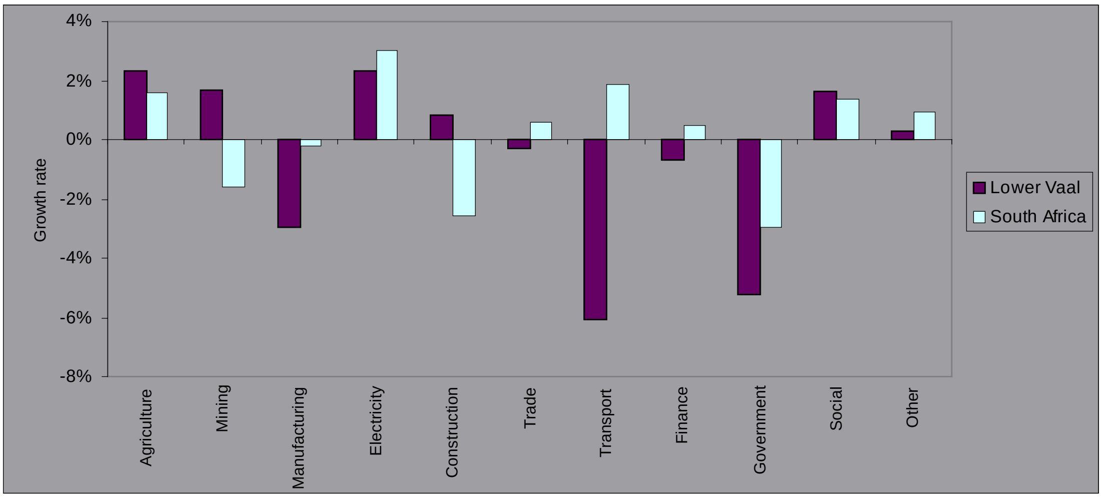
Growth in the electricity sector can be attributed to the activities of the manufacturing and mining sectors, which are large consumers of electricity and water.

Labour

Of the total labour force of 343 000, 37,52% were unemployed, which is higher than the national average of 29,3%. Fifty four percent (53,7%) are active in the formal economy. Thirty nine percent (38,8%) of the formally employed labour force work for government, while 28,9%, are involved in agriculture, and 10,4% in trade.

During the period 1980 to 1994, employment growth was only recorded in the financial services sector (1,1% per annum).

Diagram 3.3.2: Compound Annual Economic Growth by Sector off the Lower Vaal Water Management Area and South Africa, 1988-1997



3.3.5 Comparative Advantages

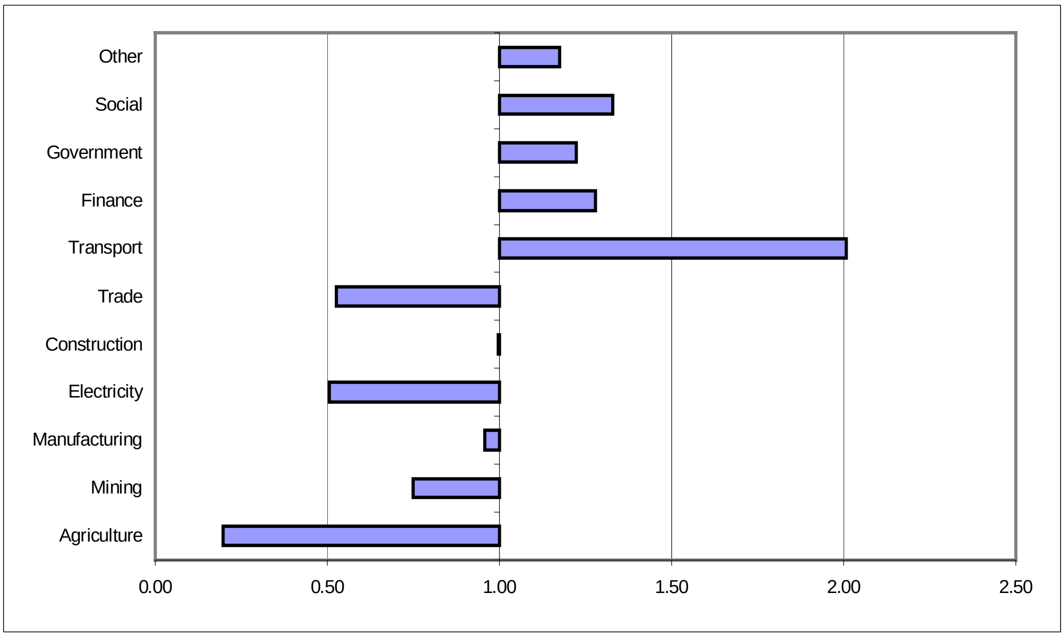
A geographic area is said to have a comparative advantage in the production of certain goods and services if it can produce them at a lower cost per unit than another region while maintaining the same quality. When this is the case, production of such goods tend to become relatively more concentrated in the region which has the comparative advantage. The location quotient is a measure of the relative concentration of economic activities in a region as compared with another region, or as compared with a larger region of which it forms part. A location quotient for an economic sector with a value of more than one implies that the sector contributes a larger percentage to a sub-region's GGP than that sector contributes to the larger area of which the sub-region forms part. The location quotient can, however, not be equated with comparative advantage, and provides only an indication.

Diagram 3.3.3 shows the location quotients for the Lower Vaal WMA.

The Figure shows that, based on the location quotients for 1997, the Lower Vaal WMA economy is relatively more competitive than the remainder of South Africa in the following economic activities:

- Agriculture : 3,1
- Mining : 2,95
- Transport : 1,1

Diagram 3.3.3: Lower Vaal Gross Geographic product Location Quotient by Sector, 1997



From **Diagram 3.3.3** it is evident that the economy is becoming increasingly service orientated. This is largely the result of growth recorded in the tertiary sector activities.

The comparative advantage of the agricultural sector could largely be attributed to the diversity of products found in this area as well as the positive growth rate recorded in this sector.

The mining sector also has a comparative advantage in national context. This is due to the spectrum of mining activities taking place in the Lower Vaal WMA. Especially diamond and iron ore mining is significant in this WMA.

Transportation is of particular importance in this WMA and its location quotient of 1,1 can be attributed to the large volume of primary products that are transported from the region to benefication plants which are mostly located in Gauteng Province.

3.4 LEGAL ASPECTS AND INSTITUTIONAL ARRANGEMENTS FOR WATER SUPPLY

3.4.1 Past History

The history of settlement in southern Africa is linked to the availability and supply of fresh water. From early times South African water law was based on the needs of white settlers who in colonizing the land promulgated a water law in which domestic and agriculture needs and later industrial needs played the major role (*res publica)* and the government had the function to regulate the use of water (*dominus fluminis*).

Initially Roman and Roman Dutch law had a strong influence in the shaping of South African water law and water running in rivers was regarded as common property. This changed in the latter half of the 19th century, after the occupation of the Cape by the British. The judges trained by the British introduced the principle that owners of property riparian to a river became entitled to water from that river.

The first codification of water law in South Africa was in the Irrigation and Conservation of Waters Act of 1912. The emphasis was still on irrigation and carried down the riparian principle. This Act was repealed by the Water Act of 1956, which also placed a major emphasis on the use of water for irrigation, although other water uses, such as domestic, urban and industrial, also received recognition.

This remained the situation until the National Water Act (Act No. 36 of 1998) (NWA) was assented to by the President on 20 August 1998. As from 1 October 1999 the whole of the NWA came into full effect and is now the only Act dealing with water law.

3.4.2 National Water Act

The NWA does away with and introduces some far-reaching concepts. These concepts have both economic and social features. The former to address water management by conservation and pricing strategy and the latter by ensuring that past discriminatory principles are not continued in the NWA. The most important of these can be summarised as follows:

- The riparian principle is done away with. The nation’s water resources become common property, belonging to the nation as a whole. Therefore the previous concept of private ownership in water is done away with;

- The national government, through the Minister of Water Affairs and Forestry, becomes responsible as the public trustee of all water resources to ensure that water resources are protected and water allocated equitably and used beneficially in the public interest. Therefore the NWA reflects the constitutional right of access to sufficient water (Section 27 of the Constitution);
- All right to use water derives from the NWA;
- Water must be available for the Reserve. The Reserve is a new concept and consists of two legs, namely the quantity and quality of water required to satisfy basic human needs as prescribed by the Water Services Act (Act No 108 of 1997) for people who now or will in future require water and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Thus environmental considerations are anchored in the NWA;
- Setting out in the purposes of the Act that institutions which have appropriate community, racial and gender representation must be developed to give effect to the NWA;
- Shifts the emphasis from the traditional “supply management” approach towards “demand management”, that is conservation of the nation’s water resources by lessening the demand and providing for an innovative pricing system.
- Providing for extensive public participation. Virtually no decision can be made without public participation;
- The abolishment of the Water Courts and introducing a Water Tribunal where administrative final decisions can be appealed to; and
- Recognition of international obligations.

3.4.3 Strategies

The NWA makes provision for establishment of two water management strategies. These are the National Water Resource Strategy and the Catchment Management Strategy. The National Water Resource Strategy is binding on the Minister of the Department of Water Affairs and Forestry, other organs of State and all water management institutions for anything contained therein, while the catchment management strategy is binding on the relevant catchment management agency and is more on a local level.

Water resource management will in future be based on the management strategies and the classification system for the protection of water resources provided for in the NWA. The contents of the National Water Resource Strategy are wide and included therein are the principles relating to water conservation and water demand management; the objectives in respect of water quality to be achieved through the classification system, as well as having to establish the future water needs. The National Water Resource Strategy will also provide for international rights and obligations.

3.4.4 Environmental Protection

The Minister must classify the nation's water resources and then determine the class and resource quality objectives for each class. This will establish clear goals for resource protection and at the same time provide for a balance between the need to protect and sustain one's water resources and the need to develop and use them on the other hand.

An important function is for the Minister to determine the Reserve, which as stated above, is closely linked to the Water Services Act (Act No. 108 of 1997).

Section 19 of the NWA provides *inter alia* that any person who is in control of land over which pollution is taking place or who causes pollution or potential pollution to take place, must take the necessary steps to prevent this from continuing. Should this not be done, the Minister shall have the right to take the necessary steps to recover the cost from the responsible person.

3.4.5 Recognition Of Entitlements

The NWA abolishes the historical distinction between public and private water. There is no ownership in water and all water is subject to a licensing system, except for the following:

- Water use that is set out under Schedule 1 of the NWA;
- General authorisations issued under section 39 of the NWA; and
- Existing lawful use recognised under the NWA until such time as the person is required to apply for a license.

The statutory difference between water resources within an area proclaimed as a government water control area in terms of the Water Act of 1956 and areas outside a government water control area has now been done away with. In actual fact the whole of the country is a government water control area.

3.4.6 Licensing

Whereas the Water Act of 1956 divided water into different categories, in the NWA all water has the same status. **Section 21** of the NWA sets out what is regarded as water use. These include, amongst other uses, taking water from a water resource, storage of water, diverting water, discharging waste into a watercourse, disposing of waste in a manner that may detrimentally impact on a water resource and recreational use.

Two new concepts of water use are created. The first is that the Minister can declare any activity to be a stream flow reduction activity, if that activity reduces the availability of water. Afforestation has already been declared a stream flow reduction activity. The second new concept is that the Minister can declare any activity to be a controlled activity if that activity impacts on a water resource. Activities such as irrigation on any land with waste, recharging of an aquifer are examples of activities that are already controlled activities.

All water use requires a license unless it falls into a Schedule 1 use (this deals with the *de minimus* use, such as water for reasonable domestic use, small gardening and animal watering (excluding feedlots); or was permissible as an existing lawful use (water use permitted under previous laws and which were exercised during the period of two years before the date that section 32 came into effect; namely 1 October 1998); and under a general authorisation.

An important innovation is that a license can only be for a maximum period of 40 years and is subject to a review period, which may not be at intervals of more than five years. A license can be increased at each review period but not for more than the review period. This is known as the “revolving license”.

If a person who has an existing lawful use applies for a license under section 43 of the NWA (compulsory licensing), and the application has been refused or has been granted for a lesser amount which results in severe economic prejudice, the applicant may claim compensation. Compensation cannot be claimed if the reduction is to provide for the Reserve, rectify a previous over-allocation or a previous unfair allocation. Compensation must be claimed from the Water Tribunal.

The Minister has the right to attach conditions to any license as well as to make regulations on various topics set out in **section 26** of the NWA.

It is important to note that although the Water Services Act (Act No. 108 of 1997) deals with water services, the actual water use is controlled under the NWA.

3.4.7 Other legislation

The NWA is aligned with other laws in order to prevent, for example, duplication of applications, unnecessary expenses and where possible, a “one stop” can be issued. Specific examples are as follows:

- Environment assessments in terms of the Environmental Conservation Act of 1989 can be taken into account by the responsible authority when issuing a license;
- If a license is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a license for water under the NWA; and
- Provisions in the Constitution of the Republic of South Africa must be complied with.

Further, there is a close connection between the Water Services Act (Act No. 108 of 1997) and the NWA.

The Abolition of Racially Based Land Measures Act repealed laws that previously restricted black persons from owning or occupying land. These acts had the effect of preventing black persons from having any water rights or under certain circumstances, limited water entitlements.

Notwithstanding the NWA there are other acts to which a water user and indeed the State must comply.

These Acts are the following:

Physical Planning Act (Act No. 125 of 1991)

Under this act no land use, development or subdivision may be permitted unless in accordance with an approved plan.

Development Facilitation Act (Act No. 67 of 1995)

This act prescribes the set of principles with which all development projects and all land use and land use planning should comply, and which will serve as guidelines for the administration of land use and development schemes.

Restitution of Land Rights (Act No. 22 of 1994)

This act is aimed at the restitution of land to those who have been deprived thereof in terms of discriminatory laws. Claims are lodged with the Land Claims Commission. It is because of this act that when a transfer of water entitlements is approved in terms of the NWA an indemnity is required from the transferor that a claim was not lodged against the land in terms of the Restitution of Land Rights Act.

Environmental Conservation Act (Act No. 73 of 1989)

This act provides for the effective protection and control of the environment. It makes provision for the declaration of an environmental conservation policy.

In terms of this act the state has a responsibility to act as trustee of the natural environment and to consider all activities which may have an influence on the environment.

Activities, which may have a detrimental effect on the environment, have been published in terms of **section 21** of this act. To undertake any of these activities, authorisation is required, which can only be obtained from the Minister of Environmental Affairs and Tourism after the prescribed procedure has been complied with. The construction of various forms of water works (dams, water diversions, water transfer schemes, etc.) are subject to the new process.

Through a consultative process a White Paper for Sustainable Coastal Development in South Africa was prepared. In terms thereof it is the joint responsibility of the Departments of Water Affairs and Forestry and of Environmental Affairs and Tourism to protect the in-shore marine environment.

In terms of this act the Department of Environmental Affairs and Tourism is responsible for issuing waste permits under this act and has published a Government Notice 1986 of 24 August 1990 relating to the identification of waste. This government notice needs drastic amendment to bring it in line with the NWA.

In May 2000 the Department of Environmental Affairs and Tourism published a White Paper on Integrated Pollution and Waste Management for South Africa. Aspects included water pollution; diffuse water pollution, marine pollution; and land pollution.

National Environmental Management Act (Act No. 107 of 1998)

This act lays a new foundation for environmental management. The act includes 20 principles that serve as a general framework within which environmental management and implementation plans must be formulated and guide any other law concerned with the protection or management of the environment. Environment is defined as the natural environment and the physical chemical, aesthetic and cultural properties of it that influence human well being.

To give effect to these principles this act creates the National Environmental Forum and the Committee for Environmental Co-ordination and defines the procedure for the establishment of a Coastal Management Subcommittee of the Committee for Environmental Co-ordination in order to achieve better inter-governmental co-ordination of coastal management.

This act provides for the drawing up of environmental implementation plans by certain scheduled national Government Departments and the Provinces. In addition, environmental management plans are to drawn up by certain national Departments. The two sets of plans do not have to be drawn up by the private sector and may be consolidated. The purpose of the plans is set out in detail and must co-ordinate and harmonise environmental policies, plans, decisions of the three spheres to prevent duplication; give effect to co-operative governance and enable monitoring the achievement. Chapter 7 of this act relates to environmental damage, duty of care, emergencies and remediation.

Conservation of Agriculture Resources Act (Act No. 43 of 1983)

This act is to provide for control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil; the water resources and vegetation and the combating of weeds and invader plants. Except for weeds and invader plants, this act does not apply to land in an urban area.

Institutions Created Under the National Water Act

The NWA creates various institutions, some of which are listed below.

The first are Catchment Management Agencies (CMA) and one CMA will be established in each of the Water Management Areas that have been promulgated by Government Notice 1160 of 1 October 1999 (19 in total). These will have various functions either delegated or assigned to them, thus bringing the management of water resources to the regional or catchment level. A CMA will operate via a board along the lines set out in Schedule 4 to the NWA. The composition of the board is recommended by an Advisory Committee that is established by the Minister and has the important task to recommend to the Minister proposed members who are racially, gender and community representative.

A second institution is that of Water User Associations (WUA) that will operate on a restricted local level and are in effect cooperative associations of individual water uses who wish to undertake related water activities for a mutual benefit. Irrigation Boards established under the Water Act of 1956 had until 29 February 2000 to transform into a WUA. All WUA's must have a constitution based on the lines set out in Schedule 5 to the NWA, which must be approved by the Minister. The policy of the Department of Water Affairs and Forestry is that these must also as far as possible be racially, gender and community representative.

A third institution is bodies to implement international agreements. This can only be established by the Minister in consultation with the Cabinet.

A fourth body that the Minister can establish is Advisory Committees. These committees may be established for a particular purpose but can also have powers delegated to it by the Minister.

Lastly the NWA establishes a Water Tribunal where appeals against administrative decisions by the Department of Water Affairs and Forestry and CMA's can be heard. The question of compensation for loss of entitlements to use water is also to be heard in this Tribunal. Appeals on questions of law from the Tribunal are heard in the High Court.

3.4.8 Institutional Arrangements

The NWA creates various institutions, some of which are listed below.

The first are Catchment Management Agencies (CMA) and one CMA will be established in each of the Water Management Areas that have been promulgated by Government Notice 1160 of 1 October 1999 (19 in total). These will have various functions either delegated or assigned to them, thus bringing the management of water resources to the regional or catchment level. A CMA will operate via a board along the lines set out in Schedule 4 to the NWA. The composition of the board is recommended by an Advisory Committee that is established by the Minister and has the important task to recommend to the Minister proposed members who are racially, gender and community representative.

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A third institution is bodies to implement international agreements. This can only be established by the Minister in consultation with the Cabinet.

A fourth body that the Minister can establish is Advisory Committees. These committees may be established for a particular purpose but can also have powers delegated to it by the Minister.

Lastly, the NWA establishes a Water Tribunal where appeals against administrative decisions by the Department of Water Affairs and Forestry and CMAs can be heard. The question of compensation for loss of entitlements to use water is also to be heard in this Tribunal. Appeals on questions of law from the Tribunal are heard in the High Court.

3.4.9 Institutions Responsible for Community Water Supplies

The Water Services Act, No. 108 of 1997, deals with the provision of water supply services and sanitation services in a manner consistent with the broader goals of water resource management. The institutional structure provided for in the Act includes, in addition to the National Government, represented by the Department of Water Affairs and Forestry, the following bodies:

(i) Water Services Authorities include municipalities, district councils, local councils, and metropolitan councils. These authorities are responsible for ensuring access to water services.

District Councils

A district council is an institutional entity which provides services to rural areas or areas not being serviced or falling under a local council. Each district council area has been subdivided into smaller areas, namely magisterial districts, and include the areas falling under a local council. (A magisterial district is not an institutional arrangement.).

The District Councils within the Lower Vaal WMA are as follows:

- The Upper Karoo, of which only a very small portion, just north of Douglas, falls within the Lower-Vaal WMA.
- The Lower Orange which falls partially into the south-western portion of the WMA.
- The Diamantveld District Council, which includes the areas of Kimberley, Barkley West and Warrenton.
- The Lejwelputswa District Council, which includes the south-eastern corner of the WMA.
- The Central District Council, which includes the north-eastern corner of the WMA, including towns such as Lichtenberg and Delareyville.
- The Bophirima District Council falls almost entirely within the Lower Vaal WMA and includes quaternary D41E in the north down to Bloemhof dam in the east.
- The Southern District Council has such a small portion of its area of jurisdiction within the Lower Vaal WMA that for all practical purposes it can be ignored.
- The Kalahari-Kgalagadi District Council falls entirely within the Lower Vaal WMA and includes towns of Vansylsrus in the north-west , Hotazel, Kuruman and Sishen in the south.

Irrigation Boards

The following irrigation boards fall within the Lower Vaal WMA. The irrigated areas scheduled under these irrigation boards are given in Chapter 4.

Water Boards

There are only two water boards in the Lower Vaal WMA, the Kalahari East Water Board and the North West Water Supply Authority.

The Kalahari East Water Board receives water from Upington’s municipal supply and distributes this to farmers in the Kalahari for stock-watering and domestic use.

3.5 LAND USE

3.5.1 Introduction

Land use within the Lower Vaal WMA is dominated by stock farming. The reason for this is that most of the area is too dry to support dry-land crops. In the east of the WMA, especially in the vicinity of Lichtenberg and Delereyville, dry-land crops are grown, but it is debatable whether or not this is commercially viable due to the low and erratic rainfall. Landuse is shown in **Table 3.5.1.1.**

There are large areas under irrigated crops in the Vaalharts area, but compared to the total area of the WMA, this area is small.

According to Le Maitre et al (1999), large areas of the Kalahari are under alien vegetation. This seems unlikely since there is insufficient rainfall to sustain any vegetation and much of the western portion of the WMA is desert.

3.5.2 Irrigation

Irrigation is by far the largest user of water in the Lower Vaal WMA. Irrigation occurs within government water schemes, irrigation boards or private irrigation. The largest irrigation scheme is the Vaalharts Government Water Scheme, which is supplied indirectly from Bloemhof Dam. The scheduled area of this scheme is 39147 ha with quotas varying from 7 700 to 9 140 m^3/ha/annum. Including losses, the water use by this scheme is in the order of 500 million m^3/annnum.

The total irrigated area and various crop areas for each sub-catchment are shown in **Table 3.5.2.1**. A map depicting the extent of the existing irrigation is shown in **Figure 3.5.1.1.** The irrigated area has been accepted as the maximum of the mid-summer crop area and the mid-winter crop area. Considering the given full range of crops being irrigated, mid-summer has been defined as January/February while mid-winter was defined as July/August. This will account for double cropping, where appropriate.

The available information on irrigation methods only stipulates the dominant irrigation method per sub-catchment. The irrigation methods used for a specific crop type however do not vary significantly between different catchments. The most common methods used are flood irrigation, sprinkler systems, mechanical systems, micro systems and drip systems.

It is generally recognised that future growth in irrigation will be severely limited by the availability of water. In more water-scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use. In order to do this it is necessary to base such decisions on sound economic principles that include the economic return per unit of water. Although acknowledged to be fairly generalised, it is suggested that only three economic categories of irrigated crops be used for the purpose of this study. Table 3.5.2.2 shows the typical crops within each category.

TABLE 3.5.1.1: LAND USE IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	CATCHMENT AREA	IRRIGATION FIELD AREA	IRRIGATION CROP AREA (from Loxton Venn, 1999)	DRYLAND SUGAR CANE	AFFORESTATION	ALIEN VEGETATION	URBAN	TOTAL
No	Descrpition	No	Description	Quaternary catchments	Description								
Z		Z		ZB-ZF	Botswana Quats	112,800	0.0	0.0	0.0	0.0	45.0	0.0	45.0
TOTAL IN BOTSWANA						112,800	0.0	0.0	0.0	0.0	45.0	0.0	45.0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	81,811	0.0	0.0	0.0	0.0	384.4	30.2	414.6
	TOTAL IN D CATCHMENT					81,811	0.0	0.0	0.0	0.0	384.4	30.2	414.6
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	10,210	35.7	35.7	0.0	0.0	25.5	21.0	117.9
				C31A-F	Harts	11,020	1.0	1.0	0.0	0.0	12.5	19.0	33.5
				C33A-C	Vaalhartz	9,843	336.9	415.7	0.0	0.0	0.3	36.0	788.9
		Sub-total				31,073	373.6	452.4	0.0	0.0	38.3	76.0	940.3
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	20,470	118.3	139.8	0.0	0.0	27.9	171.0	457.0
		Sub-total				20,470	118.3	139.8	0.0	0.0	27.9	171.0	457.0
	TOTAL IN C CATCHMENT					51,543	491.9	592.2	0.0	0.0	66.2	247.0	1397.3
TOTAL IN RSA						133,354	492	592	0	0	451	277	1,812
TOTAL IN NORTH WEST						66764	246	296	0	0	226	139	907
TOTAL IN NORTHERN CAPE						58759	217	261	0	0	199	122	798
TOTAL IN FREE STATE						7831	29	35	0	0	26	16	106
TOTAL						246,154	492	592	0	0	496	277	1,857

TABLE 3.5.2.1: LAND USE IN 1995 (from Loxton Venn, 1999, p24)

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	IRRIGATED AREA BY CROP CATEGORY (km2)				TOTAL
No	Descrpition	No	Description	Quaternary catchments	Description	Perennial	Summer	Winter	Undifferentiated	
Z		Z		ZB-ZF	Botswana Quats	0.0	0.0	0.0	0.0	0.0
TOTAL IN BOTSWANA						0.0	0.0	0.0		0.0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.0	0.0	0.0	0.0	0.0
	TOTAL IN D CATCHMENT					0.0	0.0	0.0		0.0
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	2.5	10.0	23.2	0.0	35.7
				C31A-F	Harts	6.4	7.9	6.9	0.0	21.1
				C33A-C	Vaalhartz	84.0	187.0	125.3	0.0	396.2
		Sub-total				92.9	204.8	155.4		453.0
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	25.0	59.9	55.0	0.0	139.9
		Sub-total				25.0	59.9	55.0		139.9
	TOTAL IN C CATCHMENT					117.8	264.7	210.4		592.9
TOTAL IN RSA						117.8	264.7	210.4		592.9
TOTAL IN NORTH WEST						3.1	10.4	23.3	0.0	36.7
TOTAL IN NORTHERN CAPE						114.8	254.4	187.1	0.0	556.2
TOTAL IN FREE STATE						0.0	0.0	0.0	0.0	0.0
TOTAL						117.8	264.7	210.4	0.0	592.9

Table 3.5.2.2: Assurance Categories for Irrigated Crops

Category	Crop Examples
Low	Maize, wheat, Soya bean, dry bean, groundnut and pasture for small stock
Medium	Vegetables, potatoes, tobacco, coffee, cotton, pineapple, seed production and pasture for dairying and ostrich
High	Citrus, deciduous fruit and nuts, sub-tropical fruit and nuts, grapes, sugar cane, tea, dates and speciality vegetables

The above categories include for double cropping of the different crop types where appropriate.

Potential exists for additional irrigation in the Taung Irrigation Board area.

The information on irrigated areas, crop types and irrigation methods were obtained from the Vaal Irrigation Report (1999). Since there has been little change in irrigation practice over the last few years, it is assumed that this report is representative of the situation in 1995.

3.5.3 Dryland Agriculture

Except for sugar cane, all the dryland crops produced in South Africa are assumed to use the same amount of water as that of the natural vegetation they replace. This implies that the water use of dryland crops is already accounted for in the surface water hydrology. Because of the considerable annual variation in dryland cultivation (due to climatic conditions) reliable dryland data are also not always readily available. For the above reasons only dryland sugarcane was investigated for the purpose of this study. There is no dryland sugarcane in the Lower Vaal WMA.

3.5.4 Livestock and Game Farming

The Lower Vaal WMA supports large amounts of stock, with an estimate 2,2 million equivalent large stock units. The water use by this sector, estimated at 39 million/m^3/annum is significant when compared to the limited resources of the Lower Vaal WMA. Some of the stock watering requirements are known to be supplied from the Vaal Gamagara scheme while it is assumed that the rest is supplied from groundwater.

Equivalent livestock numbers in selected key areas are shown in **Table 5.3.3.5.**

3.5.5 Afforestation and Indigenous Forests

There are exotic or natural forests in the Lower Vaal WMA.

3.5.6 Alien Vegetation

The impacts of the widespread infestations by alien plants in South Africa are increasingly recognised. The total incremental water use of invading alien plants was estimated at 3 300 million m^3/a by Le Matre et al. (1999) but this estimate is not widely recognised by the water resources planning community. This estimate is almost twice as high as the estimate for stream flow reduction resulting from commercial afforestation. Le Matre et al. (1999) estimates that the impact will increase significantly in the next 5 to 10 years, resulting in the loss of much, or possibly even all, of the available water in certain catchment areas. Again, this is a debatable point requiring more research to verify these statements.

Much of the infested areas is in the riparian zones where the degree of infestation is largely independent of the rainfall in the surrounding areas. The acacias, pines, eucalyptus, and prosopis species and melia azedarachs are among the top ten invading aliens, which account for about 80% of the water use.

Commercial afforestation has been one of the major sources of alien vegetation in South Africa, largely as a result of poor past forestry management practices. The results of a recent national scale study (Nel et al., 1999) showed that about 44% of the area invaded by plantation trees (pine, eucalyptus and black wattle) overlaps with areas affected by commercial afforestation practices. The new commercial afforestation plantations generally tend to be well-managed, maximising benefits of forestry and minimising environmental impacts.

Alien vegetation infestations across South Africa were mapped under supervision of a CSIR (Environmentek) team using a “best expert knowledge” approach, supplemented by existing detailed localised maps and Geographic Information System (GIS) data sets obtained from certain specific authorities. The expert knowledge was gathered through workshops in different regions and the expert information was mapped directly onto overlays on 1:250 000 scale topographic maps. Data capture procedures were designed to standardise the approach and terminology and to ensure consistency and comparability in the inputs made by the wide range of people involved.

Areas invaded by alien vegetation were mapped as independent polygons with each polygon accompanied by attribute data regarding species and density. All polygons and attribute data were captured in a GIS (Arc/Info). The following shortcomings and limitations of the CSIR data base on alien vegetation infestation have been highlighted by Görgens (1998):

- The quality of data gathered is known to be variable as it depended on the level of expert knowledge available, the nature of the terrain and the extent and complexity of the actual invasion.
- Mapping of alien vegetation ending very abruptly (and artificially) along some or other administrative boundary.
- Mapping of riparian infestations along rivers at the coarse scale of the available GIS coverages (generally, 1:500 000 with 1:250 000 for some areas) could have led to significant under-estimates of river lengths and, therefore, of infested riparian areas. For example, a pilot comparison by the CSIR of 1:50 000 scale (a suitable scale) and 1:500 000 scale maps yielded a river length ratio of 3,0 and greater.
- Riparian infestation identification in a particular catchment with the simple statement: “all rivers are invaded”. In these cases, all the river lengths appearing in the particular coverages were assigned a uniform infested “buffer” strip of specific width, say 20m.

Small rivers not reflected on the smaller scale mapping were not accounted for and therefore infestation along these particular rivers was not mapped or quantified.

The condensed area of alien vegetation within the Lower Vaal WMA is shown in **Table 3.5.1.1.**

3.5.7 Urban Areas

The urban areas within the Lower Vaal WMA are small in comparison with the catchment areas and the increased runoff from paved areas is negligible. The largest urban area is that of Kimberley which falls on the boundary of the Upper Orange and Lower Vaal WMA. However, Kimberley falls within an endoreic area and therefore any increase in runoff will not influence the hydrology of either WMA.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

There are no power stations or major water consuming industries within the Lower Vaal WMA.

3.7 MINES

There are a number of Manganese mines in the Lower Vaal WMA which have significant water requirements. These are all situated in the dry north-west section of the WMA and those listed in the table below have an allocation from the Vaal Gamagara scheme. The other significant mines are the Finch diamond mine and Iscor's Iron ore mine neat Sishen. Iscor also make use of ground water to meet their water requirements.

Table 3.7.1: Allocations to Mines from the Vaal Gamagara Scheme

Mine	Allocation (million/m^3/annum)
Iscor	0.072
Middelplass Manganese	0.476
De Beers Consolidated Mines (Finch Mine)	5.84 (1980) 2.50 (1996)
Associated Manganese Mines of SA (Devon)	0.072
Associated Manganese Mines of SA (Beeshoek)	1.20
Associated Manganese Mines of SA (Gloria 1)	0.42
Associated Manganese Mines of SA (Gloria 2)	0.42
Associated Manganese Mines of SA (Blackrock)	0.96
Associated Manganese Mines of SA	1.30 (1994)
SA Managanese Amcor (Wessels)	0.15
SA Managanese Amcor (Hotazel)	0.60
SA Managanese Amcor (Mamatwana)	0.30
SA Managanese Amcor (Lohatlha)	0.0365
TOTAL	**14.35**

3.8 WATER RELATED INFRASTRUCTURE

The water related infrastructure within the Lower Vaal WMA is sparse due to the arid nature of the WMA. The infrastructure relates mainly to schemes for abstracting water from the Vaal River for export into the drier areas within the WMA. A few small to medium sized dams have been constructed on the Harts River to support irrigation within this area.

The water related infrastructure is described in more detail in **Chapter 4.**

CHAPTER 4: WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The water related infrastructure in the Lower Vaal WMA is sparse. This is due to the limited available water resources in the catchment. The larger water related schemes which are in place are linked to either irrigation or abstractions from the Vaal River, the only abundant source of water within the WMA. By far the most significant of these schemes is the transfer of water from the Vaal River to the Vaalharts irrigation scheme. Smaller schemes transfer water from the Vaal to towns and mines in the arid north-west area of the WMA and to Kimberley.

There are a few significant dams in the WMA, namely the SpitskopDam, the Wentzel Dam, the Douglas weir, the Vaalharts weir and the recently constructed Taung Dam. These dams are used mostly for irrigation purposes.

4.2 DAMS IN THE LOWER VAAL WMA

A complete list of dams is included in Appendix AB3 while details of significant dams are listed below. Note that the data for dams was sourced from the Dam Safety Office and therefore only includes registered dams. Dams with a capacity of less than 50 000 m^3 are generally not registered and there is limited information as to how many of these smaller dams there are in the catchment. The Vaal River Systems Analysis Update (VRSAU, 1999) indicates significant farm dams in the Harts catchment with a total farm dam capacity of 39.3 million m^3.

Table 4.2.1: Main Dams in the Lower Vaal Catchment

Dam Name	River Name	Full supply gross storage capacity ($10^6 m^3$)	Full supply area (km^2)	Firm yield ($10^6 m^3$/annum)
Douglas	Vaal	16.7	8	Effectively zero
Vaalharts	Vaal	48.7	21.2	Unknown
Spitskop	Harts	56.6	25.1	17,0
Taung	Harts	6.6	4.7	Unknown
Wentzel	Harts	6.6	3.0	Unknown

Douglas weir was constructed to provide irrigators on the lower Vaal with water. However, the irrigation is situated upstream of the weir and the saline return flows, coupled with negligible releases from the weir during dry periods results in salinity build-up in the weir which make the water unusable. These irrigators are now supplied from the Orange River via a canal.

Vaalharts weir was constructed on the Vaal River to provide an abstraction point for the Vaalharts irrigation scheme. The weir does not have a significant yield of its own but serves as balancing storage for water released from the Bloemhof Dam.

Spitzkop Dam is situated on the Harts river and was constructed in order to supply water to irrigators on the lower Harts river. The dam is situated downstream of the Vaalharts irrigation scheme and receives return flows from this scheme.

Taung Dam was constructed in 1993 to increase the water supply to the Taung Irrigation Board and allow for additional irrigation in the Pudimoe area. However, the construction of a pump station and pipeline to transfer water to irrigators was found to be uneconomical so the dam is not utilised at present. Water can be released to augment supplies from Spitskop Dam if necessary.

Wentzel Dam is situated on the upper Harts River and supplies water to the town of Schweizer Reineke.

4.3 WATER TREATMENT

Urban demands in the Lower Vaal WMA are relatively small and hence the need for water treatment is limited. The location of significant water treatment plants are listed in **Table 4.3.1.** However, data on these plants is not readily available.

Table 4.3.1: Water Purification Works

Name of Water Purification Works	Position (Quaternary catchment)	Peak rated design flow capacity (Ml/day)	Raw water source	Current supply (1995) (million m^3/annum)
Bloemhof	C91A	Not available	Bloemhof Dam	Not available
Christiana	C91B	Not available	Vaal River	Not available
Delareyville	C31E	Not available	Not available	Not available
Lichtenburg	C31A	Not available	Ground water	Not available
Riverton	C91E	Not available	Vaal River	Not available
Schweizer-Reneke	C31F	Not available	Wentzel Dam	Not available
Vaal Gamagara Gov. Regional Water Supply scheme	C92A	36.37	Vaal River	8.4
Vryburg	C32B	Not available	Vaal-Harts scheme	Not available

4.4 WASTEWATER TREATMENT WORKS

Information on wastewater treatment plants is also not readily available in the Lower Vaal WMA. The two most significant plants are situated in Kimberley but the effluent is not discharged in to the Lower Vaal WMA. **Table 4.5.1** lists the wastewater treatment works within the Lower Vaal WMA.

Table 4.5.1: Wastewater Treatment Works

Name of Wastewater treatment Works	Position (Quaternary catchment)	Peak rated design flow capacity (Ml/day)	Point of effluent disposal
Homevale (Kimberley)	C91E	Not available	Klein Drinkwaterspruit
Beaconsfield (Kimberley)	C91E	Not available	Du Toitspan

4.5 REGIONAL WATER SUPPLY SCHEMES

4.5.1 Vaalharts

The most significant water supply scheme in the Lower Vaal is that which supplies water to the Vaalharts irrigation scheme, the largest irrigation scheme in South Africa. Water is released from Bloemhof Dam to the Vaalharts weir, situated on the Vaal River between Christiana and Warrenton, from where it is diverted into a canal. The incremental yield of Bloemhof Dam is less than the water requirements of the Vaalharts scheme and other irrigators along the lower Vaal. In times of shortages, Bloemhof Dam is therefore supplemented by releases from Vaal Dam. The Vaalharts scheme therefore forms part of the greater Vaal system.

The Vaalharts canal system consists of a Main canal of length 18,9km and capacity 48 m^3/s. This follows the right bank of the Vaal River for about 13km before splitting, the main section heading northward through a low saddle into the Harts River catchment. The smaller branch which continues along the bank of the Vaal is called the Klipdam-Barkley canal. The Main canal splits again into the West canal (length 20,9km, initial capacity 6.0m^3/s), and the North canal (length 60,4km, initial capacity 38,8 m^3/s). The North and West canals have numerous takeoffs into a secondary canals system with a total length of 183km. This secondary system splits further into a tertiary system, which has a total length of 544km and conveys water up to the boundary of each farm. All these canals are concrete lined.

The scheme also has an extensive drainage system to deal with return flows and stormwater.

The peak capacity of the scheme is 48 m^3/s while the recorded transfers peaked at 471 million m^3/annum in 1991. This implies a peak factor of over three.

The Vaal Systems Analysis Update assumed an allocation from the Vaal River of 500 million m^3/annum. This includes distribution losses.

4.5.2 Vaal-Gamagara

The Vaal-Gamagara Regional Water Supply Scheme was initiated in 1964 to supply water mainly to the mines in the Gamagara Valley in the vicinity of Postmasburg and further north of this town. An abstraction works and low-lift pumping station are located on the Vaal River near Delportshoop, just below the confluence with the Harts River, from where water is pumped to the water purification works situated next to the river. Purified water is then pumped though a 99km long double rising main to reservoirs on the watershed of the Vaal River catchment near Clifton. Intermediate pumping stations are situated at Kneukel and Trewil **(see Figure 4.1.1).** The pipeline diameters vary from 700 to 200mm.

From the reservoirs at Clifton, water is gravity fed over a distance of 182 km along the route Postmasburg – Sishen - Hotazel - Black Rock. Branch pipelines of 24 and 5 km respectively supply water to the town of Olifantshoek and a reservoir at Beesthoek.

The design capacity of the scheme is 36.37 Ml/day with allowance being made to increase this capacity with the addition of booster pumps and reservoirs. The actual abstraction of this scheme in 1995 was 8.4 million m^3/annum. This includes the water use by the Kalahari East Rural Water Supply scheme **(see Section 4.5.3).**

4.5.3 Kalahari Rural Water Supply Schemes

Kalahari West

The Kalahari West Rural Water Supply Scheme was constructed in1982 to supply farmers north of Upington with water for stock water and domestic use. The scheme serves a total of 74 farms covering an area of 633 000ha. This scheme was implemented as an emergency scheme when groundwater sources in the region started to fail and at the time only the part of the Kalahari experiencing the worst problems were supplied with water.

Water is sourced from Upington's municipal system and pumped north via a number of balancing reservoirs and small booster pumpstations. The pipeline diameters vary from 250mm to 110mm with a total length of 330km. The peak design capacity of the scheme is 1,99 Ml/day while actual water use in 1995 is estimated at 0,42 million m^3/annum. Taking peak factor requirements into account, it appears as if this scheme is being operated at or near its peak capacity.

Kalahari East

The Kalahari East Rural Water Supply Scheme was constructed in the early nineties to supply water to farmers in the Kalahari north of Upington with water for stock watering and domestic use. The scheme was prompted by the successful implementation of the Kalahari West Rural Water Supply Scheme.

The scheme sources its water from the Vaal-Gamagara pipeline, which is underutilised. The Kalahari East pipeline taps into the Vaal-Gamagara pipeline near Kathu, north-east of Olifantshoek, from where water is pumped through a 32km long rising main heading west to a 4,3 Ml reservoir. From here, water is fed, mostly under gravity, into an extensive pipe network serving an area of 14 120 km^2. The total length of pipeline comprising this network is 1 059km with diameters varying from 450 to 63mm.

The scheme is designed to deliver a peak flow of 6.18 Ml/day with provision made to increase this to 8,52 Ml/day. The actual water supplied by the scheme in 1995 was 1,3 million m^3/annum.

Karos-Geelkoppan Rural Water Supply Scheme

This is a very small scheme, which supplies water to rural communities north of Upington. The actual water supplied by the scheme in 1995 was 0.04 million m^3/annum.

4.5.4 Riverton-Kimberley Transfer

Water is abstracted from the Vaal River at Riverton and purified at the Riverton water treatment plant before being pumped to Kimberley. The rising main consists of, initially, one 900mm diameter pipeline in parallel with a 600mm pipeline. This increases to two 600mm diameter and a single 965mm pipes along the route. The total static head of this rising main is 168m with a maximum capacity of 0,46 m^3/s.

4.5.5 Douglas Irrigation Scheme

A 24km long canal diverts water from the Douglas Weir to irrigate a scheduled area of 1 270ha. This area lies within the Lower Orange WMA, however, and is therefore not reported on in this report. The capacity of the canal is 2 m^3/s.

4.5.6 Orange-Vaal transfer scheme

In 1984 a canal was constructed to transfer water from the Orange River to the Lower Vaal. The purpose of this transfer was to provide additional, good quality water, to irrigators in the vicinity of Douglas on the lower Vaal. The water from this transfer scheme is also used to improve the quality of the water in the Douglas weir, which tends to experience salinity problems due to its position at the downstream end of the Vaal system.

Water is pumped out of the Orange River from a pump station situated just upstream of the Marksdrift weir. A short rising main delivers the water into the 22km long Bosman canal. The irrigation area associated with this scheme is 8113 ha but this lies within the Lower Orange WMA.

The capacity of the scheme is 6 m^3/s. The amount of water flowing into the Douglas Weir, and hence into the Lower Vaal WMA from the Lower Orange WMA, was estimated to be 18 million m^3/annum in 1995.

4.5.7 Harts River Government Water scheme

The Spitskop Dam was constructed to regulate the natural flow of the Harts River and the return flows from the Vaal Harts scheme in order to increase the assurance of supply to riparian irrigators along the lower Harts River. The scheme's allocated irrigation area is 1 663 ha with an application rate of 7 700 m^3/ha/annum. The water allocation is therefore 12,8 million m^3/annum.

The yield of the dam is in the order of 17 million m^3/annum but the river losses associated with releases from the dam to irrigators downstream are large. Taking these losses into account, it appears as if the yield of Spitskop Dam is fully allocated.

4.6 HYDRO-POWER AND PUMPED STORAGE

There are no hydro power stations or pumped storage schemes in the Lower Vaal WMA.

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

The water requirements of the Lower Vaal WMA have been sub-divided into various user sectors for the purposes of this report. These are as follows:

- Bulk water use:
  This includes any large water user which is not supplied by a municipality or is individually metered. Bulk users were further sub-divided into Strategic, Mining and Other users. Strategic use is water for the generation of power ie the cooling of thermal power generators.
- Urban water use:
  Water use by towns and cities. This includes direct use by domestic households and indirect use by offices, light industry, municipal use, hospitals etc.
- Rural water use:
  This includes domestic water use by rural communities, stock-watering and subsistence irrigation
- Irrigation
- Ecological Reserve
  Although not a consumptive use, the water requirements of the ecological reserve are considered to be a water use for the purpose of determining a yield balance.
- Stream flow reduction activities
  Afforestation and alien vegetation reduce the natural runoff which reduces the available yield.

The total water requirement of the Lower Vaal WMA is estimated at 1 305 million m3/annum and includes all distribution and conveyance losses. However, the impact that this water use has on the available yield varies according to the assurance of supply required by the various user sectors. Strategic users, for example, require a very high level of assurance and their water supply infrastructure is designed for an assurance of supply of 99,5%. Irrigators, on the other hand, are prepared to tolerate a much higher risk of failure in return for a greater total volume of water on average and typically operate at an assurance of 80 to 90%.

It is therefore necessary to convert the actual water use of the various water users to an equivalent water use at a common assurance of supply in order to carry out a meaningful yield balance. The assurance level chosen for comparison purposes is the 1:50 year assurance level, or 98% assurance. The conversion from the assurance of supply of each user to a 1:50 year assurance was done by means of stochastic modelling carried out over the whole country to determine factors for converting water use at a given assurance to a 1:50 year assurance.

The water use within the Lower Vaal WMA, at a 1:50 year assurance, is estimated at 735 million m^3/annum **(see Table 5.1.1).** The reason for the large difference between the unassured and assured water use is due to the water required for the ecological environment. While large volumes of water are required in the lower reaches of the Vaal River in order to sustain the riverine ecology, this water is released from the Bloemhof Dam upstream of the Lower Vaal WMA. The ecological requirement therefore impacts on the Middle Vaal and not the Lower Vaal.

Table 5.1.1: Water Requirements Per User Group in 1995

USER GROUP	SUB GROUP	ESTIMATED WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT OR IMPACT AT 1:50 YEAR ASSURANCE (10^6 m^3/a)
Bulk water use (4)	Strategic	0.0	0.0
	Mining	5.3	5.0
	Other	0.8	0.8
Irrigation		615	529
Ecological reserve		481	0
Urban (1)		54	54
Rural (5)		49	52
Neighbouring states		0.0	0.0
Afforestation		0.0	0.0
Alien vegetation		6.0	0.0
Water transfers (3)		0.0	0.0
River losses		94	94.0
TOTAL		**1 305**	**735**

(1) Includes urban domestic, commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, livestock and game.
(3) Only transfers out of the WMA are included.
(4) Includes thermal powerstations, major industries and mines.
(5) Includes subsistance irrigation and stockwatering

5.2 ECOLOGICAL COMPONENT OF THE RESERVE

5.2.1 Introduction

The classification of the main stem rivers in the vicinity of the outlets of the quaternary catchments is described in **Section 2.6.2.** On the basis of this classification, a so-called desktop method has been developed (Hughes and Münster, 1999) to provide a low-confidence estimate of the water required for the ecological component of the Reserve, which is suitable for use in this water resources situation assessment.

The method involves the extrapolation of high confidence results of previous instream flow requirement (IFR) workshops, the use of a reference time series of monthly runoff at the outlet of the quaternary catchment and a number of hydrological indices or parameters that have been defined for 21 desktop Reserve parameter regions in South Africa. These desktop Reserve parameter regions are described and shown in **Figure 5.2.1.1**. The instream flow requirements that were determined previously were mostly based on the use of the Building Block Method (King and Louw, 1998). The monthly time series of natural flow that were used in this WMA are those of the WR90 study. The following are the two main hydrological parameters:

- a measure of the longer term variability, which is a combination of the coefficients of variation of winter and summer volumes (CV); and
- an estimate of the proportion of the total flow that occurs as base flow (BFI), which can be considered to be a measure of short-term variability.

The ratio of the above two indices (CV/BFI) has been used as an overall hydrological index of flow variability or reliability. Rivers with low variability and a high base flow response have very low hydrological indices of flow variability and vice versa.

A relationship has been found between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows for the so-called maintenance and drought periods of the modified flow regime for the river. The essence of the relationship is that for a particular ecological status or class, the water required for the ecological component of the Reserve will increase as the hydrological index of flow variability decreases, and vice versa. Likewise the water requirement will decrease as the ecological status is decreased.

The method that has been used is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The extrapolations from past IFR workshops are based on a very limited data set, which does not cover the whole of the country. While some development work has been completed to try and extend the extrapolations and has improved the high flow estimations for dry and variable rivers, this has been quite limited.
- The extrapolations are based on a hydrological index and no allowance (in the desktop method adopted for this water resources situation assessment) has been made for regional, or site specific ecological factors. It is unlikely that an index based purely on hydrological characteristics can be considered satisfactory but it represents a pragmatic solution in the absence of sufficient ecological data.
- The method assumes that the monthly time series of natural flows are representative of real natural flow regimes and many of the algorithms rely upon the flow characteristics being accurately represented. Should the data indicate more extended base flows than actually occur, the hydrological index of flow variability would be under-estimated and the water requirements for the ecological component of the Reserve would be over-estimated.

5.2.2 Quantifying the Water Requirements

A simulation model has been developed to simulate the relationships that were found to exist between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows and for so-called maintenance and drought flow periods (Hughes and Münster, 1999).

The simulation model provides annual maintenance and drought low flows and maintenance high flows (expressed as a proportion of the mean annual runoff). The model also provides for the seasonal distribution and assurances associated with the monthly flows on the basis of a set of default parameters that has been developed for each of the 21 desktop Reserve parameter regions of South Africa referred to in **Section 5.2.1**. The quaternary catchments in the Lower Vaal WMA fall within the parameter region number 18 and 21.

The monthly time series of natural flows at the outlets of the quaternary catchments have been used to generate an equivalent time series of water requirements for the ecological component of the Reserve. This has been accomplished by relating the assurances of the natural flows in a particular month to the assurances of the flow required for the ecological component of the Reserve during the same month.

In the water balance model it is necessary to express the water requirements for the ecological component of the Reserve in terms of annual requirements that are directly comparable to those of any other sector. It therefore becomes necessary to reduce these water requirements to a common assurance and more specifically the effect that these requirements will have on the capacity of the river system to supply water at a specific assurance i.e. the effect on the yield of the river system.

The effects on the yield of the river system of the water required for the ecological component of the Reserve have been based on an analysis of the monthly time series of these water requirements for the same 70-year period as for the natural time series of flows derived from the WR90 study. This has been estimated by establishing the average annual quantity of water required for the ecological component of the Reserve during the most severe or so-called critical drought that has determined the yield of the river system at a recurrence interval of 50 years. The duration of the critical drought can be approximated by the (inverse of) marginal rate of increase of the yield of the river system per unit increase in storage capacity i.e. the slope of the storage-yield curve at the storage capacity under consideration. The periods of high and low flows in the monthly time series of water requirements for the ecological component of the Reserve also mimic the periods of high and low flows in the monthly time series of natural flows used to establish the yield of the river system. Therefore, the portion of the yield of the system that is required for the ecological component of the Reserve can be estimated by finding the least average flow for all periods in the monthly time series of water requirements for the ecological component of the Reserve that are as long as the critical drought period.

The monthly time series of water requirements for the ecological component of the Reserve has been determined at the outlet of each quaternary catchment for each of the ecological status Classes A to D. These time series have been analysed for various lengths of the critical drought to establish the system yield required for the ecological component of the Reserve. This has been done for a range of system capacities, from which the appropriate value corresponding to the storage capacity being considered has then been selected for use in the water balance.

The method that has been used to quantify the water requirements is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The seasonal distributions of the annual estimates of water requirements are based on analyses of the base flow characteristics of some 70 rivers using daily data, the results of which were then regionalised. Some individual quaternary catchments that have been allocated to a specific region may however, have somewhat different characteristics.
- Similarly, the regional parameters for the assurance rule curves have been based on the duration curve characteristics of the natural flow regimes represented by the monthly time series of flow and some experience of setting assurance rules used at past IFR workshops. Regionalising was done by investigating a representative sample of quaternary catchments and it is therefore possible that some have been assigned to the wrong regions.
- The estimates of water required for the ecological component of the Reserve are the best estimates that can be given at this stage, but must be regarded as low confidence estimates. As more detailed estimates are made for a wider range of rivers, the estimates will be improved through modifications made to the delineation of the regions and the regional parameters that have been assigned. It is also anticipated that a better way of accounting for regional or site specific ecological considerations will be added in due course.

5.2.3 Presentation of results

Estimates of the water requirement of the ecology, as determined by the process described above, are shown in **Table 5.2.3.1** and **Figure 5.2.4.1** at key point level of resolution.

5.2.4 Discussion and Conclusions

It appears from the above low-confidence estimates of the ecological reserve requirements that the impact of the Ecological Reserve on the yield available within the Lower Vaal WMA is negligible. The reason for this is that this WMA is mostly very dry with naturally low winter flows and the Ecological Reserve does not make any demand on low flows where rivers are non-perennial.

The instream flow requirements of the Vaal River, which is perennial, are large at 481 million m^3/annum. However, this water is supplied from the Bloemhof Dam and impacts on the yield of the Middle Vaal WMA and is not reflected as an impact on the Lower Vaal.

5.3 URBAN AND RURAL

5.3.1 Introduction

For the purpose of this study, urban use includes direct use by households and indirect use, which includes industrial and institutional use within the urban area. Rural use includes stock watering and subsistence irrigation.

Rural water use is mostly not metered, and at the time of collecting data for this report, there was no readily available data on the per capita water use in rural areas. DWAF's Directorate of Water Services base their planning and designs on 25 ℓ per person per day while the National Water Resources Strategy (DWAF, 2002) used an amount of between 25 and 40 ℓ per person per day in the Lower Vaal WMA. This Water Resources Situation Assessment uses rates of between 25 and 40 ℓ per person per day in order to be consistent with the National Water Resources Strategy.

The basic human reserve as prescribed by the National Water Act (Act no 36 of 1998), is included in the urban and rural domestic requirements. This Act does not stipulate the quantity of this reserve but an amount of 25 ℓ per person per day seems to be the currently accepted norm.

The urban and rural domestic requirements are shown in **Table 5.3.1.**

TABLE 5.2.3.1: ECOLOGICAL RESERVE

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	PRESENT ECOLOGICAL CLASS	VIRGIN MAR (Incremental)	ACCUMULATIVE	ECOLOGICAL WATER REQUIREMENTS			
No	Descrpition	No	Description	Quaternary catchments	Description				% VIRGIN MAR	Incremental	Accumulative	IMPACT ON 1:50 YEAR YIELD
Z		Z		ZB-ZF	Botswana Quats	#N/A	31.9	31.9	#N/A	#N/A	#N/A	0.0
TOTAL IN BOTSWANA							31.9	31.9				
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	2.1	165.2	165.2	14.8	24.4	24.4	0.0
	TOTAL IN D CATCHMENT						165.2	165.2				0.0
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	3.1	48.7	48.7	12.1	5.9	5.9	0.0
				C31A-F	Harts	3.1	59.0	59.0	11.9	7.0	7.0	0.0
				C33A-C	Vaalhartz	4.1	40.2	147.8	8.0	3.2	11.8	0.0
		Sub-total					147.8	147.8			11.8	
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	3.1	43.0	3,908.0	12.3	5.3	480.7	0.0
		Sub-total					43.0	3,908.0	12.3	5.3	480.7	0.0
	TOTAL IN C CATCHMENT							4,055.8			492.5	0.0
TOTAL							240.1	4,087.7			517.0	0.0

5.3.2 Urban

Introduction

A study by Schlemmer *et al* (2001) in support of the development of the National Water Resource Strategy developed a methodology to provide a framework for estimation of both direct and indirect water requirements for the entire South Africa, as well as for the development of long-term projections. A framework methodology was developed on the basis of available information. Information collected in the field as part of the Water Resources Situation Assessments was used to refine the analysis, identify default values and where available update the default database figures.

Methodology

Urban water requirements were classified into direct use by the population plus indirect use by commerce, industries, institutions and municipalities related to the direct use. These are dealt with below.

Direct Water Use: The following criteria were considered significant in identifying categories of direct water use:

- Economic strata.
- Types of housing.
- Levels of service provided.
- Extent of local authority records.

It was recognised that a critical factor to be considered was the dependence on data that was required from Local and Water Service Authorities. Generally many authorities have records of water supplied to different users; individual households, and at times to flats and multi-household complexes. Further detail is not common.

Categories of direct water use were then identified in order to develop profiles of use per urban centre **(**see **Table 5.3.2.1).** The populations of the urban centres that had been determined were allocated to these categories by Schlemmer *et al* (2001), on the basis of socio-economic category characteristics of each centre.

TABLE 5.3.1: 1995 URBAN AND RURAL DOMESTIC WATER REQUIREMENTS

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	URBAN (million m^3/a)	RURAL (million m^3/a)	TOTAL (million m^3/a)	1:50 YEAR ASSURANCE (million m^3/a)	SOCIAL RESERVE (AT 1:50 YEAR ASSURANCE) (million m^3/a)
No	Descrpition	No	Description	Quaternary catchments	Description					
Z		Z		ZB-ZF	Botswana Quats	0.0	0.1	0.1	0.1	0.0
TOTAL IN BOTSWANA						0.0		0.0	0.0	0.0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	6.3	5.3	11.6	11.7	0.4
	TOTAL IN D CATCHMENT					6.3	5.3	11.6	11.7	0.4
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	3.2	0.7	3.9	4.0	0.1
				C31A-F	Harts	2.9	1.1	4.0	4.0	0.2
				C33A-C	Vaalhartz	2.6	0.8	3.4	3.4	0.1
		Sub-total				8.7	2.6	11.3	11.4	0.5
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	14.0	0.5	14.6	14.7	0.3
		Sub-total				14.0	0.5	14.6	14.7	0.3
	TOTAL IN C CATCHMENT					22.7	3.2	25.8	26.1	0.8
TOTAL IN RSA						29.0	8.5	37.4	37.8	1.2
TOTAL IN NORTH WEST						9.4	6.7	16.1	16.3	0.7
TOTAL IN NORTHERN CAPE						17.9	1.6	19.4	19.6	0.4
TOTAL IN FREE STATE						1.7	0.2	1.9	1.9	0.1
TOTAL						29.0	8.5	37.4	37.8	1.2

The study then proceeded to derive per capita water use for each of these categories using information from the South African Local Government Handbook, and the data collected as part of the Water Resources Situation Assessments from local authorities at the time. Where detailed data was not available, an estimation procedure was followed. The categories defined were associated with default unit water uses to generate overall water use estimates where hard data was not available. These categories and default unit water uses are listed in **Table 5.3.2.1.**

Table 5.3.2.1: Direct Water Use: Categories and Estimated Unit Water Use

	Category	Water Use l/c/d
1.	Full service: Houses on large erven > 500m^2	320
2.	Full service: Flats, Town Houses, Cluster Houses	320
3.	Full service: Houses on small erven <500m^2	160
4.	Small houses, RDP houses and shanties with water connection but minimal or no sewerage service	90
5.	Informal houses and shanties with service by communal tap only	10
6.	No service from any water distribution system	6
7.	Other/Miscellaneous	90

Indirect Water Use:

Indirect water use was considered in terms of four categories, viz. commercial, industrial, institutional and municipal. Again, available information was complemented by data collected as part of the Water Resources Situation Assessments from local authorities at the time. Limited hard data was obtained at the level of detail sought.

In order to develop a comprehensive set of estimates, a standard table relating the components of indirect water use to the total direct water use of an urban centre was developed. The urban centres were first classified according to shared characteristics related to water use. The classification used is shown in **Table 5.3.2.2.**

Where detailed data was not available, **Table 5.3.2.3** was used as a basis for estimating the indirect water use.

Water losses

Urban water losses are included in **Table 5.3.3.4** to show a complete picture of the Urban sector.

Return flows

There is no significant increase in runoff due to paved urban areas within the Lower Vaal WMA. This is because of the very limited urban development and the fact that much of the catchment lies in endoreic areas from which there is no runoff. For example, the largest urban area within the WMA is Kimberley which lies partially within the WMA. However, there are no return flows from Kimberley because it lies within an endoreic area.

Table 5.3.2.2: Classification of Urban Centres Related to Indirect Water Use

Classification	Type of Centre	Perception
1.	Long established Metropolitan centres (M)	Large conurbation of a number of largely independent local authorities generally functioning as an entity.
2.	City (C)	Substantial authority functioning as a single entity isolated or part of a regional conurbation.
3.	Town: Industrial (Ti)	A town serving as a centre for predominantly industrial activity.
4.	Town: Isolated (Tis)	A town functioning generally as a regional centre of essentially minor regional activities.
5.	Town: Special (Ts)	A town having significant regular variations of population consequent on special functions. (Universities, holiday resorts, etc.).
6.	Town: Country (Tc)	A small town serving essentially as a local centre supporting only limited local activities.
New Centres		
7.	Contiguous (Nc)	A separate statutory authority, or number of authorities adjacent to, or close to, a metropolis or city and functioning as a component part of the whole conurbation.
8.	Isolated (Nis)	A substantial authority or group of contiguous authorities not adjacent to an established metropolis or city.
9.	Minor (Nm)	Smaller centres with identifiable new or older established centres not constituting centres of significant commercial or industrial activity.
10.	Rural (Nr)	All other areas not having significant centres.

Table 5.3.2.3: Indirect Water Use as a Component of Total Direct Water Use

<table>
<tr><th>Classification</th><th>Commercial</th><th>Industrial</th><th>Institutional</th><th>Municipal</th></tr>
<tr><td>Metropolitan</td><td rowspan="4">0.2</td><td rowspan="4">0.3</td><td rowspan="4">0.15</td><td rowspan="4">0.08</td></tr>
<tr><td>Cities</td></tr>
<tr><td>Towns Industrial</td></tr>
<tr><td>Towns Isolated</td></tr>
<tr><td>Towns Special</td><td>0.30</td><td>0.15</td><td>0.08</td><td>0.03</td></tr>
<tr><td>Towns Country</td><td>0.10</td><td>0.15</td><td>0.03</td><td>0.10</td></tr>
<tr><td>New Centres</td><td>0.15</td><td>0.08</td><td>0.08</td><td>0.08</td></tr>
</table>

The return flow from losses and treated effluent are also negligible within the WMA.

The only significant return flow from the WMA is from irrigators. The is generally in the order of 10% of the total requirement. In the case of the Vaalharts scheme, return flows are estimated at only 6% of the total requirement. This seems unusually low and needs to be verified.

Return flows are included in **Table 5.3.3.4** to show a complete picture on the Urban sector but a more detailed discussion of return flows is included in **section 5.15.**

Default profiles of indirect water use in relation to total water use were developed on the basis of available information for these classes, and are given in the **Table 5.3.2.3.**

5.3.3 Rural

Water requirements

Rural water requirements are shown in **Table 5.3.3.5** and **Figure 5.3.1.1**.

The following water use has been included under the heading of Rural water requirements:

- Domestic rural use:
  Data on domestic rural water uses is not readily available. The rural population in each quaternary was calculated by Markdata as described in **Chapter 3.2**. A per capita requirement of between 25 and 40ℓ per capita per day was used to calculate the domestic requirements of the rural population.

- Losses:
  No information on rural losses is available. A loss of 20% was assumed. See also section 5.15
- Subsistence irrigation:
  No information on subsistence irrigation is available. It was assumed that the Lower Vaal WMA is too dry for subsistence irrigation on a sustainable and that the water use by this sector is negligible.
- Livestock watering
  Water requirements of livestock and game correspond to the distribution of livestock and game described in **Table 5.3.3.5.** A unit water requirement of 45 l/LSU was assumed where LSU is an equivalent Large Stock Unit. A Table indicating the water use by various livestock and game is shown in **Appendix F.**

5.4 BULK WATER USE

5.4.1 Introduction

Bulk water users are classed as those mines, industries and thermal powerstations that have their own bulk raw water supply systems. This may be a direct supply from a water board or DWAF, or a supply from local groundwater or surface water resources. Those industries and powerstations that are supplied with potable water by municipalities are included in urban water requirements.

Distribution losses are included in the water requirements presented in the **Table 5.4.3.1** and **5.4.4.1**, and are discussed in greater detail in **Section 5.15**.

TABLE 5.3.3.4: URBAN WATER REQUIREMENTS IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	URBAN WATER REQUIREMENTS						Total Urban Require-ment	Total at 1:50 Yr Assu-rance	Per Capita Consumption (L/C/Day)	RETURN FLOWS			Total at 1:50 Assu-rance
No	Descrpition	No	Description	Quaternary Catchments	Description	Direct	Indirect	% Direct Use	Bulk Transport Losses	Distribu-tion Losses	Total Losses				Including Clean Returns	Imper-vious Urban Areas	Total Returns (Incl. Imports)	
Z		Z		ZB-ZF	Botswana Quats	0.0	0.0	N/A			0.0	0.0	0.0	N/A	0.00	0.00	0.00	0.00
TOTAL IN BOTSWANA						0.0	0.0	N/A	5.00%	20.00%	0.0	0.0	0.0	N/A	0.0	0.0	0.0	0.0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	6.3	2.3	73.3%	5.00%	20.00%	2.2	10.8	11.0	380	4.97	0.99	5.96	5.89
	TOTAL IN D CATCHMENT					6.3	2.3	73.3%	5.00%	20.00%	2.2	10.8	11.0	380.3	5.0	1.0	6.0	5.9
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	3.2	0.8	79.6%	5.00%	20.00%	0.9	4.9	5.0	305	0.00	0.96	0.96	0.96
				C31A-F	Harts	2.9	1.7	62.3%	5.00%	20.00%	1.2	5.7	5.8	143	0.00	0.94	0.94	0.94
				C33A-C	Vaalhartz	2.6	1.5	63.7%	5.00%	20.00%	1.6	5.6	5.7	300	0.00	1.61	1.61	1.61
		Sub-total				8.7	4.0	68.3%	5.00%	20.00%	3.6	16.3	16.4	217	0.0	3.5	3.5	3.5
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	14.0	7.0	66.9%	5.00%	20.00%	5.4	26.3	26.5	253	0.00	6.71	6.71	6.71
		Sub-total				14.0	7.0	66.9%	5.00%	20.00%	5.4	26.3	26.5	253	0.0	6.7	6.7	6.7
	TOTAL IN C CATCHMENT					22.7	11.0	67.4%	5.00%	20.00%	9.0	42.7	42.9	238	0.0	10.2	10.2	10.2
TOTAL IN RSA						29.0	13.3	68.6%	5.00%	20.00%	11.2	53.5	53.9	258	5.0	11.2	16.2	16.1
TOTAL IN NORTH WEST						9.4	4.3	68.6%	5.00%	20.00%	3.6	17.3	17.5	83.5	1.6	3.6	5.2	5.2
TOTAL IN NORTHERN CAPE						17.9	8.2	68.6%	5.00%	20.00%	6.9	33.0	33.3	159.0	3.1	6.9	10.0	9.9
TOTAL IN FREE STATE						1.7	0.8	68.6%	5.00%	20.00%	0.7	3.1	3.2	15.2	0.3	0.7	1.0	0.9
TOTAL						29.0	13.3	68.6%	5.00%	20.00%	11.2	53.5	53.9	258	5.0	11.2	16.2	16.1

TABLE 5.3.3.5: RURAL WATER REQUIREMENTS IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	RURAL POPULATION	LIVESTOCK	DAILY DOMESTIC REQUIREMENT (l/c/day)	DAILY LIVESTOCK REQUIREMENT (l/c/day)	DOMESTIC million m^3/a	LIVESTOCK million m^3/a	SUBSISTENCE IRRIGATION million m^3/a	TOTAL RURAL million m^3/a	LOSSES	TOTAL DOMESTIC million m^3/a	RURAL PER CAPITA (l/c/day)	TOTAL AT 1:50 YR ASSURANCE million m^3/a
No	Descrpition	No	Description	Quaternary catchments	Description												
Z		Z		ZB-ZF	Botswana Quats	9,500.0	23,000.0	30.0	45.0	0.10	0.38	0.01	0.50	20.00%	0.13	37.5	0.54
TOTAL IN BOTSWANA						9,500.0	23,000.0	30.0	45.0	0.1	0.4	0.0	0.5	20.00%	0.1	37.5	0.5
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	361,947.0	718,700.0	40.1	45.0	5.29	11.97	3.29	20.55	20.00%	6.62	50.1	21.64
	TOTAL IN D CATCHMENT					361,947.0	718,700.0	40.1	45.0	5.29	11.97	3.29	20.55	20.00%	6.62	50.10	21.64
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	78,160.0	449,900.0	25.0	45.0	0.71	7.49	0.00	8.20	20.00%	0.89	31.2	8.63
				C31A-F	Harts	121,000.0	481,900.0	25.0	45.0	1.10	8.02	0.00	9.13	20.00%	1.38	31.2	9.61
				C33A-C	Vaalhartz	89,110.0	127,200.0	25.0	45.0	0.81	2.12	0.00	2.93	20.00%	1.02	31.2	3.09
		Sub-total				288,270.0	1,059,000.0	25.0	45.0	2.63	17.63	0.00	20.26	20.00%	3.29	31.20	21.33
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	58,930.0	477,500.0	25.0	45.0	0.54	7.95	0.00	8.49	20.00%	0.67	31.2	9.09
		Sub-total				58,930.0	477,500.0	25.0	45.0	0.54	7.95	0.00	8.49	20.00%	0.67	31.20	9.09
	TOTAL IN C CATCHMENT					347,200.0	1,536,500.0	25.0	45.0	3.17	25.58	0.00	28.75	20.00%	3.96	31.20	30.42
TOTAL IN RSA						709,147.0	2,255,200.0	32.7	45.0	8.46	37.55	3.29	49.30	20.00%	10.58	40.9	52.06
TOTAL IN NORTH WEST						574,492.0	1,410,932.6	32.0	45.0	6.71	23.40	2.86	32.97	20.00%	8.39	40.0	40.88
TOTAL IN NORTHERN CAPE						110,666.0	520,868.6	40.0	45.0	1.62	8.56	0.43	10.61	20.00%	2.02	50.0	9.84
TOTAL IN FREE STATE						23,989.0	215,095.5	25.0	45.0	0.22	3.53	0.00	3.75	20.00%	0.27	31.3	1.33
TOTAL						718,647.0	2,278,200.0	32.7	45.0	8.57	37.93	3.29	49.79	20.00%	10.71	40.8	52.60

5.4.2 Strategic

For the purposes of this study, only thermal powerstations are regarded as strategic water users. There are no thermal power stations in the Lower Vaal WMA

5.4.3 Mining

There are a few mines in the Lower Vaal WMA, the most notable being ISCOR's Iron ore mine near Sishen. Although the water use by these mines is insignificant when compared to the total water use of the WMA, the mines are situated in very dry regions where local water resources are scarce. The so-called Vaal Gamagara scheme transfers water to ISCOR as well as the manganese mines in the area although many of these mines also rely on groundwater. It is therefore difficult to obtain accurate information on the total water requirements of the mining sector in the Lower Vaal WMA.

The total water requirements of the mining sector is estimated to be 5 million m^3/a **(**see **Table 5.4.3.1),** 40% of which is supplied from the Vaal River by the Vaal-Gamagara Scheme. It is assumed that the balance of the requirement is met from groundwater.

5.4.4 Other Bulk Users

There are very few industries in the WMA that receive bulk water supplies, as most industries are connected to the municipal supply systems **(**see **Table 5.4.4.1).**

5.5 NEIGHBOURING STATES

The Lower Vaal WMA shares its northern border, the Molopo River, with Botswana. However, this region is very dry and the flows in this river are highly seasonal and erratic. For all practical purposes, there is no utilisable surface water resource in the Molopo River and therefore there has never been the need for an agreement on the joint utilisation of this resource. There are no water transfers to Botswana from this WMA.

TABLE 5.4.3.1: WATER REQUIREMENTS OF MINES

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	ON-SITE SUPPLY (Unassured)	LOSSES		TOTAL	TOTAL AT 1:50 YR ASSU-RANCE	RETURN FLOWS
No	Descrpition	No	Description	Quaternary catchments	Description	million m^3/a	%	million m^3/a	million m^3/a	million m^3/a	million m^3/a
Z		Z		ZB-ZF	Botswana Quats	0.0	10.00%	0.0	0.0	0.0	0.0
TOTAL IN BOTSWANA						0.0	10.00%	0.0	0.0	0.0	0.0
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	4.8	10.00%	0.5	5.3	5.0	1.4
	TOTAL IN D CATCHMENT					4.8	10.00%	0.5	5.3	5.0	1.4
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	0.0	10.00%	0.0	0.0	0.0	0.0
				C31A-F	Harts	0.0	10.00%	0.0	0.0	0.0	0.0
				C33A-C	Vaalhartz	0.0	10.00%	0.0	0.0	0.0	0.0
		Sub-total				0.0	10.00%	0.0	0.0	0.0	0.0
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	0.0	10.00%	0.0	0.0	0.0	0.0
		Sub-total				0.0	10.00%	0.0	0.0	0.0	0.0
	TOTAL IN C CATCHMENT					0.0	10.00%	0.0	0.0	0.0	0.0
TOTAL IN RSA						4.8	10.00%	0.5	5.3	5.0	1.4
TOTAL IN NORTH WEST						0.5	10.00%		0.5	0.5	0.1
TOTAL IN NORTHERN CAPE						4.3	10.00%		4.8	4.5	1.3
TOTAL IN FREE STATE						0.0	10.00%		0.0	0.0	0.0
TOTAL						4.8	10.00%	0.5	5.3	5.0	1.4

TABLE 5.4.4.1: OTHER BULK WATER REQUIREMENTS

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	ON-SITE SUPPLY (Unassured)	LOSSES		TOTAL	TOTAL AT 1:50 YR ASSURANCE	RETURN FLOWS
No	**Descrpition**	**No**	**Description**	**Quaternary catchments**	**Description**						
Z		Z		ZB-ZF	Botswana Quats	1.5	5.0%	0.1	1.6	1.6	0.9
TOTAL IN BOTSWANA						1.5	5.0%	0.1	1.6	1.6	0.9
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.8	5.0%	0.0	0.8	0.8	0.2
	TOTAL IN D CATCHMENT					0.8	5.0%	0.0	0.8	0.8	0.2
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	0.0	5.0%	0.0	0.0	0.0	0.0
				C31A-F	Harts	0.0	5.0%	0.0	0.0	0.0	0.0
				C33A-C	Vaalhartz	0.0	5.0%	0.0	0.0	0.0	0.0
		Sub-total				0.0	5.0%	0.0	0.0	0.0	0.0
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	0.0	5.0%	0.0	0.0	0.0	0.0
		Sub-total				0.0	5.0%	0.0	0.0	0.0	0.0
	TOTAL IN C CATCHMENT					0.0	5.0%	0.0	0.0	0.0	0.0
TOTAL IN RSA						0.8	5.0%	0.0	0.8	0.8	0.2
TOTAL IN NORTH WEST						0.0	5.0%	0.0	0.0	0.0	0.0
TOTAL IN NORTHERN CAPE						0.8	5.0%	0.0	0.8	0.8	0.2
TOTAL IN FREE STATE						0.0	5.0%	0.0	0.0	0.0	0.0
TOTAL						2.3	5.0%	0.1	2.4	2.4	1.0

5.6 IRRIGATION

5.6.1 General

Accurate and comprehensive observed data on water use for irrigation is mostly not available in South Africa. Irrigation water requirements were therefore mostly calculated from available information on irrigated areas and typical quotas applied at the various irrigation schemes within the WMA **(see Table 5.6.2.1).** However, in the case of the Lower Vaal WMA, the irrigated area lies mostly within the area covered by a comprehensive study of irrigation within the Vaal WMA (Loxton Venn, 1999). The information given in this report is therefore thought to be fairly accurate.

Losses and return flows from irrigation are discussed further in **Section 5.15**

By far the largest irrigation scheme within the Lower Vaal WMA is the Vaalharts scheme which utilises in the order of 500 million m^3/annum to irrigate an area of about 356 km^2. The water for this scheme is sourced from Bloemhof dam from where it is released down the Vaal River to the Vaalharts weir. From here it is diverted into a network of canals. Note that the Taung Irrigation board, shown as being in the Dry Harts key area in this report, is also part of the Vaalharts scheme while the Harts irrigation scheme, included in the Vaalharts key area is not.

Table 5.6.2.1 gives the irrigation requirements per key area while the allocation from each irrigation scheme is given in **Table 5.13.4.1.** Note that the Taung irrigation scheme is not using their full allocation of 54 million m^3/annum but are only irrigating 35,7 km^2 out of their allocated area of 64,24 km^2.

5.6.2 Water Use Patterns

An approximate breakdown of the irrigated crops into summer, winter, perennial and undifferentiated crops, shown in **Table 3.5.2.1**, indicates that the crops are fairly evenly distributed amongst these categories. The relatively large areas under perennial and winter crops are made possible by the fact that water is supplied to the Vaalhartz scheme from the Bloemhof dam and can hence be supplied throughout the year. Double cropping is possible due to this continuous supply of water and is practised to a limited extent.

5.6.3 Water losses

Conveyance losses

Water losses can and do occur between the point of water abstraction, typically a river or dam, and the point of application on the crops. These losses vary from negligible amounts where the crops are close to the river or dam and a well managed piped reticulation system is in place, to huge amounts where long unlined canals are used to transport water over long distances.

Irrigation conveyance losses in the Lower Vaal range from 10 % for run-of-river abstractions to 32 % (VRSU, 1999) in the case of the Vaalharts Government water scheme. These high losses are due to the long reaches of open canals from which losses are mainly due to leakage and evaporation.

Application efficiency

The irrigation efficiency is dependent on the irrigation method used, i.e. flood irrigation, sprinkler, mechanical, micro or drip systems. At the Vaalharts scheme irrigators make use of flood irrigation which is probably in the order of 65 to 70% efficient. At the Taung scheme, most of the irrigators are using centre pivot irrigation systems which are more efficient, probably in the order of 75 to 80%.

5.6.4 Return Flows

Not all the water applied as irrigation is utilised by the crops. Some of the water seeps down into the soil beyond the root zone of the crops and can return to the river as ground water seepage. Typically this return flow is in the order of 10 to 15% of the water applied to the crops but is dependant on a number of factors. In dry areas where the irrigated area is far from a perennial river, there will not be any return flow to the river while in areas such as the Sundays river irrigation scheme where soil salinity is a problem, irrigators may over-irrigate to flush out salts which are accumulating in the soils resulting in higher than normal return flows.

TABLE 5.6.2.1: WATER USE BY IRRIGATION IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	TOTAL HARVESTED AREA km²	ALLOCATED AREA km²	DOUBLE CROPPING PROPORTION	QUOTA	FIELD EDGE REQUIREMENT ACCORDING TO LOXTON VENN REPORT	CONVEYANCE LOSS (proportion)	CONVEYANCE LOSS (volume)	TOTAL THEORETICAL WATER REQUIREMENT (SAPWAT)	TOTAL ACTUAL WATER REQUIREMENTS (INCLUDING LOSSES)	TOTAL ACTUAL WATER REQUIREMENT AT 1:50 YR ASSURANCE	RETURN FLOWS
No	Description	No	Description	Quaternary catchments	Description				m³/ha/annum							
Z		Z		ZB-ZF	Botswana Quats	0.0	0.0	N/A		0.0	0.00	0.0	0.0	0.0	0.0	
TOTAL IN BOTSWANA						0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.0	0.0	N/A		0.0	0.00	0.0	0.0	5.0	4.0	0.00%
	TOTAL IN D CATCHMENT					0.0	0.0		0.0	0.0	0.0	0.0	0.0	5.0	4.0	0%
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	35.7	35.7	1.0	8,740.0	21.6	0.32	10.2	11.3	31.8	27.4	10%
				C31A-F	Harts	1.0	1.0	1.0	7700	0.9	0.25	0.3	1.2	1.2	1.1	10%
				C33A-C	Vaalhartz	415.7	336.9	1.2	9140 to 11 855	312.5	0.32	147.1	478.8	459.6	395.2	6%
		Sub-total				452.4	373.6	1.2		335.1	0.9	157.5	491.3	492.6	423.7	100%
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	139.8	118.3	1.2	9,140.0	106.0	0.10	11.8	116.6	117.8	101.3	10%
		Sub-total				**139.8**	**118.3**	**1.2**	**9,140.0**	**106.0**	**0.1**	**11.8**	**116.6**	**117.8**	**101.3**	**10%**
	TOTAL IN C CATCHMENT					**592.2**	**491.9**	**2.4**	**9,140.0**	**441.1**	**1.0**	**169.3**	**607.9**	**610.4**	**524.9**	**10%**
TOTAL IN RSA						**592.2**	**491.9**	**2.4**	**9,140.0**	**441.1**	**1.0**	**169.3**	**607.9**	**615.4**	**528.9**	**10%**
TOTAL IN NORTH WEST						331.3	275.2			246.7		94.7	340.0	344.3	295.9	10%
TOTAL IN NORTHERN CAPE						260.9	216.7			194.3		74.6	267.8	271.1	233.0	10%
TOTAL IN FREE STATE						0.0	0.0			0.0		0.0	0.0	0.0	0.0	10%
TOTAL						**592.2**	**491.9**	**2.4**	**9,140.0**	**441.1**	**1.0**	**169.3**	**607.9**	**615.4**	**528.9**	**10%**

Generally there is very little reliable data on return flows. Estimates from the Vaalhartz scheme put return flows at about 21 million m^3/annum which is only 6%of the field edge requirement (VRSAU, 1999). For the remainder of the WMA, return flows have been assumed to be 10% of the field-edge requirement.

Although it is usually assumed that return flows are available as yield for downstream users, the quality of return flows is often a problem as they are rich in nutrients and salts. These water quality issues are addressed in section 6.4 of this report.

5.7 DRYLAND SUGARCANE

There is no sugarcane in the Lower Vaal WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

Significant water losses from major wetlands and river do occur and can be quantified but these losses are generally accepted to be natural occurrences and are incorporated into the hydrology of the catchment. Where the intervention of man, through the construction of a dam or the changed operation of the river, leads to increased losses, these must be taken into account in the water resources planning of a catchment.

In the case of the Lower Vaal WMA, there are losses due to evaporation from dams, but because the dams in this WMA are fairly small, these losses are limited.

Large losses occur downstream of the Bloemhof Dam due to releases made from this dam for irrigators at the Vaal Harts scheme and along the banks of the Vaal river down to Douglas. These losses consist of evaporation losses, estimated to be in the order of 90 million m^3/annum and system losses of approximately 100 million m^3/annum. These system losses occur from releases made to irrigators downstream of Bloemhof Dam which are not fully utilised due to the lack of balancing storage along the lower Vaal. Although these system losses are a loss to the Vaal system yield, the water does become available to users further downstream and is therefore not totally lost.

River and dam losses are shown in **Table 5.8.1.**

TABLE 5.8.1: RIVER AND EVAPORATION LOSSES IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	LOSSES FROM RIVERS AND WETLANDS	EVAPORATION FROM DAMS	TOTAL
No	Descrpition	No	Description	Quaternary catchments	Description			
Z		Z		ZB-ZF	Botswana Quats	0.0	1.3	1.3
TOTAL IN BOTSWANA						0.0	1.3	1.3
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.0	9.2	9.2
	TOTAL IN D CATCHMENT					0.0	9.2	9.2
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	0.0	0.5	0.5
				C31A-F	Harts	0.0	6.6	6.6
				C33A-C	Vaalhartz	4.0	24.3	28.3
		Sub-total				4.0	31.3	35.3
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	90.0	30.0	120.0
		Sub-total				90.0	30.0	120.0
	TOTAL IN C CATCHMENT					94.0	61.3	155.3
TOTAL IN RSA						94.0	70.5	164.5
TOTAL IN NORTH WEST						0.0	22.6	22.6
TOTAL IN NORTHERN CAPE						94.0	36.0	130.0
TOTAL IN FREE STATE						0.0	11.9	11.9
TOTAL						94.0	71.8	165.8

5.9 AFFORESTATION

There are no indigenous or exotic forests in the Lower Vaal WMA.

5.10 HYDROPOWER AND PUMPED STORAGE

There is no hydropower or pumped storage in the Lower Vaal WMA.

5.11 ALIEN VEGETATION

Tertiary and quaternary catchment information on condensed areas of infestation by alien vegetation and stream flow reductions was obtained from the CSIR who carried out a Water Research Commission funded study on the impact of alien vegetation on surface runoff (Versfeld, et al. 1998).

It has been assumed that the reduction in runoff due to alien vegetation outside of the riparian zone cannot exceed the natural runoff and water use inside and outside of the riparian zone has been estimated separately wherever possible. In the absence of any better information, it was assumed that 10% of the condensed area under alien vegetation is riparian. The reduction in runoff due to alien vegetation was taken from WSAM using the above assumptions. The impact of this reduction in runoff on catchment yield was determined as follows:

The impact of the reduction in runoff due to alien vegetation on the yield of a catchment depends on the storage in that catchment. It was accepted that the storage/yield characteristics of a catchment with alien vegetation were similar to those of the natural catchment and that the latter characteristics could be used to estimate the yield of a catchment with alien vegetation. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under both natural conditions and the effects of only the alien vegetation. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The difference between the incremental yields under natural conditions and with only the effects of alien vegetation was the impact of the reduction in runoff due to afforestation in the incremental catchment on the yield of the catchment.

Although according to the CSIR report (Versfeld, et al. 1998), there are large areas under alien vegetation in the Lower Vaal WMA, the reduction in runoff due to this alien vegetation is estimated to be only 6 million m^3/a, most of which is in the Molopo catchment. The impact of this reduction on the yield is estimated to be zero, due to the fact that there is already no yield available from the Molopo catchment where the majority of the alien vegetation apparently occurs.

5.12 WATER CONSERVATION AND DEMAND MANAGEMENT

5.12.1 Introduction

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and use. This concept has been strongly emphasised, both in legislation and through key demonstration water conservation and water demand management projects. The Department of Water Affairs and Forestry is therefore developing a National Water Conservation and Demand Management Strategy, which is aimed at the water supply industry and South African society at large and aims to cover all water use sectors including agriculture, forestry, industry, recreational, ecological, and water services.

Evidence of inefficient water usage can be found in all water use sectors throughout the country and the value of water seems largely unrecognised by many water users. South Africa is a developing country that is water stressed and requires improved management of its limited water resources.

The implementation of water conservation and demand management principles is essential in meeting the national goals of basic water supply for all South Africans and the sustainable use of water resources.

Water conservation and water demand management are not synonymous. The following meanings are therefore assigned to these terms in this report:

Water conservation is the minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water. Water conservation should be both an objective in water resource and water services management as well as a strategy.

Water demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water requirements and use of water in order to meet any of the objectives of economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability. Water supply institutions should set water demand goals and targets by managing the distribution systems and consumer requirements in order to achieve the above objectives.

Water demand management is deemed to include the entire water supply chain - from the point of abstraction at the source to the point of use. This includes all levels of water distribution management and consumer demand management. The conservation measures related to the water resources and return flow are part of water resource management and return flow management respectively.

Various obstacles and constraints have to be overcome before the full potential of water conservation and demand management can be achieved.

This section describes the National Water Conservation and Demand Management Objectives that will lead to the development of action plans to be implemented by the various water institutions. The needs and opportunities for the implementation of water conservation are described, as are some of the important principles on water conservation and demand management. This section also describes the platform on which the National Water Conservation and Demand Management Strategy will be based. This National Strategy Framework will also be used to develop the functions of the Directorate: Water Conservation within the Department of Water Affairs and Forestry and the functions of other departments and other water institutions. It is also intended that those principles will assist the water industry to comprehensively implement water conservation and demand management.

5.12.2 Background

Water resources and supply

The sustainability of the limited water resources is threatened in terms of quantity and quality. Unless the current water use pattern is changed, future water requirements will greatly exceed existing available fresh water resources. Frequently the water supply and quality are unreliable or improperly managed, leading to the wasteful use of water by consumers in anticipation of possible supply failures.

Environment

Environmental degradation and the prevention thereof is a key focus in the current policy and legislation. Measures such as providing for water of suitable quality in sufficient quantity in the Reserve to protect the integrity, health and productivity of the rich and diverse ecosystems have become necessary.

Neighbouring states

South Africa and the neighbouring states of Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe have certain common water resources and must collaborate to achieve the optimal use of these resources. Except for Lesotho, all of these countries are water scarce and it is imperative that none of them should allow the wastage of water resources to the detriment of the other countries.

Basic water supply needs

By the application of water demand management measures to existing water services, water resources and bulk infrastructure can be reallocated for the provision of new services where adequate services do not yet exist. Water demand management is also essential in ensuring the sustainability of the new water service delivery projects and can help to ensure that water remains affordable.

Existing water services

It is estimated that up to 50% of the total quantity of water that is supplied is not accounted for in many of the urban areas. This unaccounted for water consists of a combination of reticulation system leaks, unauthorised water connections, faulty water meters and domestic plumbing leaks. These factors, combined with the low levels of payment and institutional problems of local authorities, affect the sustainability of water services. Current indications are that levels of unaccounted for water are growing despite the formulation of several water conservation strategies in the past.

Irrigation

Irrigation accounts for an estimated 73% of total water use in the Lower Vaal WMA. Irrigation losses are often quite significant and it is estimated that often no more than 50% of water abstracted from the water source is correctly applied to the root systems of plants. Some irrigation system losses return to the river systems but this return water can be of reduced quality. Irrigation methods, irrigation scheduling, soil preparation, crop selection, crop yield targets and evaporation all affect the efficient use of water.

Industry, mining and power generation

Industry is expected to be the biggest contributor to future economic growth in South Africa. The industrial sector is projected to have the greatest growth in water requirements. Much of this growth will occur in major urban centres that only have limited water resources nearby. It is imperative to have assured water supplies at a reasonable cost to support the industrial development and for the industrial sector to improve its efficiency of water use and to minimise waste.

5.12.3 Legal and regulatory framework

General

The Water Services Act (No. 108 of 1997) and the National Water Act (No. 36 of 1998) variously require and provide for the implementation of water conservation and demand management measures. One of the functions of the National Water Conservation and Demand Management Strategy is to fulfil the requirements made through the legislation and to utilise the opportunities created through the legislation to develop comprehensive policies and to identify and develop regulations.

Complimentary to the regulations promulgated in terms of the above two Acts are codes of practice that present guidelines for the maintenance of uniform standards within the water supply industry.

Water Services Act

The Water Services Act (No. 108 of 1997) sets out a framework to ensure the provision of basic water supply and sanitation and a regulatory framework for water services institutions. All water services institutions are required to develop conditions for the provision of water services that must include for measures to promote water conservation and demand management.

National Water Act

The purpose of the National Water Act (No. 36 of 1998) is to inter alia ensure that the nation’s water resources are protected, used, developed, conserved, managed and controlled in ways that, amongst others, promote efficient, sustainable and beneficial use of water in the public interest.

Codes of Practice

The SABS Code of Practice 0306:1998 titled *The Management of Potable Water in Distribution Systems* has been drafted to establish the management, administrative and operational functions required by a water services institution to account for potable water within distribution systems and apply corrective actions to reduce and control unaccounted for water.

5.12.4 The role of water conservation and demand management

Security of supply

The role of water conservation and demand management in ensuring security of supply can be divided into short-term rationing measures during droughts, which amount to a reduction in assurance of supply in respect of some of the water, and sustainable long-term functions.

With the current growth of water requirements it is estimated that unless water conservation and sustainable development policies are implemented, South Africa will utilise all its natural fresh water resources within 30 years. Possible alternative water resources such as importation of water from neighbouring states, desalination and harvesting icebergs are considered to be too expensive.

Protection of the aquatic environment

Aquatic ecosystems are under threat from current land use practices and over-utilisation of water resources. Reducing water requirements reduces water abstractions that affect the aquatic environment and results in increased stream flows and/or decreased demand on groundwater sources and also reduces or defers the need for dams that have their own impacts on the environment

Protection of existing water resources

The protection of water resources through water conservation measures can be achieved as follows:

- The removal of alien invading plants, which reduce surface runoff and the yield of existing resources.
- Rehabilitation of wetlands.
- Protection of groundwater resources by limiting abstraction to the sustainable yield.
- Minimising pollution of water resources.

Economic efficiency

One of the main objectives of water demand management is economic efficiency through the entire water cycle.

In the potable water services sector, economic efficiency may often be a more important objective than water resource considerations. A certain measure that may be economically efficient from the perspective of society may not be economically efficient from the perspective of a specific water institution or user, which can be a major constraint on water demand management. However, the perspective of society needs to have priority over the economic efficiency perspective of the various water institutions or users.

Reducing the growth in water requirements can postpone large infrastructure development costs.

Social development, equity and accountability

Water demand management can enhance the objectives of social development and equity in a number of ways, some of which are given below:

- To promote maintenance, management and prevention of abuse of water infrastructure.
- To reduce domestic water consumption and waste and the cost of potable water services.
- To provide new services to people by using existing resources and bulk infrastructure.
- To offer more employment opportunities to the community.
- To make water institutions accountable to the public and understand the consumers and their needs.

5.12.5 Planning considerations

Water conservation and demand management initiatives are not only strategies associated with environmental or communications initiatives but must be integrated into the water resource planning process as potential alternatives to increasingly expensive supply side management options.

All water demand management activities that decrease the water requirement tend to affect supply management because existing system capacity is released for other users.

The opportunities for water demand management exist where there are high levels of loss and inefficient use, particularly where water is used for the service that is derived from it and not for the water itself.

5.12.6 Water conservation and demand management measures

There are a number of categories of water conservation and demand management measures and initiatives that can be implemented. The following categories are general for all water sectors and are according to the different components of the water supply chain:

- Water conservation measures in resource management.
- Water demand management in distribution of supply management.
- Water demand management measures of customer or end user.
- Water conservation measures for return flow management.

5.12.7 Objectives of the national water conservation and demand management strategy

The objectives of the National Water Conservation and Demand Management Strategy are as follows:

- Create a culture of water conservation and demand management within all water management and water service institutions in South Africa.
- Support water management and water services institutions to implement water demand management and water conservation.
- Create a culture of water conservation and demand management for all consumers and users in South Africa.

- Promote international co-operation and participate with other Southern African countries, particularly co-watercourse states, to develop joint water conservation and demand management strategies.
- Enable water management and water resources institutions to adopt integrated resource planning.
- Promote social development and equity in South Africa.
- Contribute to the protection of the environment, ecology and water resources.
- Contribute the parameters of water economics to development planning processes.

5.12.8 Water conservation in South Africa

History

Since 1982 the droughts have accentuated the awareness of the need to conserve water. In 1985 the Water Research Commission initiated a process to establish the National Water Supply Regulation (NWSR), which was proposed to be promulgated under the then Water Act. Participating local authorities were however, encouraged to promulgate the NWSR as their own Water Regulations (by-laws). Port Elizabeth Municipality was the first to adopt the NWSR in 1987. However, in 1992 the Department of Water Affairs and Forestry indicated it would not be involved with the administration of the (then) proposed NWSR and although the United Municipal Executive resolved in 1993 that the NWSR should be adopted by local authorities, little progress was made.

The proceedings of the National Water Supply and Sanitation Policy Conference of 1994 included an estimate of the extent of the problem of water losses due to leakage at 330 million m^3/a and proposed a policy of water demand management. The subsequent Water Supply and Sanitation Policy White Paper published in 1994 referred to water conservation and demand management and encouraged a culture of water conservation and the introduction of stringent water demand management strategies to reduce water usage and the stress on resources.

The Working for Water programme

The Working for Water programme is part of the National Water Conservation Campaign and is based on the key assumption that invading alien plants pose a considerable threat to South Africa’s extremely rich biological diversity, and to the ecological functioning of its natural systems. Also provided by the campaign is a catalogue of devices that can contribute to the efficient consumption of water.

Water restrictions

Restricting water use during extreme droughts through the imposition of conservation measures on consumers is an intermittent form of water demand management. The effects of past water restrictions give an indication of the extent and direction that future water conservation strategies could have.

Overall savings in water use (median estimates) achieved through water restrictions were found to vary according to region and severity of restriction. In the Rand Water area of supply mild restrictions saved about 15% whereas stringent restrictions saved about 27%. For the rest of Gauteng, Free State and Northern Cape these savings were about 19% (mild) and 34% (stringent). In the Umgeni Water area of supply mild restrictions saved only 1% to 5%, whereas stringent measures saved as much as 50%. For the rest of KwaZulu/Natal these savings were 29% (mild) and 46% (stringent).

It was difficult to determine the financial effects of water restrictions. In the Vaal River Supply Area the reduction in water requirements due to water restrictions for the Rand Water, Goldfields and Vaal River supply areas for the period 1982 to 1984 was almost 240 million m^3 of water or 22,5% of the requirement for the year 1982. The greatest total direct tangible financial impact was on public institutions such as the Department of Water Affairs and Forestry, Water Boards, Local Authorities and Eskom. Private households also bore a large financial impact of water restrictions. Mining had the least financial burden to bear because of water restrictions, yet achieved a net saving in water use of almost 32% in the same period. The greatest reduction in water use was for the agricultural sector, which had the second lowest direct financial impact.

From analyses of return flows in Gauteng it is concluded that the ratio of return flow to water use is not materially altered by the imposition of water restrictions. In other words, if the supply is reduced by (say) 20%, it can be assumed that the return flow will also be reduced by 20%.

Experience from past water restrictions that have proved to be the most effective during times of drought, which are relevant to future water conservation efforts are:

- The overall reduction in water use depends on a number of factors. However, when water use is reduced beyond 30% it can be detrimental to the user from a financial and motivational perspective.
- Voluntary reduction in water use fails to achieve the savings possible with mandatory steps.
- The most effective methods of reducing water use are higher tariffs, restriction of garden watering times, the banning of domestic hose pipe usage and allotting quotas to industry, bulk consumers and irrigators.
- The most effective motivations are pamphlets/newsletters, higher tariffs and punitive measures.
- The major interventions required to reduce both physical and non-physical losses from pipe networks are leak detection/monitoring, replacing old plumbing and the repair/monitoring of meters.
- The most effective methods of saving water used by commerce and industry are technical adjustments, recycle/re-use and promotion campaigns.
- The ratio of return flow to water use is not materially changed by changes in water use.

The measures implemented during the drought in the mid-1980's reduced water use and the growth rate in water usage after the drought had ended. However, there is little or no incentive for existing or new consumers to continue to retain or to adopt the water saving measures when there is no drought.

5.12.9 Water conservation in the Lower Vaal Water Management area

Based on experience elsewhere in South Africa an overall sustainable reduction in water use of up to 25% can be expected without having a detrimental effect on users. Return flows could be reduced by up to 10% of total water use.

However, reductions in the use of water for urban and rural use will have little impact in this WMA since only 15% of the water use is for Urban or rural purposes. Water conservation efforts should rather be focused in the areas where the biggest losses are currently occurring, which in the case of the Lower Vaal WMA is the irrigation sector. The Vaalharts irrigation scheme has an allocation of 500 million m^3/annum from the Vaal system, of which an estimated 51% reaches the root zone of the irrigated crop.

Although much of this loss is unavoidable, the economic and environmental implications of continuing to irrigate land with water which has an increasingly high economic value to upstream users needs to be questioned.

5.13 WATER ALLOCATIONS

5.13.1 Introduction

As explained in **Section 3.4,** numerous allocations of water have been made in the past under the provisions of the Water Act of 1956 and earlier legislation. Under the National Water Act (Act No. 36 of 1998) these allocations will be replaced by general authorisations or by licensing of specific water uses.

5.13.2 Allocations and Permits Issued Under the Old Water Act

Allocations of water were made and permits for use of water issued under the following articles of the Water Act of 1956:

(a) Article 63: Irrigation scheduling and quotas from Government Water Schemes.

(b) Article 56(3): Allocations to other users from Government Water Schemes.

(c) Article 62: Scheduling and quotas from Government Water Control Areas.

(d) Articles 32A and 32B: Scheduling and quotas from Government Underground Water Control Areas.

(e) Industrial, mining and effluent permits (including Articles 12, 12B and 21).

(f) Other allocations (including Section 9B permits, Water Court orders and older legislation).

With the implementation of the National Water Act of 1998, Government Water Control Areas no longer exist.

The allocations and permits which were issued within the area now defined by the Lower Vaal WMA are poorly documented, and in many instances is now outdated, but were still valid in 1995, and are summarised in this section of the report for comparison with estimated water availability in 1995.

5.13.3 Government Water control areas in the WMA

The Vaal river downstream of Bloemhof Dam and the Harts river downstream of Spitskop Dam have been declared Government Water Control Areas. In the past water abstractions from these sources were only permitted if authorised in terms of section 56(3), 62 or 63 of the old Water Act. In the interim period leading up to the issuing of water use licences, these abstractions are considered as existing lawful use and irrigators may continue to exercise their rights.

It appears as if there are no **section 62** allocation per se in the Lower Vaal WMA since all allocations have been made in terms of section 56(3) an and section 63 of the old Water Act.

5.13.4 Government Water Schemes: Irrigation

There are several Government Water Schemes in the Lower Vaal WMA. These are as follows:

- The Lower Vaal GWS which receives water from the Orange River via the Orange-Vaal canal
- The Harts River GWS which receives its water from the Spitskop Dam.
- The Vaalharts GWS which receives its water from the Vaal system via releases out of the Bloemhof Dam.
- The Kalahari West Rural Water Supply Scheme
- The Kalahari East Rural Water Supply Scheme, and
- The Karos-Geelkoppan Rural Water Supply Scheme

The allocations made to irrigators from these schemes are shown in **Table 5.13.4.1.**

Table 5.13.4.1: Scheduling and Quotas in Government Water Schemes

SCHEME	SOURCE OF WATER	SCHEDULED AREA (ha)	ANNUAL QUOTA (m^3/ha)	ALLOCATED WATER (million m^3/annum)
Vaalharts GWS	Bloemhof Dam			
SECTION 63				
- Vaalharts canal		29 416	9 140	268.9
- Klipdam-Barkly canal		2 327	11 855	27.6
- Taung		6 424	8 470	54.4
SECTION 56				
		980.3	9 140	9.0
Sub-total		**39 147.3**		**359.9**
Harts River GWS	Spitskop Dam	1663	7700	12.8
Lower Vaal GWS	Vaal River (with support from Bloemhof Dam)	6541	9140	59.8
TOTAL FOR WMA				**432.5**

5.13.5 Government Water Schemes: Other

Water allocations from Government Water Schemes, other than irrigation, are listed in Appendix D and summarised in **Table 5.13.4.2**.

Table 5.13.4.2: Allocations from Government Water Schemes (Article 56(3))

Scheme	Household and stockwatering	Municipalities /Water Boards	Other industries	Mining	TOTAL
Vaal-Gamagara	0.30	4.14*	1.79	13.67	19.91
Kalahari West	0.42	0.0	0.0	0.0	0.42
Kalahari East	1.80	0.0	0.0	0.0	1.8
Karos - Geelkoppan	0.04	0.0	0.0	0.0	0.04
TOTAL	**2.56**	**4.14**	**1.79**	**13.67**	**20.37***

* The allocation to Water Boards from the Vaal-Gamagara scheme includes the 1,8 million m^3/annum allocated the Kalahari East Water Board and is reflected under the Kalahari East GWS

5.13.6 Subterranean Water Control Areas

The area surrounding Lichtenberg is under-layen with dolomitic rock from which relatively large amounts of groundwater can be abstracted on a sustainable basis. The urban requirements of Lichtenburg and Mbabatho are supplied from this source. This area was declared a Subterranean Water Control Area (SWCA) to prevent overexploitation of this important water resource.

According to a report produced by DWAF's Directorate of Geohydrology (1989), the water use from this source totalled 68 million m^3/annum, 42 million m^3/annum of which was from boreholes and 26 million m^3/annum from fountains. This same source quotes an irrigated area of 3 000ha while the Gazetted quota at that time was 7 500 m^3/ha/annum. From this one can deduce that 22,5 million m^3/annum was used for irrigation and the remaining use of 45,2 million m^3/annum was for Lichtenburg and Mafikeng. However, the latest estimates of the water use by these two towns is only 14.8 million m^3/annum. The figures quoted in the Geohydrology report (1989) are therefore not considered to be accurate.

Regardless of the actual water use, the groundwater resource was over-exploited and in 1995 the quota to irrigators was reduced to 4 000 m^3/ha/annum.

The Water Management Areas boundaries upon which this situation assessment report is based, places catchment C31A in the Lower Vaal WMA and D41A in the Crocodile West and Marico WMA.

This complicates the issue since it is difficult to split the groundwater water resource and use between these two water management areas. However, during the preparation of this report the WMA boundaries were changed to include C31A in the Crocodile West and Marico WMA. This was a sensible decision so as to keep the significant Upper Molopo groundwater resource in a singe WMA.

Due to this change, there is little point in trying to determine the portion of the groundwater resource which is available to the Lower Vaal WMA and the actual water use from this resource within this WMA. It is assumed that the registration process will document this water use accurately, both spatially and in terms of quantities allocated. Once this has been done it is recommended that the resources and water requirements of the Lichtenberg/Mafikeng area be reassessed.

5.13.7 Allocations in Relation to the Water Requirements and Availability

The total allocations made from the Vaal-Gamagara GWS (19.91 million m^3/annum) are higher than the current capacity of the scheme (13.28 million m^3/annum). However, the actual water consumption of the scheme was only 8,4 million m^3/annum in 1995. The reason for this discrepancy is that many of the mines are not using their full allocation. It is unlikely that the water use of the mines will exceed the capacity of the works within the next several years.

The allocation to the Vaalharts GWS of 360 million m^3/annum is a field edge allocation and does not include losses. The losses associated with this scheme are large due to the long conveyance route through open channel canals. In order to allow for these losses, estimated to be 31% of the gross use, an abstraction of about 520 million m^3/annum is required at the Vaalharts weir.

The allocations from the smaller Kalahari-East, Kalahari-West and Karos-Geelkoppan match the capacity of the works and are close to fully utilised.

5.14 EXISTING WATER TRANSFERS

5.14.1 Introduction

As a result of the scarcity of water in South Africa, it is often necessary to transfer water from areas of surplus to areas of deficit. Water transfers to augment the supply of water for urban, industrial and agricultural use have been categorised as follows:

- Transfers to and from neighbouring states.
- Transfers between Water Management Areas (e.g. Lower Orange – Lower Vaal transfer).
- Transfers within Water Management Areas are transfers between and within quaternary catchments within a WMA (e.g transfers from the Bloemhof Dam for the Vaalharts irrigation area).
- Potential or future inter-basin augmentation schemes.

5.14.2 Transfers to and from Neighbouring States

There are no transfers to or from the Lower Vaal WMA from or to neighbouring states.

5.14.3 Existing Transfers between Water Management Areas

The only significant inter-WMA transfer is from the Orange River at Markdrift in the Lower Orange WMA to the Douglas Weir on the Vaal River in the Lower Vaal WMA. An estimated 74 million m^3/annum is abstracted at Marksdrift for irrigation purposes, as well as to improve the quality of the water in the Vaal River. Most of the water is used in the Lower Orange WMA and only an estimated 18 million m^3/annum is received by the Lower Vaal WMA.

A small amount of water (0,5 million m^3/annum), originating from the Lower Orange WMA, is transferred into the Lower Vaal WMA. These small transfers form part of the Kalahari West and Karos-Geelkoppan schemes.

For all practical purposes, there are no transfers out of the Lower Vaal WMA. However, some of the water use in Kimberley does fall outside of the WMA and since Kimberley is supplied from the Vaal River, this use could be considered as a transfer. For water balance purposes though, Kimberley's water use has been assumed to be within the Lower Vaal WMA.

Table 5.14.3.1: Transfers into the Lower Vaal WMA (at 1:50 year assurance)

Description of Transfer	Source WMA	Transfer Quantity Receiver WMA (10^6m^3)	Transfer Quantity Source WMA		
			Transfer (10^6m^3)	Losses	Total (10^6m^3)
Inter–WMA transfers into the WMA:					
Orange-Douglas transfer	Lower Orange	18	18+	Unknown	18+
Kalahari West Karos-Geelkoppan	Lower Orange Lower Vaal	0.42 0.04	0.42+ 0.04+	Unknown	0.42+ 0.04+
Total water imports in 1995:		18.46			18.46+

Note that while the Orange-Vaal transfer can transfer much larger volumes than those indicated in **Table 5.14.3.1,** only the portion of the transfer earmarked for release into the Douglas Weir to improve the water quality is considered to be a transfer into the Lower Vaal WMA. The remainder of the transferred water is utilised by irrigators within the Lower Orange WMA. The losses associated with this transfer are unknown.

5.14.4 Existing Transfers within Water Management Areas

Within the Lower Vaal WMA there are inter-quaternary transfers. The most significant transfer of water is from Bloemhof Dam, via the Vaalharts Weir, for use by irrigators in the Vaalharts Government Water Scheme and the Taung irrigation area. Irrigators situated in the Lower Vaal Government Water Scheme downstream of Bloemhof Dam receive water via the Vaal River.

Water is also transferred from the Vaal River at Delportshoop to mines and small urban centres via the Vaal-Gamagara Government Water Scheme.

Table 5.14.4.1: Within WMA transfers for 1995.

Source & Quaternary	Destination & Quaternary	Quantity [$10^6 m^3$] At 1:50 year assurance	Description of Transfer
Irrigation users:			
Bloemhof Dam C91A	Vaalharts irrigation area C33A, C33B, C33C	422	Vaalharts Government Water Scheme
Bloemhof Dam C91A	Taung irrigation area C32D, C33A		Taung Irrigation Board
Bulk users:			
Vaal River (Delportshoop) C92A	ISCOR, Finsch Diamond Mine and manganese mines D41J, D41K	3.3	Vaal-Gamagara Government Water Scheme
Urban users:			
Bloemhof Dam C91A	Pampierstad, Jan Kempdorp, Hartswater, Vryburg C32B, C33A	8.5	Vaalharts Government Water Scheme
Vaal River (Delportshoop) C92A	Postmasburg, Olifantshoek D41J	0.3	Vaal-Gamagara Government Water Scheme
Vaal River	Kimberley	23.2	Riverton-Kimberley transfer

5.14.5 Future Inter-Catchment Transfers

It is unlikely that any significant new transfer schemes will be developed in the Lower Vaal WMA.

5.15 SUMMARY OF WATER LOSSES AND RETURN FLOWS

Losses

Water losses are summarised in **Table 5.15.1**. Water losses from the agricultural sector are by far the greatest water losses in the Lower Vaal WMA, both as a proportion of water use by this sector and in absolute terms. The losses from the Urban sector are the next highest, but when compared to similar losses in other WMAs, are not unduly high. Losses from the industrial sector are the lowest. Although a figure has been given for the losses from the rural sector, the figure quoted is speculative since the actual loss is not known.

Return Flows

Return flows are summarised in **Table 5.15.1.** Return flows from the irrigation sector are significant, but this is to be expected since irrigated crops are situated close to the major rivers or, in the case of the Vaalharts scheme, near substantial drainage channels.

Although there should theoretically be return flow from urban areas, much of the Lower Vaal WMA is endoreic i.e. there is no runoff from the catchment. It is unlikely; therefore, that urban return flows will add significantly to the available resource.

Table 5.15.1: Losses and Return Flows

CATEGORY	REQUIREMENTS (10^6 m^3/a)	LOSSES		RETURN FLOW
		(10^6 m^3/a)	(%)	
Irrigation	615	241	40%	40.6
Urban	54	11.2	21%	0.0
Rural	49	9.9	20%	0.0
Bulk: Strategic	0.0	0.0	N/A	0.0
: Mining	5.0	0.5	10%	0.0
: Other	0.8	0.04	5%	0.0
Rivers, wetlands and dams		161		0.0
TOTAL	**724**	**423**	**59%**	**40.6**

Note: Bulk is mining and industrial use

Diagram 5.15.1: Category loss as a portion of the total losses in the WMA

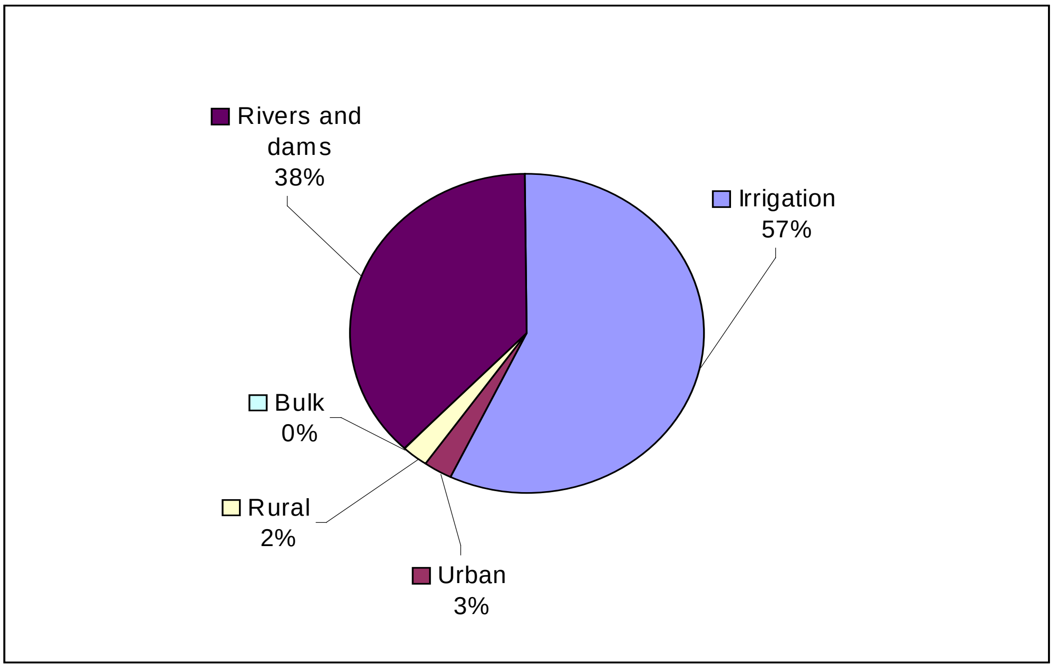
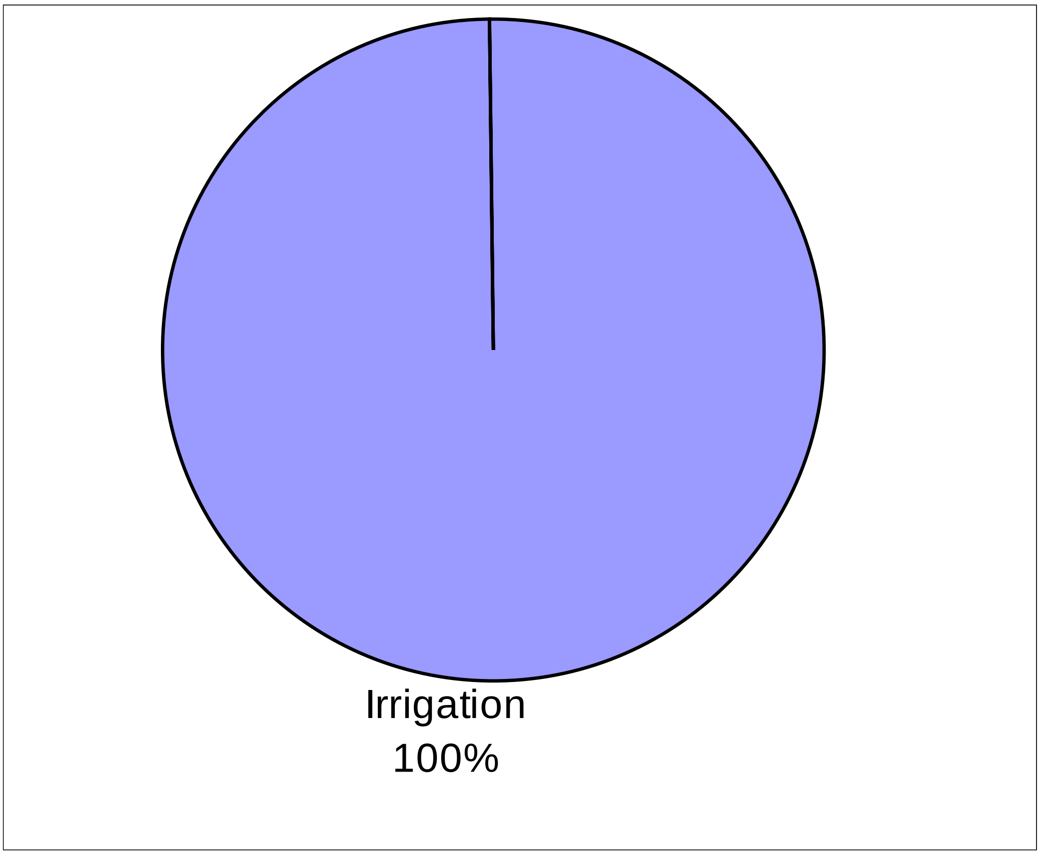


Diagram 5.15.2: Category return flow as a portion of the total return flow in the WMA



CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

The Mean annual runoff (MAR) from the total Vaal River catchment is approximately 4000 million m^3/annum When expressed as an equivalent unit runoff from the 196 000 km^2 catchment, the unit runoff averages out at about 20 mm. However, the pattern of runoff over the catchment is one of a fairly gradual decline from east to west, in accordance with the east to west decline of rainfall and an increase in evaporation rates. Unit runoff varies from over 100 mm in the upper reaches of the Wilge and Elands tributaries to as little as 2 mm in the vicinity of the Vaal/Orange confluence. Equivalent figures for mean annual rainfall (MAP) are 1000 mm (east) and 300 mm (west) and, for mean annual evaporation (MAE) – 1300 mm (east) and 2300 mm (west).

Due to the low rainfall in the Lower Vaal WMA, the surface water resource generated within the WMA is very limited. Accurate estimates of this resource are not available and it is recommended that this be determined more accurately in order to improve the efficiency of the water use within the WMA. The groundwater resource is more substantial, with an estimated 128 million m^3/annum currently being supplied from groundwater. By far the greatest proportion of the water used in the Lower Vaal originates from the Upper and Middle Vaal WMAs. The Vaalharts irrigation scheme has an allocation of about 360 million ^{3}/annum, and, together with conveyance and river losses, necessitates releases of over 500 million m^3/annum from Bloemhof Dam. Bloemhof Dam is in turn supported by the Vaal Dam with releases when required.

The total resource of the Lower Vaal WMA, excluding imports from other catchments, is estimated at approximately 180 million m^3/annum, 50 of which is from surface water resources. **Table 6.1.1** shows the total resource available to the Lower Vaal WMA.

The method used to determine the extent of the available groundwater resources is described in **Section 6.2**. The method used to determine the available surface resource within a key area is complex and is described in detail in **section 7.1.4**. However, in order to understand the concept of *'Developed Resource'* used in **Table 6.1.1** and **Table 6.3.1,** it is necessary to explain some of the methods used here.

For the purposes of this study, the term '*Yield'* is defined as the rate (in million m^3/annum) at which water which can be abstracted from a dam or river at a defined level of assurance (usually 1:50 year), at a uniform distribution throughout the year, after taking into account all the abstractions, transfers, water use, and stream flow reduction activities upstream of the dam. The term '*Resourc*e', on the other hand, is the sum of the *yield* and all the abstractions, transfers, water use, and stream flow reduction activities which take place within the catchment area under consideration. Imports into a catchment are therefore considered to be part of the resource available within a catchment. Great care must however be taken when aggregating the resource from quaternary catchment scale to larger scales so as not to double-count transfers. This concept is described in more detail in section 7.2 but suffice is to explain at this point that this is the reason why the resource in **Table 6.1.1** and **6.3.1** cannot be aggregated from key area scale to a larger scale due to transfers between key areas.

6.2 GROUNDWATER

Groundwater is an important part of the total water resources of South Africa and is included in the hydrological cycle. The information provided here gives an overview of the groundwater resources, its interaction with the base flow component of the surface water, the present groundwater use (1995), and its potential for further development.

It must be noted that this information is intended for regional strategic planning and is not suitable for local site evaluations. More detailed information on the approach and methodology can be obtained in **Appendix K.** All information was collated on a quaternary catchment basis.

The Groundwater Harvest Potential (Seward and Seymour, 1996) was used as the basis for the evaluation. The Harvest Potential is defined as the maximum volume of groundwater that is available for abstraction without depleting the aquifer systems, and takes into account recharge, storage and drought periods **(**see **Figure 6.2.1).**

The Harvest Potential was then reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential ie the portion of the Harvest Potential which can practically be exploited (see **Table 6.2.1** and **Figure 6.2.2).**

The interaction of the groundwater and the surface water was assessed by evaluating the base flow component of the surface water, or more specifically the contribution of the Harvest Potential to the base flow. This contribution can be seen as water which can either be abstracted as groundwater or surface water. From this, the extent to which groundwater abstraction will reduce the base flow component of the surface water has been qualitatively evaluated **(**see **Figure 6.2.3).** Where the contribution of groundwater to the base flow component of the surface flow is zero the impact will be negligible, where the contribution is less than 30% of the base flow the impact will be low, where the contribution is between 30% and 80% of the base flow the impact will be moderate, and where the contribution to base flow is more than 80% the impact will be high. This assessment of the interaction of groundwater and the base flow component of the surface water can however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilizable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. The estimates of utilizable surface water given in **Section 6.3** have been derived on the basis of no groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilizable groundwater not contributing to the base flow of the surface water that can be added to the utilizable surface water to estimate the total utilizable resources has therefore been ignored.\

The existing groundwater use was determined by Baron and Seward (2000). The information was then verified at a workshop held with persons knowledgeable on the water resources of the Lower Vaal WMA and the water resources situation assessment team. This provided local input to the estimates of groundwater use provided by Baron and Seward which were then adjusted accordingly **(see Table 6.2.1** and **Figure 6.2.4).**

The groundwater balance then compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilized **(see Figure 6.2.5).** If the total use was greater than the Harvest Potential the groundwater in the catchment was considered to be over-utilized, if the total use was greater than the Exploitation Potential but less than the Harvest Potential the groundwater in the catchment was considered to be

TABLE 6.1.1: WATER RESOURCES IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	SURFACE WATER RESOURCES				TOTAL POTENTIAL	TOTAL WATER RESOURCE	
No	Descrpition	No	Description	Quaternary catchments	Description	Natural Runoff	1:50 Year Developed Resource 1995	1:50 Year Total Potential yield	Developed In 1995		1:50 Year Developed Yield In 1995	1:50 Year Total Potential Yield
Z		Z		ZB-ZF	Botswana Quats	31.9	1.4	1.4	0.0	75.1	1.4	76.4
TOTAL IN BOTSWANA						31.9	1.4	1.4	0.0	75.1	1.4	76.4
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	165.2	0.0	0.0	31.1	184.8	31.1	184.8
	TOTAL IN D CATCHMENT					165.2	0.0	0.0	31.1	184.8	31.1	184.8
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	48.7	27.4	27.4	19.9	47.5	47.3	74.9
				C31A-F	Harts	59.0	4.5	4.5	12.0	60.4	16.5	64.9
				C33A-C	Vaalhartz	40.2	419.0	419.0	10.3	56.2	429.3	475.2
		Sub-total				147.8	450.9	450.9	42.2	164.1	493.1	615.0
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	43.0	42.0	42.0	54.3	73.6	96.3	115.6
		Sub-total				43.0	42.0	42.0	54.3	73.6	96.3	115.6
	TOTAL IN C CATCHMENT					190.8	492.9	492.9	96.5	237.7	589.4	730.6
TOTAL IN RSA						356.0	492.9	492.9	127.6	422.5	620.5	915.4
TOTAL IN NORTH WEST									67.5			
TOTAL IN NORTHERN CAPE									37.6			
TOTAL IN FREE STATE									22.6			
TOTAL						387.9	494.3	494.3	127.6	497.5	621.9	991.8

heavily utilized, if the total use was more than 66% of the Exploitation Potential the groundwater in the catchment was considered to be moderately-utilized and if the total use was less than 66% of the Exploitation Potential the groundwater in the catchment was considered to be under-utilized.

6.3 SURFACE WATER RESOURCES

6.3.1 Previous Water Resources Studies

The Vaal catchment has been studied in detail as part of the Vaal River Systems Analysis studies. These studies included the lower Vaal but not the D-region quaternary catchments which now form part of the Lower Vaal WMA. This region is, however, very dry and for all practical purposes it can be assumed that the surface water resource of this region is zero.

The latest report on the Vaal system was the Vaal River System Analysis Update study, referred to as the VRSAU study. As part of this study the hydrology of the Vaal basin was rigorously reviewed and updated. Four reports were issued, covering the following catchment sub-divisions: Upper Vaal, Vaal Barrage, Middle Vaal and Lower Vaal. This study was undertaken for DWAF by a consortium involving BKS Inc., Stewart Scott Inc. and Ninham Shand Inc. and reports were finalised in January 1999. In modelling the Vaal Barrage catchment, account was taken of all known abstractions and discharges.

6.3.2 Current Surface Water Resources Situation

The surface water resources generated within the Lower Vaal WMA are limited by the low rainfall and most of the water requirements of the WMA are met by water supplied from the Upper Vaal catchment. The only significant local surfaces resources are those of the Spitzkop, Taung and Wentzel Dams. Accurate estimates of the yields of these dams are not available but the combined yield of these dams is estimated to be in the order of 25 million m^3/annum. The Douglas and Vaalharts weirs on the Vaal River also appear to generate some yield by regulating the natural flow and releases from Bloemhof Dam.

The surface water resources, including imports, are shown in **Table 6.3.1.**

TABLE 6.2.1: GROUNDWATER RESOURCES IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	GROUND-WATER EXPLOITA-TION POTENTIAL 10^6 m^3	GROUND-WATER USE IN 1995 10^6 m^3	UNUSED GROUND-WATER EXPLOITA-TION POTENTIAL 10^6 m^3
No	Description	No	Description	Quaternary catchments	Description			
Z		Z		ZB-ZF	Botswana Quats	75.1	0.0	75.1
TOTAL IN BOTSWANA						75.1	0.0	75.1
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	184.8	31.3	153.5
	TOTAL IN D CATCHMENT					184.8	31.3	153.5
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	47.5	19.9	27.6
				C31A-F	Harts	60.4	12.1	48.3
				C33A-C	Vaalhartz	56.2	10.3	45.9
			Sub-total			164.1	42.4	121.7
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	73.6	54.4	19.2
			Sub-total			73.6	54.4	19.2
	TOTAL IN C CATCHMENT					237.7	96.8	140.9
TOTAL IN RSA						422.5	128.1	294.4
TOTAL IN NORTH WEST						244.1	67.9	176.2
TOTAL IN NORTHERN CAPE						154.1	37.6	116.4
TOTAL IN FREE STATE						24.4	22.6	1.7
TOTAL						497.5	128.1	369.4

TABLE 6.3.1: SURFACE WATER RESOURCES IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	CATCHMENT AREA	MEAN ANNUAL PRECIPITATION	MEAN ANNUAL EVAPORATION	NATURALISED MAR		RESOURCE (1:50 YEAR)	
No	Descrpition	No	Description	Quaternary catchments	Description				INCREMENTAL	CUMULATIVE	DEVELOPED IN 1995	TOTAL POTENTIAL
Z		Z		ZB-ZF	Botswana Quats	112,800.0	181.7	2,250.0	31.9	31.9	1.4	1.4
TOTAL IN BOTSWANA						112,800.0	181.7	2,250.0	31.9	31.9	1.4	1.4
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	81,811.0	281.4	2,414.0	165.2	165.2	0.0	0.0
	TOTAL IN D CATCHMENT					81,811.0	281.4	2,414.0	165.2	165.2	0.0	0.0
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	10,210.0	443.5	1,960.0	48.7	48.7	27.4	27.4
				C31A-F	Harts	11,020.0	529.9	1,948.0	59.0	59.0	4.5	4.5
				C33A-C	Vaalhartz	9,843.0	414.4	2,100.0	40.2	147.8	419.0	419.0
		Sub-total				31,073.0	1,387.8	6,008.0	147.8	255.5	450.9	450.9
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	20,470.0	404.6	2,030.0	43.0	3,908.0	42.0	42.0
		Sub-total				20,470.0	404.6	2,030.0	43.0	3,908.0	42.0	42.0
	TOTAL IN C CATCHMENT					51,543.0	1,792.4	8,038.0	190.8	4,163.5	492.9	492.9
TOTAL IN RSA						133,354.0	2,073.8	10,452.0	356.0	4,328.7	492.9	492.9
TOTAL IN NORTH WEST						66,764.0						
TOTAL IN NORTHERN CAPE						58,759.0						
TOTAL IN FREE STATE						7,831.0						
TOTAL						246,154.0	2,255.5	12,702.0	387.9	4,360.6	494.3	494.3

6.3.3 Future Surface Water Resources Development

Given the low rainfall of the region, it is highly unlikely that the surface resources will be developed any further. Irrigators in the Lower Vaal will have to continue to rely on water from the Upper Vaal, supplemented by return flows from the southern portion of the Johannesburg metropolitan area. With the implementation of Phase 1A of the Lesotho Highlands Water Scheme in 1998 and additional water that will soon be available from Phase 1B, there will be more than sufficient water available in the Lower Vaal for some time to come. Although possible future augmentation schemes for the Vaal system have not considered the possibility of reallocating irrigation water from the Vaalharts scheme to domestic and/or industrial users in the Upper Vaal, this is an option which may well be considered in the future.

6.4 WATER QUALITY

6.4.1 Mineralogical Surface Water Quality

The purpose of this assessment is to provide an indication of where water quality problems can be expected rather than provide a comprehensive overview of water quality in the Water Management Area.

The mineralogical water quality of the surface water bodies is described in terms of total dissolved salts (TDS). Data for the assessment were obtained from the water quality database of the Department of Water Affairs and Forestry.

The surface water quality monitoring stations that were used to provide the data are shown in **Figure 6.4.1.1** Unfortunately, not all the records are consistent and complete. In drainage region A3 insufficient data is available to assess the water quality.

Only data sets that had data for the last five years (1994-1998) were used. The data sets were filtered to monthly data, and where possible various techniques were used to fill in missing values. The assessment method calls for the consultants to use only those data sets that spanned at least two years and contained at least 24 data points for analysis. These should be used to derive the mean and maximum TDS concentrations. Due to the poor status of water quality monitoring in the WMA, the whole 5 year data set of monthly TDS values was used in some cases to characterise the water quality because there were no monitoring points which fully met the criteria.

Details of the TDS and electrical conductivity (EC) for the various catchments are given in **Appendix G.**

The water quality is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements for other uses. The South African Water Quality Guidelines of the Department of Water affairs and Forestry (1996) for these two uses were combined into a single classification system as shown in **Table 6.4.1.1.**

Table 6.4.1.1: Classification System for Mineralogical Water Quality

CLASS	COLOUR CODE	DESCRIPTION	TDS RANGE (mg/ℓ)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 – 600
2	Yellow	Marginal water quality	601 – 1800
3	Red	Poor water quality	1801 – 3400
4	Purple	Completely unacceptable water quality	>3400

Where water quality data were available, water quality was assessed at a quaternary catchment level of resolution. The final classification of the mineralogical surface water quality of a quaternary catchment was based on both average conditions and extreme conditions. For this purpose the data set was inspected for the worst two-year period. The average concentration and the maximum were used to determine the class of the water as shown in **Table 6.4.1.2.**

Table 6.4.1.2: Overall Classification

AVERAGE CONCENTRATION CLASS	MAXIMUM CONCENTRATION CLASS	OVERALL CLASSIFICATION
Blue	Blue Green Yellow Red Purple	Blue Green Green Yellow Red
Green	Green Yellow Red Purple	Green Yellow Yellow Red
Yellow	Yellow Red Purple	Yellow Red Purple
Red	Red Purple	Red Purple
Purple	Purple	Purple

The water quality of the Lower Vaal WMA is summarised in **Table 6.4.1.4** and is shown in **Figure 6.4.1.1.**

Table 6.4.1.4 : Summary of Water Quality Assessment

Quaternary catchment	No. of records	Class			
		Blue	Green	Yellow	Red
D40	26	2	2	0	0
C30	3	0	1	2	0
C90	4	0	4	0	0

Conclusions

The water quality data of the Harts River catchment indicates high TDS values and the water quality would be classified as marginal. This is to be expected, however, due to the large return flows from the Vaalhartz irrigation scheme. A build up of salinity in the soils of the Vaalharts scheme is being experienced and it is accepted practise to apply extra irrigation water to leach these salts out of the soil. These salts then appear in the Hartz River downstream of the irrigation scheme with the resultant marginal water quality in this stretch of river. Since irrigators are actively trying to flush salts out of the soil, the water quality is not expected to improve in the near future.

According to the available water quality data, the Vaal river downstream of the Bloemhof Dam, has a surprisingly good water quality. Higher TDS concentrations could be expected as a result of return flows from southern Johannesburg.

Recommendations

Although the water quality of the Harts River is marginal, this is an inevitable cost associated with large-scale irrigation. Since there are no major water users downstream of the Vaalharts scheme, this poor quality is not an immediate problem. It is recommended that the situation be monitored and steps taken to ensure that the quality does not deteriorate any further.

6.4.2 Mineralogical Groundwater Quality

The groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (Simonic, 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegter's maps (Vegter, 1995). The potability evaluation done by Simonic (2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

The portion of the groundwater resources considered to be potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the classification system given in **Section 6.4.1.** Water classified as poor and unacceptable (Class 3 and 4) has been considered to be **not** potable.

In catchments where no information was available estimates of the portion of potable groundwater were made using Vegters maps (Vegter, 1995).

Figure 6.4.2.1 gives an evaluation of the mean TDS per quaternary catchment and **Figure 6.4.2.2** gives an estimate of the percentage of potable groundwater per quaternary catchment

6.4.3 Microbiological (or Microbial) Water Quality

Background

A method was developed and applied to assess the risk of microbial contamination of surface water and groundwater resources in South Africa. Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution **(**see **Figure 6.4.3.1** and **6.4.3.2).** The maps provide a comparative rating of the risk of faecal contamination of the surface water and groundwater resources. The microbial information that has been provided is, however, intended for planning purposes only and is not suitable for detailed water quality assessments.

Mapping microbial contamination of surface water resources

As part of the National Microbiological Monitoring Programme a screening method was developed to identify the risk of faecal contamination in various catchments. This screening method uses a simple rule based weighting system to indicate the relative faecal contamination from different land use areas. It has been confirmed that the highest faecal contamination rate is derived from high population densities with poor sanitation services. The Programme produced a map, at quaternary catchment resolution, showing the potential faecal contamination in the selected catchments. Unfortunately, the map did not cover the entire country.

As part of this study, the same screening method was applied to produce a potential surface faecal contamination map for the whole of South Africa using national databases for population density and degree of sanitation. The portion applicable to the Lower Vaal WMA is shown in **Figure 6.4.3.1.**

Mapping aquifer vulnerability of groundwater resources

Certain aquifers are more vulnerable to contamination than others. The DRASTIC method used in this study is an acknowledged method for assessing aquifer vulnerability to contamination. The method is a weighting and rating technique that considers up to seven geologically and geohydrologically based factors to estimate groundwater vulnerability. The magnitudes or severities of pollution sources are, however, not considered. Three of the above factors were used in this study to estimate the vulnerability of groundwater to microbial contamination.

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider groundwater depth, soil media and impact of the vadose zone media. Comparison of the different maps showed remarkable similarity and confirmed that the vulnerability is largely controlled by the selected three parameters. This similarity promotes confidence in the resultant microbial contamination vulnerability map.

A GIS model, which considered the three factors, was developed and a vulnerability rating of low, medium and high was calculated for each grid element in the GIS coverage. A numerical control was included to account for deep groundwater below 35 metres. At this depth it was assumed that the surface contamination rate would be low, irrespective of the other two factors.

Mapping microbial contamination of groundwater resource*s*

The potential surface faecal contamination and aquifer vulnerability maps were then intersected to derive a potential groundwater faecal contamination map for South Africa at a quaternary scale. The portion applicable to the Lower Vaal WMA is shown in **Figure 6.4.3.2**. This map shows the degree of potential faecal contamination in groundwater using a rating scale which ranges from low to medium to high.

Conclusions and recommendations

A limitation of the study was the inability to validate results due to the limited information on groundwater contamination resulting from human wastes.

Once sufficient microbial data becomes available, the numerical methods and associated assumptions should be validated and the maps replotted. Monitoring data from selected areas should also be collected to assess the validity of the vulnerability assessment presented in this report.

6.5 SEDIMENTATION

The WR90 Series 8 maps showing the sediment yield regions; erodibility indices and sediment yield were used to estimate the potential loss of reservoir storage due to sedimentation over the next 25 years. This is presented per key area in **Table 6.5.1** while the information is given at a quaternary level of detail in **Appendix H** and shown in **Figure 6.5.1.** There is no information available on actual sediment accumulation in dams within the Lower Vaal WMA.

Sedimentation is not a major problem in the Lower Vaal WMA. The rates of sedimentation are generally low, whether viewed in absolute terms or as a percentage of the MAR. The sediment yield varies from zero in the D40 catchment, due to negligible runoff, to over 70 tons/ km^2/annum in the C90C catchment.

Table 6.5.1: Sedimentation Rates

KEY AREA	SEDIMENTATION RATE (t/a)	25 YEAR SEDIMENT VOLUME (million m^3)
Molopo	27 000	0.0
Dry Harts	448 000	12.3
Harts	371 000	10.2
Vaalharts	383 000	10.5
D/S of Bloemhof	815 000	22.3

CHAPTER 7: WATER BALANCE

7.1 METHODOLOGY

7.1.1 The Water Situation Assessment Model

The Water Situation Assessment Model (WSAM) was developed with the purpose of providing a reconnaissance level decision support tool. The model is intended to provide a broad overview of the water situation in South Africa taking into account all significant water uses and resources. The model can produce output at a variable resolution, down to quaternary catchment scale.

The data input to the model was gathered by various organisations and individuals, but the Water Resources Situation Assessments (WRSA) were the main vehicle for providing data for the model. **Appendix H** lists the organisations responsible for the various components of the data. This list also gives the reader a good indication of the type of data in the database.

The intention was to use the WSAM to determine the water balance for the WRSA reports and also to use the WSAM reporting tools to produce as many of the tables in the WRSA reports as was practical. However, due to various unresolved developmental problems with the WSAM, another approach was adopted, as described in this section. For this reason, the WSAM is not described in any detail in this report. The reader is referred to the WSAM user manual for more information on this model (DWAF, 2002a).

7.1.2 Estimating the Water Balance

The water balance is simply the difference between the water resource and the sum of all the water requirements and losses. While the water requirements and losses are easily abstracted from the database, to estimate the water resource directly from the known yields of dams would be difficult and impractical. The main reason for this is that the run-of-river component of the resource is difficult to determine without some form of modelling, especially where there are multiple dams and abstractions and the different modes of operation of the dams influence the yields.

The water balance produced by the WSAM is not yet correct in all cases due to the following unresolved problems:

- The ecological Reserve has spurious impacts on the water balance, which do not appear to be correct;
- The impacts of afforestation and alien vegetation, as reported on the balance do not appear to be correct;
- It is not possible to model actual known river losses; and
- Return flows from irrigation are not modelled correctly.

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modelling procedure. This is done relatively easily. The above impacts (ecological Reserve, etc.) were then determined externally to the model and added or subtracted from the WSAM water balance as appropriate. This procedure achieved a resultant water balance that seemed to be in reasonable agreement with other estimates in most cases.

7.1.3 Estimating the water requirement

The water requirements determined by the WSAM are mostly accepted to be correct. In order to facilitate the production of the WRSA reports, this data was abstracted from the WSAM into a spreadsheet and various worksheets set up, which reference this abstracted data. These worksheets were structured so a to present most of the information contained in the tables of this report. This is not only limited to water requirements but also lists land uses such as irrigated areas, afforested areas, etc.

The data was abstracted in two different formats: at key area resolution (incremental between key points) and at quaternary catchment resolution. The key area data has been aggregated by the WSAM except for a few parameters relating mainly to irrigation, which the WSAM did not aggregate correctly. In these cases, default values were used. A list of these parameters and the default values is attached as **Appendix H.** The data at quaternary catchment resolution was abstracted for information purposes only. It is attached in the Appendixes to this report.

Water requirements or gains that the WSAM could not calculate were determined as follows:

Ecological Reserve

The impact of the ecological Reserve on the yield of a catchment depends on the storage in that catchment. It was accepted that the water required for the ecological Reserve follows the same general pattern of (i.e. mimics) the natural flow and that the storage/yield characteristics of the natural catchment could therefore also be used to estimate the yield of the catchment after allowing for the water requirements of the ecological Reserve. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under natural conditions, both with and without provision for the ecological Reserve. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The incremental impact of the ecological Reserve on the water resources of a particular key area was taken to be the difference between the impact at the downstream key point less the impact at the upstream key point.

The impact of the ecological Reserve on the run-of-river yield was accepted to be the annual equivalent of the lowest 4-month water requirement for the ecological Reserve. This value was used to establish the incremental impact of the ecological Reserve on the yield at a key point at which there was no significant storage in the incremental catchment.

Using the above method, negative impacts are sometimes possible. The reason for this is that the water required for the ecological Reserve at an upstream point may become available for use further downstream, if the ecological Reserve is less at the downstream point.

Water losses

The WSAM models losses as a function of the flow in the river. The water loss under natural flow conditions is used in the WSAM to calculate the water loss under the altered flow conditions. While this is conceptually correct, it is found to be very difficult to model the known loss under current conditions. For this reason, the WSAM was run with zero losses and the known losses taken into account external to the model when determining the water balance.

Irrigation return flows

The average return flow from irrigation in South Africa according to the WSAM is in the order of 3%. This is clearly erroneous and not in accordance with the 10% to 15% default agreed upon at various workshops. Irrigation return flows were therefore calculated external to the model and were usually assumed to be 10%. Where the consultant and/or other persons had more detailed information of the return flows that could be expected these were adopted instead.

7.1.4 Estimating the water resource

The WSAM does not report directly on the available water resource, as required for this WRSA report. This was therefore calculated external to the model as follows:

- The water balance produced by the WSAM, as described in paragraph 7.1.2 above, was mostly deemed to be correct. In the few instances where it was clearly incorrect an adjustment was made based on the results of other studies. These changes have been documented. A few adjustments were made to the model to allow for the following:
  - ***Runoff into dams***

    It appears as if WSAM assumes, as a default, that the runoff into minor dams is equal to the entire incremental flow generated within a quaternary. Considering the definition of a minor dam, ie a dam which is not situated on the main stream of the catchment, this is not possible. An assumption was made that only 50% of a catchment's runoff flows into minor dams and this assumption was applied nationally, except in the case of the upper Letaba catchment where the yield was found to be very sensitive to this assumption. Here information relating to the runoff into minor dams was obtained from a recent systems analysis.

  - ***Impact of afforestation and aliens on yield***

    While WSAM seems to determine the impact of afforestation and aliens on yield in a realistic manner, it does not report correctly on what this impact is for areas consisting of more than one quaternary catchment. This problem was solved by assuming zero afforestation and aliens when running WSAM and calculating these impacts external to the model. The impacts were then accounted for external to the model when determining the balance.

- The yield balance was calculated as the difference between the 1:50 year yield of the catchment and the water requirements at 1:50 year assurance that are supplied from the catchment.
- In some cases, there are negative balances within the quaternary catchments making up a key area. These negative balances are not routed through the system, and it was therefore necessary to sum these negative balances and subtract them from the water resource.

In some cases the WSAM did not model the yield of major dams correctly and the yield curves were adjusted to approximate the yield as obtained from more detailed studies.

7.2 OVERVIEW

The water balance is essentially the difference between the water requirements and the water availability, either available from resources within the WMA or imported from other WMAs. The requirements and resources are expressed in terms of the 1:50 year assurances so that they can be compared. The water requirements are summarised in **Table 7.2.1** while the resource is shown in **Table 6.1.1.** The balance is shown in **Table 7.2.2.** For the purposes of this report, water balances were determined on a so-called key area level of detail and reported on at key points. The Key points used in this WMA are defined in **Table 2.1.**

From **Table 7.2.2** it is apparent that there is a large deficit within the Lower Vaal WMA. However, this is to be expected since there are large water requirements within the WMA, mostly irrigation, and very limited local resources. This large deficit is only apparent when the WMA is considered in isolation. The Lower Vaal WMA is in fact part of the larger Vaal System and water is allocated to users in the Lower Vaal from the Upper Vaal. The planning and operation of the entire Vaal System does take the requirements of the Lower Vaal into account and should continue to do so.

There is currently surplus water available in the Upper and Middle Vaal WMA and this water is released from Bloemhof Dam to meet requirements in the Lower Vaal. This surplus yield from Bloemhof is estimated to be 672 million m^3/annum (Middle Vaal Water Resoruces Situation Assessment).

The overall balance for the entire Lower Vaal WMA is therefore as follows:

Yield available from Middle Vaal:	672	million m^3/annum
Balance in Lower Vaal without support from upstream:	(462)	million m^3/annum
Balance for Lower Vaal with support from upstream:	210	million m^3/annum

7.3 THE MOLOPO RIVER CATCHMENT

Reconciling the water requirements with the water resource in the Molopo catchment, there appears to be a significant deficit. In reality what this implies is that either there is more ground water than assumed or, consumption is less than assumed. It is an established fact that in the drier portions of this key area water is extremely scarce and in all likelihood, water consumption is less than assumed.

7.4 THE DRY HARTZ CATCHMENT

According to the information presented in this report, the combined groundwater and surface water resource of the Dry Harts key area exceed the water requirement by about 7 million m^3/annum. However, the irrigation requirement of this key area, is met from imports via the Vaalhartz scheme. The apparent surplus is therefore derived from groundwater. The information on groundwater supply must therefore be incoreect since groundwater will only be abstracted to meet a specific requirement, in this case the urban and rural requirement of 13,6 million m^3/annum. The groundwater data gathered as part of this study indicates a groundwater supply of 19,0 million m^3/annum and this must be an overestimate. In reality, the Dry Harts key area is probably in balance.

7.5 THE HARTS CATCHMENT

The Harts River catchment is approximately in balance. The groundwater supply of 12,0 million m^3/annum seems plausible given the rural and urban requirements of 15,4 million m^3/annum. The remainder of the requirement is met by the Wentzel and Taung Dams.

7.6 THE VAALHARTS CATCHMENT

The water resources of the Vaalharts key area are essentially all transferred in from the Vaal River. This key area is essentially in balance because water is only imported to meet the irrigation requirement. The surplus that is indicated in **Table 7.2.2** is derived from irrigation return flows.

7.7 THE VAAL D/S OF BLOEMHOF DAM CATCHMENT

This key area is also essentially in balance with the surplus indicated in **Table 7.2.2** derived from return flows. This catchment has only a small incremental surface resource, which is the yield of the Vaalharts weir. All the other resources are derived from releases from the Bloemhof Dam and return flow from the Modder/Riet irrigation scheme.

TABLE 7.2.1: WATER REQUIREMENTS

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	STREAMFLOW REDUCTION ACTIVITIES			WATER USE	WATER REQUIREMENTS (at 1:50 year assurance)							ECOLO-GICAL RESERVE	TOTAL
No	Descrpition	No	Description	Quaternary catchments	Description	Affore-Station	Dryland Sugar Cane	Alien Vege-Tation	River Losses	Bulk	Irriga-Tion	Rural	Urban	Hydro-Power	Water Trans-Fers Out Of Key Area	Neigh-Bouring States	Impact On Yield	
Z		Z		ZB-ZF	Botswana Quats	0.0	0.0	0.0	0.0	1.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	2.1
TOTAL IN BOTSWANA						0.0	0.0	0.0	0.0	1.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	2.1
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.0	0.0	0.0	0.0	5.8	4.0	21.6	11.0	0.0	0.0	0.0	0.0	42.4
	TOTAL IN D CATCHMENT					0.0	0.0	0.0	0.0	5.8	4.0	21.6	11.0	0.0	0.0	0.0	0.0	42.4
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	0.0	0.0	0.0	0.0	0.0	27.4	8.6	5.0	0.0	0.0	0.0	0.0	40.9
				C31A-F	Harts	0.0	0.0	0.0	0.0	0.0	1.1	9.6	5.8	0.0	0.0	0.0	0.0	16.5
				C33A-C	Vaalhartz	0.0	0.0	0.0	4.0	0.0	395.2	3.1	5.7	0.0	0.0	0.0	0.0	408.0
		Sub-total				0.0	0.0	0.0	4.0	0.0	423.7	21.3	16.4	0.0	0.0	0.0	0.0	465.4
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	0.0	0.0	0.0	90.0	0.0	101.3	9.1	26.5	0.0	422.0	0.0	0.0	648.9
		Sub-total				0.0	0.0	0.0	90.0	0.0	101.3	9.1	26.5	0.0	422.0	0.0	0.0	648.9
	TOTAL IN C CATCHMENT					0.0	0.0	0.0	94.0	0.0	524.9	30.4	42.9	0.0		0.0	0.0	692.3
TOTAL IN RSA						0.0	0.0	0.0	94.0	5.8	528.9	52.1	53.9	0.0		0.0	0.0	734.7
TOTAL IN NORTH WEST						0.0	0.0	0.0	0.0	0.0	295.9	40.9	17.5	0.0	0.0	0.0	0.0	354.3
TOTAL IN NORTHERN CAPE						0.0	0.0	0.0	94.0	0.0	233.0	9.8	33.3	0.0	422.0	0.0	0.0	370.2
TOTAL IN FREE STATE						0.0	0.0	0.0	0.0	4.4	0.0	1.3	3.2	0.0	0.0	0.0	0.0	8.9
TOTAL						0.0	0.0	0.0	94.0	7.4	528.9	52.6	53.9	0.0	422.0	0.0	0.0	734.7

NOTES
1. The sum of transfers out of the key area does not equal the total transfers out of a secondary catchment or the total WMA
2. The requirement includes transfers out of the key area. The sum of the requirements does therefore not equal the total requirements for the secondary catchment or for the whole WMA

TABLE 7.2.2: YIELD BALANCE IN 1995

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	AVAILABLE RESOURCE			WATER TRANSFERS		RETURN FLOWS		WATER REQUIREMENTS	WATER BALANCE		Transfer down	Receiv-ing	Revised balance
No	Descrpition	No	Description	Quaternary catchments	Description	Surface Water	Ground Water	Total	Imports	Exports	Re-Usable	To Sea						
Z		Z		ZB-ZF	Botswana Quats	1.4	0.0	1.4	0.0	0.0	0.9		2.1	0.1				0.1
TOTAL IN BOTSWANA						1.4	0.0	1.4	0.0	0.0	0.9	0.0	2.1	0.1	0.0	0.0	0.0	0.1
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	0.0	31.1	31.1	3.3	0.0	0.0		42.4	-11.3				-11.3
	TOTAL IN D CATCHMENT					0.0	31.1	31.1	3.3	0.0	0.0	0.0	42.4	-11.3	0.0	0.0	0.0	-11.3
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	27.4	19.9	47.3	27.4	0.0	1.0		40.9	7.3		7.3		0.0
				C31A-F	Harts	4.5	12.0	16.5	0.0	0.0	1.0		16.5	1.1		1.1		0.0
				C33A-C	Vaalhartz	419.0	10.3	429.3	395.2	0.0	21.0		408.0	42.4		42.4		0.0
		Sub-total				450.9	42.2	493.1	422.6	0.0	23.0	0.0	465.4	50.8	0.0			50.8
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	42.0	54.3	96.3	18.0	422.0	50.8		648.9	-501.8			722.8	220.9
		Sub-total				42.0	54.3	96.3	18.0	422.0	50.8	0.0	648.9	-501.8	0.0			220.9
	TOTAL IN C CATCHMENT					492.9	96.5	589.4	440.6	422.0	73.8	0.0	692.3	-451.1	0.0			220.9
TOTAL IN RSA						492.9	127.6	620.5	443.9	422.0	73.8	0.0	734.7	-462.4	0.0		0.0	209.6
TOTAL IN NORTH WEST							65.6						354.3					
TOTAL IN NORTHERN CAPE							37.6						370.2					
TOTAL IN FREE STATE							22.6						8.9					
TOTAL						494.3	127.6	621.9	19.0	0.0	0.0		734.7					209.7

CHAPTER 8: COSTS OF WATER RESOURCES DEVELOPMENT

The surface water resources of the Lower Vaal WMA are considered to be fully developed and there is little or no scope for the construction of new dams or the raising of existing dams. Any increases in water requirements in the future would probably be supplied from the upper Vaal System with the additional water ultimately sourced from the Lesotho Highlands scheme.

However, the water requirements are unlikely to grow significantly. The reason for this is that urban and rural requirements are predicted to decrease in the Lower Vaal WMA due to the impact of AIDS and the gradual movement of rural communities to the cities. The main water user sector in the Lower Vaal, namely irrigation, is unlikely to increase since it is unlikely to be economically viable to do so.

There is a large potential for increased groundwater use, especially in the dolomitic areas in the central portion of the WMA. Although the cost of developing groundwater is very site specific, an attempt has been made to estimate this cost based on experience gained in developing well fields in the Crocodile West and Marico WMA (Jeremy Cooke, personal communication). The cost of groundwater development is largely dependent on the borehole yield as well as the depth of the borehole. In the dolomitic area within the WMA, the borehole yields are high and the depth at which water can be found relatively shallow while in the drier western areas, boreholes are very deep and yield very little.

An estimate of the cost of developing groundwater to its full potential is shown in Table 8.1

TABLE 8.1: GROUNDWATER COST (in terms of 1995 costs)

PRIMARY		SECONDARY		KEY AREA	CATCHMENT	EXISTING GROUND-WATER USE	GROUNDWATER POTENTIAL	UNUSED GROUNDWATER POTENTIAL	ESTIMATED BOREHOLE YIELD (l/s)	DEVELOPMENT COST (R/m3/annum)	DEVELOPMENT COST (R million)
No	Descrpition	No	Description	Quaternary catchments	Description						
Z		Z		ZB-ZF	Botswana Quats	0.0	75.1	75.1	5.0	2.0	150
TOTAL IN BOTSWANA						0.0	75.1	75.1			150
D	Molopo	D4, D7	Molopo	D41B-M, D73A-E	Molopo River	31.3	184.8	153.5	2.0	4.0	614
	TOTAL IN D CATCHMENT					31.3	184.8	153.5			614
C	Vaal-Hartz	C3	Hartz	C32A-D	Dry Hartz	19.9	47.5	27.6	5.0	2.0	55
				C31A-F	Harts	12.1	60.4	48.3	5.0	2.0	97
				C33A-C	Vaalhartz	10.3	56.2	45.9	10.0	1.0	46
		Sub-total				42.4	164.1	121.7			198
		C9		C91A-E, C92A-B	Vaal D/S Bloemhof	54.4	73.6	19.2	5.0	2.0	38
		Sub-total				54.4	73.6	19.2			38
	TOTAL IN C CATCHMENT					96.8	237.7	140.9			236
TOTAL IN RSA						128.1	422.5	294.4			850
TOTAL IN NORTH WEST						67.9	244.1	176.2			530
TOTAL IN NORTHERN CAPE						37.6	154.1	116.4			294
TOTAL IN FREE STATE						22.6	24.4	1.7			177
TOTAL						128.1	497.5	369.4			999.9

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

The Lower Vaal WMA, when considered in isolation, is in deficit with the water requirements exceeding the local resources by almost 500 million m^3/annum. However, this is to be expected since there are large water requirements within the WMA, mostly irrigation, and very limited local resources. This large deficit is only apparent when the WMA is considered in isolation. Provided the Lower Vaal WMA is operated as part of the larger Vaal System, as is currently the case, the bulk of the requirements of the Lower Vaal WMA can be met from the Middle and Upper Vaal WMA.

While the Lower Vaal WMA receives most of its water from the Middle Vaal, the extent of the local resources is not well understood. The Spitskop and Taung Dams are significant dams and it is not clear if the yields of these dams are being optimally utilised. This aspect needs to be studied in more detail.

Water losses within the Lower Vaal are exceptionally high, both in absolute terms and as a percentage of total water consumption. Although there is no urgency in addressing the problem since there is currently sufficient water available to the Lower Vaal WMA, a reduction in these losses could delay the implementation of a future scheme to augment the water supply to the Vaal System. It is recommended that a water conservation study be initiated to investigate methods of reducing conveyance losses and well as reducing losses by means of improved irrigation application techniques. Evaporation and systems losses downstream of Bloemhof Dam also need to be investigated with a view to reducing these large losses.

The economic viability of irrigation in the Lower Vaal when compared with the economic value of water in the Upper Vaal also needs to be investigated. The macro-economic study indicates that agriculture has a large comparative advantage within the Lower Vaal WMA when compared with agriculture in the rest of South Africa. While there is currently surplus water available in the Vaal system the value of the surplus water is minimal, but when increasing requirements necessitate the implementation of an augmentation scheme, the value of the water used by irrigators in the Lower Vaal will become much greater. If irrigators were to pay this full economic value of the water, the comparative advantage would probably become a comparative disadvantage. It is recommended therefore that this be studied in detail and the allocation of the water resources of the Upper Vaal to irrigators in the Lower Vaal be carefully considered before implementing the next augmentation scheme for the Vaal System.

It is interesting to note that the Vaal system would have been approximately in balance in 1995 if it had not been for the imposition of water restrictions. The implementation of the Lesotho Highlands phase 1a and 1b has therefore made surplus water available which can be utilised at any point downstream of the Vaal Dam. Consideration should be given to the short-term utilisation of this surplus water. The latest water demand projections for the Vaal System predict much lower growth in water requirements than previously and indications are that surpluses will be available for some time to come.

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APPENDICES

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

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APPENDIX A

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APPENDIX A1

CATCHMENT DEFINITION

Percentage of quaternary catchment in each province and within the Water Management Area

Catchment	Percentage in				
	North West	Northern Cape	Free State	Total	Lower Vaal WMA
C31A	100			100	100
C31B	100			100	100
C31C	100			100	100
C31D	100			100	100
C31E	100			100	100
C31F	100			100	100
C32A	100			100	100
C32B	100			100	100
C32C	100			100	100
C32D	100			100	100
C33A	68	32	0	100	100
C33B	34	66	0	100	100
C33C		100		100	100
C91A	85	0	15	100	100
C91B	35	5	60	100	100
C91C			100	100	100
C91D	0	50	50	100	100
C91E	0	95	5	100	100
C92A		100		100	100
C92B		100		100	100
D41B	100			100	100
D41C	100			100	100
D41D	100			100	100
D41E	100			100	100
D41F	100			100	100
D41G	86	14		100	100
D41H	83	17		100	100
D41J		100		100	100
D41K		100		100	100
D41L	68	32		100	100
D41M		100		100	100
D73A		100		100	100
D73B		100		100	5
D73C		100		100	61
D73D		100		100	10
D73E		100		100	10

LAND USE DATA

Quaternary catchment	Alien vegetation km2	Dry-land sugarcane km2	Afforestation km2	Indigenous forests km2	Irrigated area km2	Urban area km2
C31A	0.0	0.0	0.0	0.0	0.0	0.0
C31B	0.0	0.0	0.0	0.0	0.0	0.0
C31C	0.0	0.0	0.0	0.0	0.0	0.0
C31D	0.0	0.0	0.0	0.0	0.0	0.0
C31E	10.2	0.0	0.0	0.0	1.0	0.0
C31F	2.3	0.0	0.0	0.0	0.0	19.0
C32A	0.0	0.0	0.0	0.0	0.0	0.0
C32B	11.6	0.0	0.0	0.0	0.0	0.0
C32C	11.3	0.0	0.0	0.0	0.0	0.0
C32D	2.6	0.0	0.0	0.0	7.9	21.0
C33A	0.3	0.0	0.0	0.0	176.0	36.0
C33B	0.0	0.0	0.0	0.0	34.9	0.0
C33C	0.0	0.0	0.0	0.0	33.1	0.0
C91A	19.8	0.0	0.0	0.0	9.7	0.0
C91B	4.6	0.0	0.0	0.0	19.7	11.0
C91C	2.3	0.0	0.0	0.0	0.0	0.0
C91D	0.8	0.0	0.0	0.0	12.0	0.0
C91E	0.1	0.0	0.0	0.0	12.0	160.0
C92A	0.0	0.0	0.0	0.0	12.0	0.0
C92B	0.3	0.0	0.0	0.0	12.0	0.0
D41B	89.0	0.0	0.0	0.0	0.0	0.0
D41C	1.4	0.0	0.0	0.0	0.0	0.0
D41D	0.2	0.0	0.0	0.0	6.4	0.0
D41E	1.3	0.0	0.0	0.0	0.0	0.0
D41F	1.0	0.0	0.0	0.0	0.0	5.3
D41G	0.6	0.0	0.0	0.0	0.0	0.0
D41H	0.3	0.0	0.0	0.0	16.1	0.0
D41J	0.1	0.0	0.0	0.0	0.0	0.0
D41K	0.1	0.0	0.0	0.0	0.0	0.0
D41L	0.0	0.0	0.0	0.0	1.2	11.8
D41M	0.1	0.0	0.0	0.0	0.0	0.0
D42C	0.8	0.0	0.0	0.0	0.0	0.0
D42D	22.2	0.0	0.0	0.0	0.0	0.0
D73A	64.2	0.0	0.0	0.0	0.0	5.5
D73B	0.1	0.0	0.0	0.0	0.0	0.0
D73C	0.1	0.0	0.0	0.0	0.0	0.0
D73D	0.5	0.0	0.0	0.0	0.0	0.0
D73E	2.7	0.0	0.0	0.0	0.0	7.6
Z10B	0.0	0.0	0.0	0.0	0.0	0.0
Z10C	0.0	0.0	0.0	0.0	0.0	0.0
Z10D	0.0	0.0	0.0	0.0	0.0	0.0
Z10E	35.0	0.0	0.0	0.0	0.0	0.0
Z10F	10.0	0.0	0.0	0.0	0.0	0.0
TOTAL	295.5	0.0	0.0	0.0	354.0	277.2

Notes

1 All shaded areas indicate values changed from those of the WSAM database

2 Alien vegetation apportioned. Only 10% of D42D in Lower Vaal WMA

3 Irrigation assumed to be in Lower Orange and not Lower Vaal

STREAMFLOW REDUCTION ACTIVITIES

Quaternary catchment	Area under alien vegetation km2	Area under dryland sugar cane km2	Area under afforestation km2	Area of indigenous forests km2	Reduction in runoff due to alien vegetation million m3/annum	Reduction in runoff due to dryland sugar cane million m3/annum	Reduction in runoff due to afforestation million m3/annum	River losses million m3/annum
C31A	0.00	0.00	0.00	0.00	0.00	0	0	0
C31B	0.00	0.00	0.00	0.00	0.00	0	0	0
C31C	0.00	0.00	0.00	0.00	0.00	0	0	0
C31D	0.00	0.00	0.00	0.00	0.00	0	0	0
C31E	10.16	0.00	0.00	0.00	0.19	0	0	0
C31F	2.33	0.00	0.00	0.00	0.03	0	0	0
C32A	0.00	0.00	0.00	0.00	0.00	0	0	0
C32B	11.61	0.00	0.00	0.00	0.30	0	0	0
C32C	11.28	0.00	0.00	0.00	0.31	0	0	0
C32D	2.58	0.00	0.00	0.00	0.08	0	0	0
C33A	0.31	0.00	0.00	0.00	0.01	0	0	0
C33B	0.00	0.00	0.00	0.00	0.00	0	0	0
C33C	0.00	0.00	0.00	0.00	0.00	0	0	0
C91A	19.80	0.00	0.00	0.00	0.38	0	0	0
C91B	4.63	0.00	0.00	0.00	0.08	0	0	0
C91C	2.25	0.00	0.00	0.00	0.04	0	0	0
C91D	0.81	0.00	0.00	0.00	0.01	0	0	0
C91E	0.08	0.00	0.00	0.00	0.00	0	0	0
C92A	0.04	0.00	0.00	0.00	0.00	0	0	0
C92B	0.27	0.00	0.00	0.00	0.01	0	0	0
D41B	88.99	0.00	0.00	0.00	2.07	0	0	0
D41C	1.38	0.00	0.00	0.00	0.02	0	0	0
D41D	0.19	0.00	0.00	0.00	0.00	0	0	0
D41E	1.26	0.00	0.00	0.00	0.01	0	0	0
D41F	1.01	0.00	0.00	0.00	0.01	0	0	0
D41G	0.59	0.00	0.00	0.00	0.01	0	0	0
D41H	0.26	0.00	0.00	0.00	0.00	0	0	0
D41J	0.06	0.00	0.00	0.00	0.00	0	0	0
D41K	0.07	0.00	0.00	0.00	0.00	0	0	0
D41L	0.00	0.00	0.00	0.00	0.00	0	0	0
D41M	0.07	0.00	0.00	0.00	0.00	0	0	0
D42C	0.76	0.00	0.00	0.00	0.00	0	0	0
D42D	22.30	0.00	0.00	0.00	0.04	0	0	0
D73A	64.18	0.00	0.00	0.00	1.95	0	0	0
D73B	0.06	0.00	0.00	0.00	0.00	0	0	0
D73C	0.12	0.00	0.00	0.00	0.00	0	0	0
D73D	0.45	0.00	0.00	0.00	0.01	0	0	0
D73E	2.70	0.00	0.00	0.00	0.05	0	0	0
Z10B	0.00	0.00	0.00	0.00	0.00	0	0	0
Z10C	0.00	0.00	0.00	0.00	0.00	0	0	0
Z10D	0.00	0.00	0.00	0.00	0.00	0	0	0
Z10E	35.00	0.00	0.00	0.00	0.00	0	0	0
Z10F	10.00	0.00	0.00	0.00	0.00	0	0	0
TOTAL	295.60	0.00	0.00	0.00	5.63	0	0	0

Notes

1 All shaded areas indicate values changed from those of the WSAM database

2 Alien vegetation apportioned

DAMS IN THE LOWER VAAL WMA

AreaName	Name	Use	DamClas	Full supply capacity (million m3)	Full supply area (km2)	Dead storage (factor)
C31A	DAUTH ROODE	Leisure	Minor	0.1	0.02	0.05
C31A	EEUFEES	Leisure	Minor	0.15	0.02	0.05
C31E	WENTZEL	Irrigation	Major	6.58	2.98	0.05
C31F	TAUNG DAM	Irrigation	Major	6.6	4.65	0.05
C32C	GLEN UNA	Irrigation	Minor	0.5	0.36	0.05
C33B	SPITSKOP	Irrigation	Major	56.63	25.08	0.05
C91B	VAALHARTS-STUWAL	Domestic Water Use	Major	48.66	21.19	0.05
C92B	DOUGLAS-ATHERTON WEIR/STUWAL	Information	Major	16.7	8	0.05
D41B	KOEDOESRAND	Irrigation	Minor	0.75	0.46	0.05
D41C	BLACKHEATH	Irrigation	Minor	0.124	0.08	0.05
D42A	ZEEKOEGAT-NOOD	Pollution	Minor	0.112	0.04	0.05

APPENDIX B

MACRO - ECONOMICS

APPENDIX B.1

GRAPHS: GROSS GEOGRAPHIC PRODUCT, LABOUR AND SHIFT-SHARE

APPENDIX B.1
DESCRIPTION OF GRAPHS

DIAGRAM NO	GRAPHIC ILLUSTRATION	DESCRIPTION
	• **Gross Geographic Product:**	
B.1.1	⇨ Contribution by Magisterial District to Lower Vaal Economy, 1997 (%)	Each WMA comprises a number of Magisterial Districts. This graph illustrates the percentage contribution of each MD to the WMA economy as a whole. It shows which are the most important sub-economies in the region.
B.1.2	⇨ Contribution by sector to National Economy, 1988 and 1997 (%)	This graph illustrates the percentage contribution of each sector in the WMA economy, e.g. agriculture, to the corresponding sector in the national economy.
	• **Labour Force Characteristics:**	
B.1.3	⇨ Composition of Lower Vaal Labour Force 1994 (%)	The total labour force may be divided into three main categories, namely formal employment, informal employment and unemployment, as outlined in this graph.
B.1.4	⇨ Contribution by Sector to Lower Vaal Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.1.5	⇨ Contribution by Sectors of Lower Vaal Employment to National Sectoral Employment, 1980 and 1994 (%)	Similar to the production function (i.e. GGP), this graph illustrates the percentage contribution of each sector in the WMA economy, e.g. mining, to the corresponding sector in the national economy.
B.1.6	⇨ Compound Annual Employment Growth by Sector of Lower Vaal versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
	• **Shift-Share:**	
B.1.7	⇨ Shift-Share Analysis, 1997	Compares the contribution of each sector in the WMA economy to its recent growth performance. This serves as an instrument to identify sectors of future importance (towards top right hand side of the graph) and sectors in distress (towards the bottom left hand side of the graph).

DIAGRAM B.1.1: CONTRIBUTION BY MAGISTERIAL DISTRICT TO MIDDLE VAAL ECONOMY, 1997 (%)

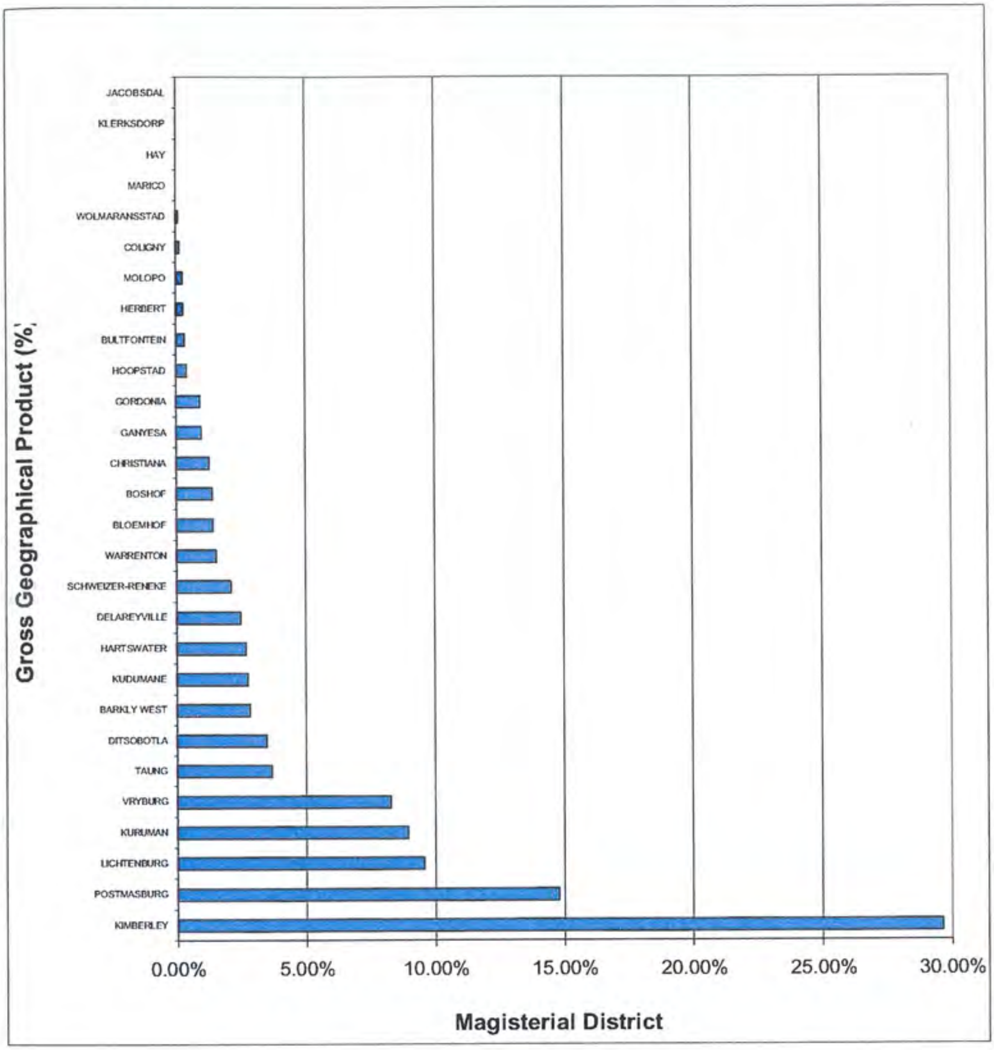


DIAGRAM B.1.2: CONTRIBUTION BY SECTOR TO NATIONAL ECONOMY, 1988 AND 1997 (%)

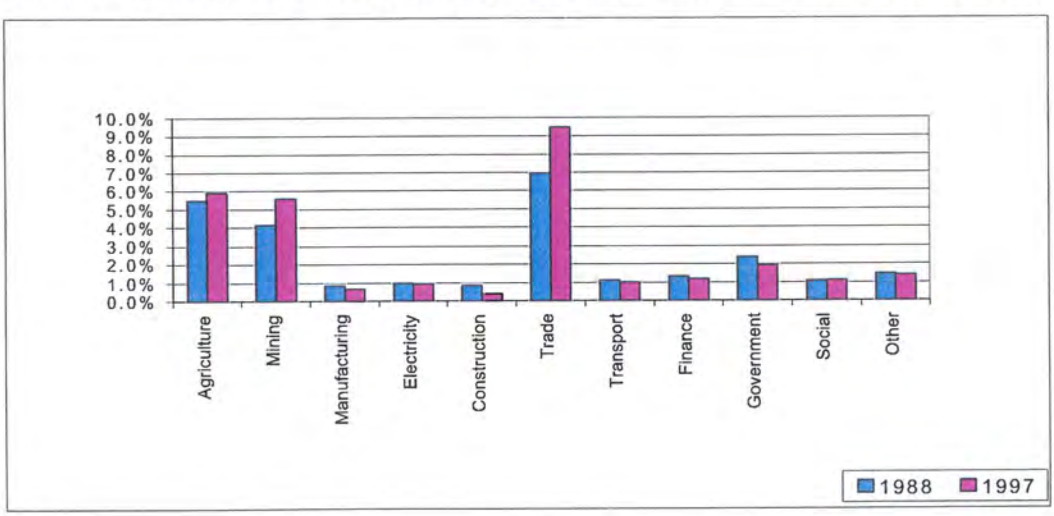


DIAGRAM B.1.3: COMPOSITION OF MIDDLE VAAL LABOUR FORCE, 1994 (%)

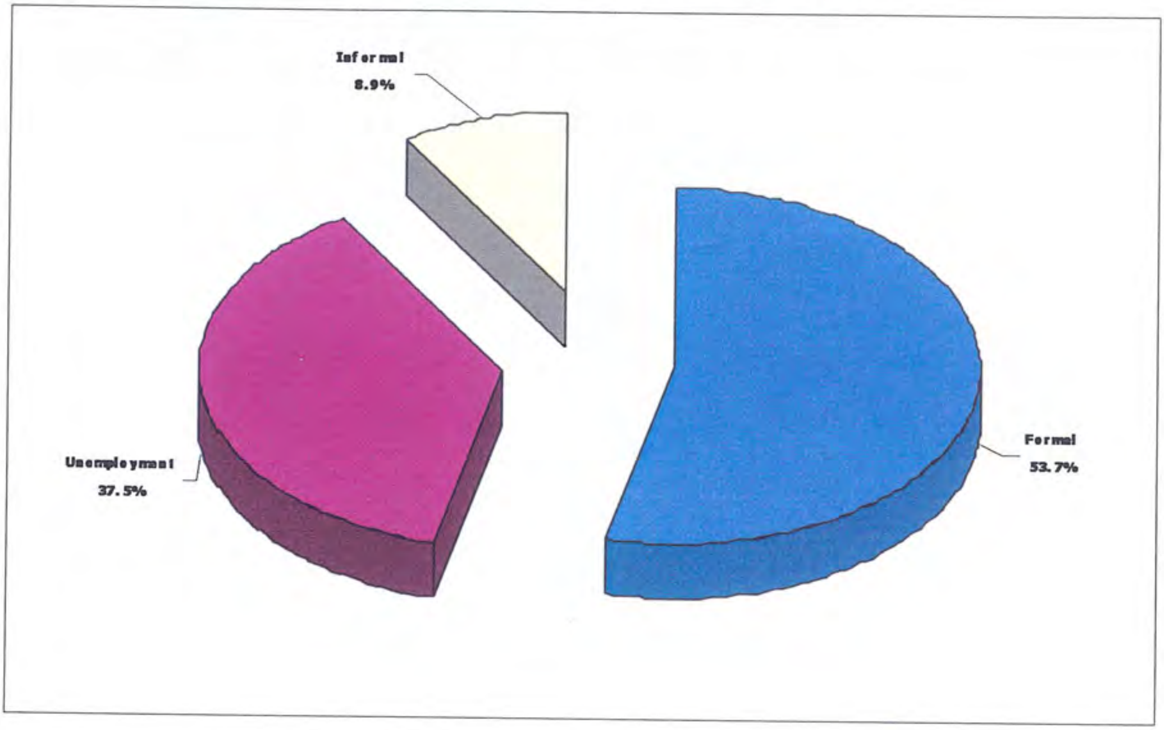


DIAGRAM B.1.4: CONTRIBUTION BY SECTOR TO MIDDLE VAAL EMPLOYMENT, 1980 AND 1994(%)

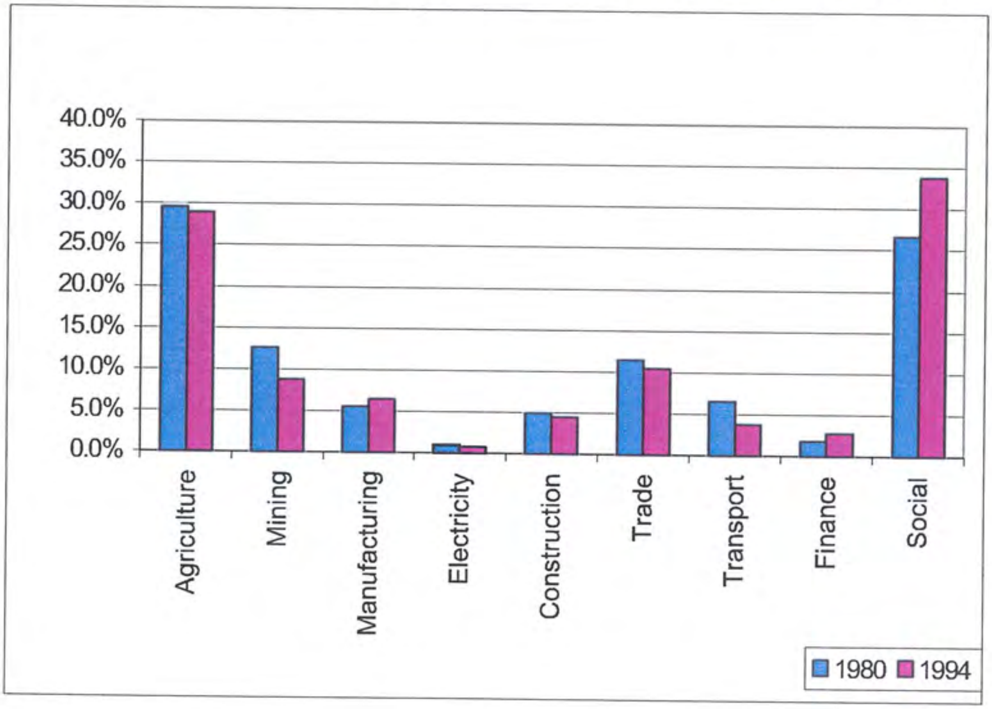


DIAGRAM B.1.5 CONTRIBUTION BY SECTORS OF MIDDLE VAAL EMPLOYMENT TO NATIONAL SECTORAL EMPLOYMENT, 1980 AND 1994 (%)

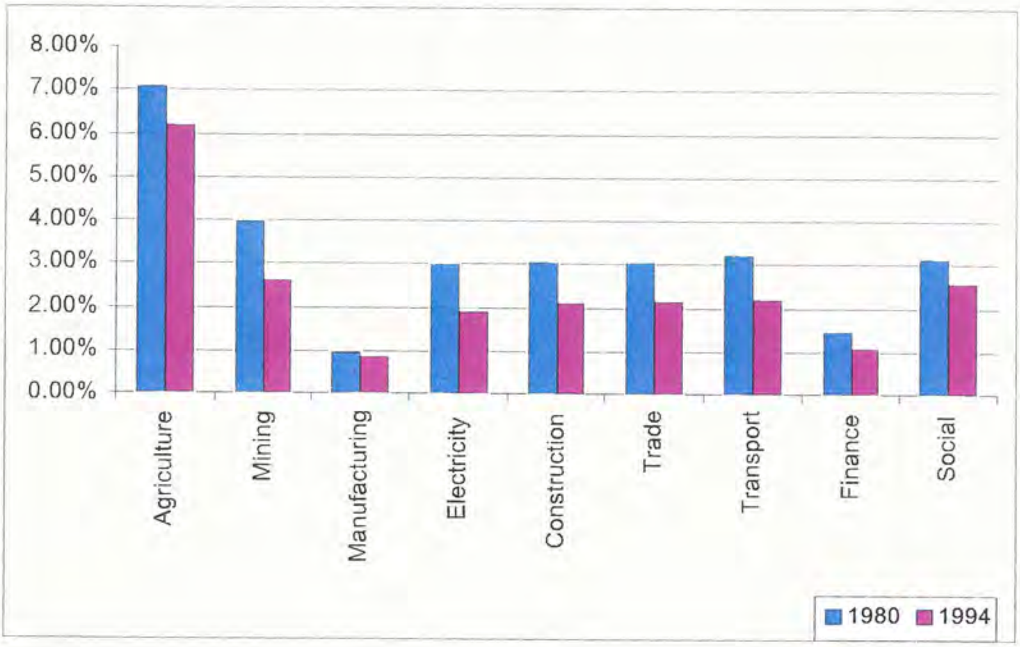


DIAGRAM B.1.6: AVERAGE ANNUAL EMPLOYMENT GROWTH BY SECTOR OF MIDDLE VAAL VERSUS SOUTH AFRICA, 1980 TO 1994 (%)

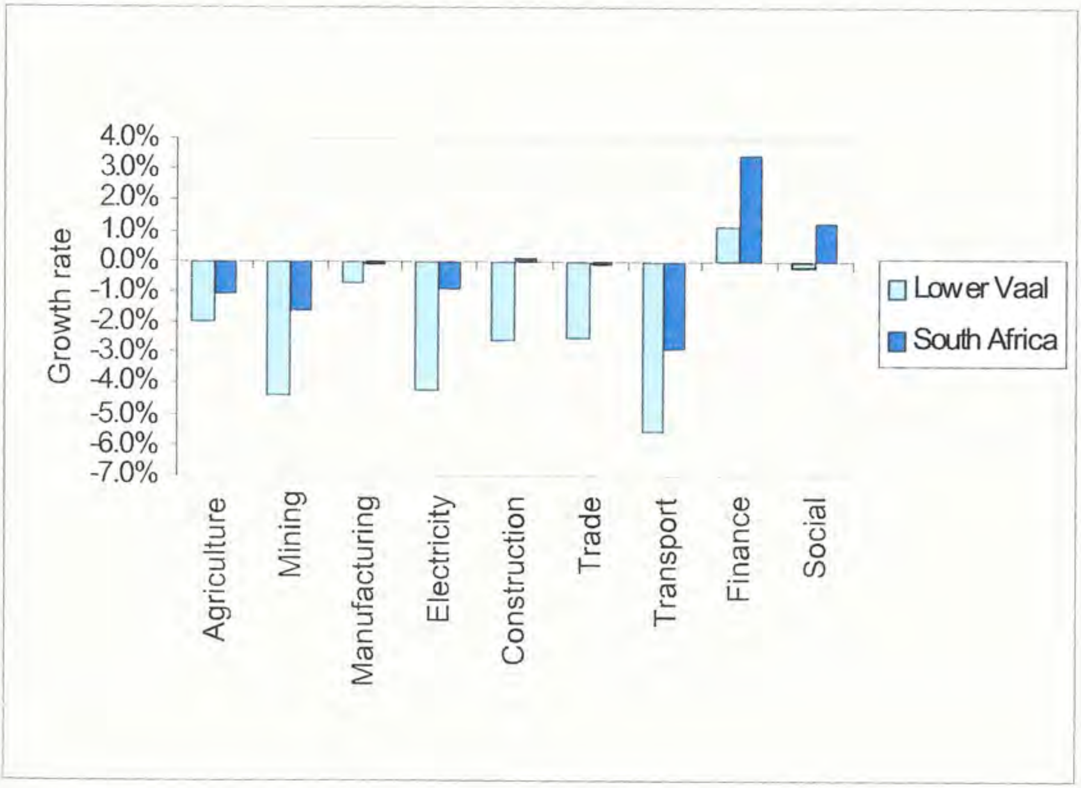
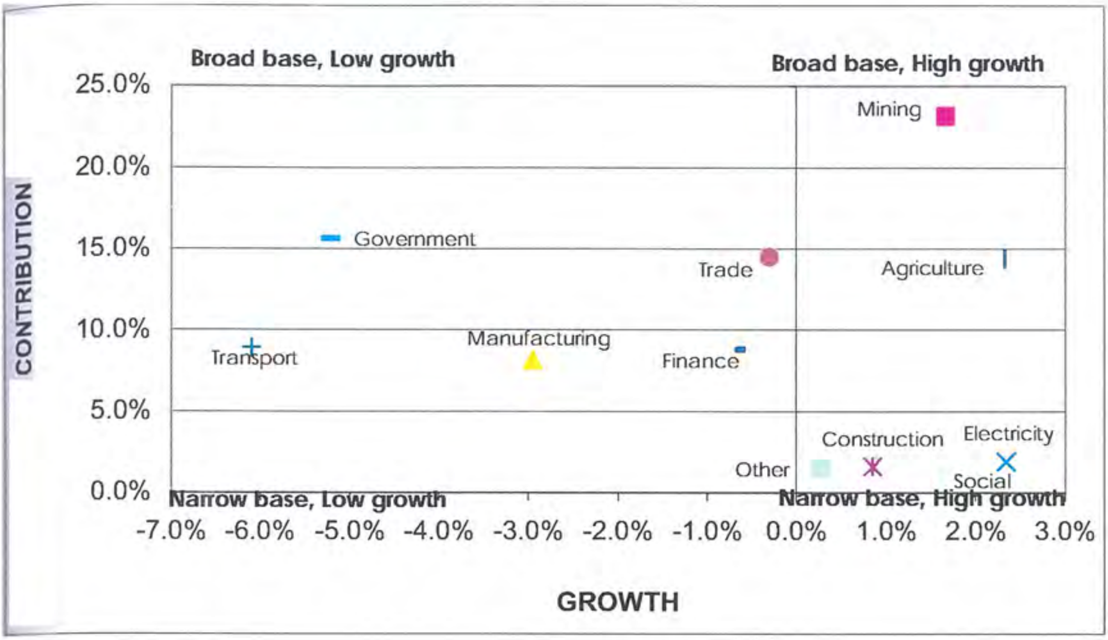


DIAGRAM B.1.7: SHIFT-SHARE ANALYSIS (%)



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B2: WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

1 INTRODUCTION

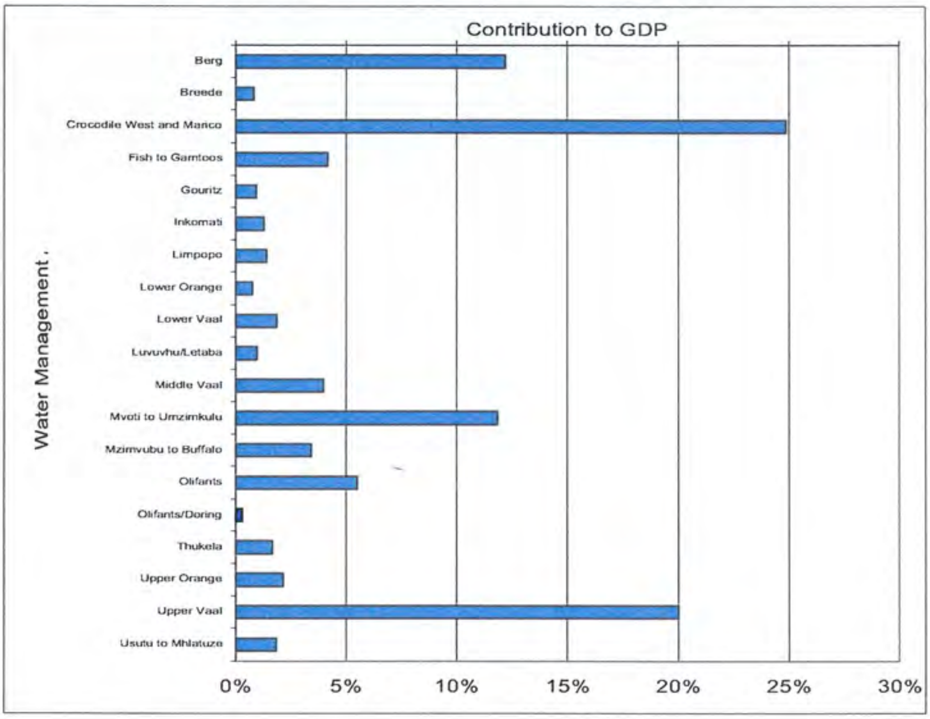
The purpose of this appendix is to illustrate the relative importance of the nineteen different water management areas (WMAs) in South Africa. The following aspects are outlined:

- Contribution by WMA to national economy
- Contribution by WMA to formal employment
- Economic growth by WMA.

2 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL ECONOMY

- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.
- The second largest WMA to the national economy, is the Upper Vaal, which contributes 16.6% to GDP. This WMA comprises mainly portions of Johannesburg, Vereeniging and Vanderbijlpark.
- The Berg WMA contributes 11.25% to the GDP of the national economy and comprises mainly the Cape Metropolitan Area (CMA).
- Mvoti to Umzimkulu WMA makes the fourth largest contribution of 10.72% to the GDP of the national economy. This WMA includes the Durban-Pinetown Metropolitan Area.

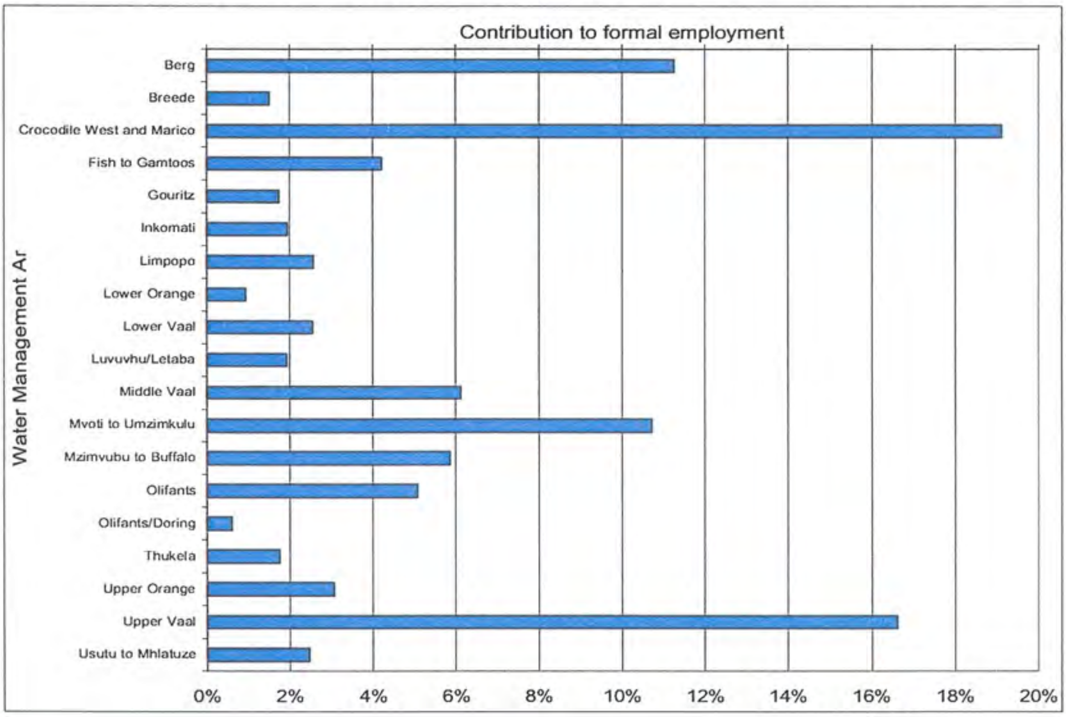
DIAGRAM B.2.1: TOTAL GGP BY WATER MANAGEMENT AREA (% OF COUNTRY)



3 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL EMPLOYMENT

- Contribution to formal employment corresponds to economic production and is mainly concentrated in the four dominant WMAs.

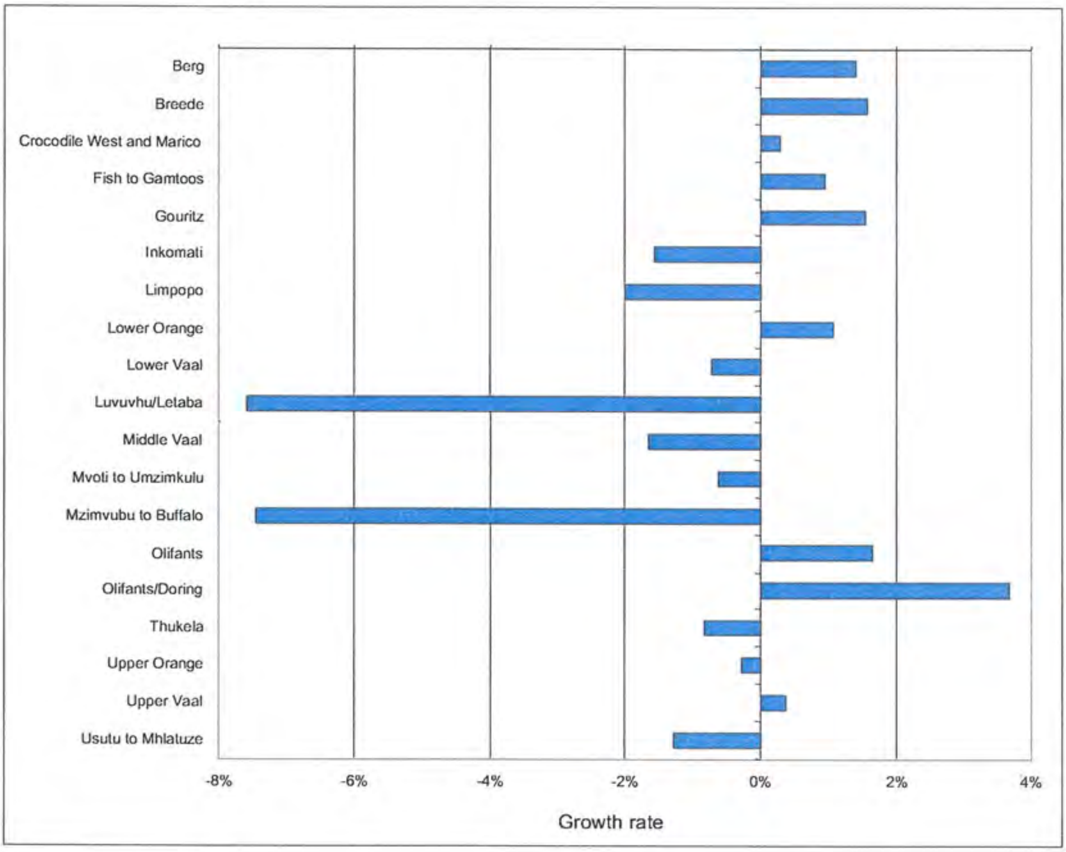
DIAGRAM B.2.2: FORMAL EMPLOYMENT BY WATER MANAGEMENT AREA (% OF COUNTRY)



4 ECONOMIC GROWTH BY WATER MANAGEMENT AREA

- In terms of economic growth, three of the dominant four WMAs recorded positive economic growth between 1988 and 1997: the Berg grew at 1.4% per annum, Crocodile West and Marico at 0.28% per annum and Upper Vaal at 0.36% per annum. Marginal negative growth was recorded over the nine year period in the Mvoti to Umzimkulu WMA: -0.62% per annum.

DIAGRAM B.2.3: AVERAGE ANNUAL ECONOMIC GROWTH BY WATER MANAGEMENT AREA, 1988-1997 (%)



APPENDIX B.3
ECONOMIC SECTOR DESCRIPTION

B3: ECONOMIC INFORMATION SYSTEM for Department of Water Affairs and Forestry

1. BACKGROUND

The Economic Information System was developed for the Department of Water Affairs and Forestry due to a need for a comprehensive source of readily available economic data that can be utilised as a management tool for decision making.

Relevant information required for planning the allocation and utilisation of scarce resources such as water has always been a difficult process due to:

- **inaccessibility of information**
- **incompatibility of information**
- **lack of a reference framework for analysis**

The purpose of the Economic Information System was thus to combine all readily available economic information into a single computer package that would be readily accessible, easy to use and could be distributed without restrictions.

2. THE SYSTEM

The characteristics of the Economic Information System can be summarised as follows:

- Provides immediate access to a comprehensive economic database.
- Stand alone software programme that can be loaded onto a personal computer.
- System provides not only the existing data but also allows first degree transformation of data both geographically and functionally.
- Allows multidimensional access and presentation of information, that is, on a sectoral, geographical and functional basis.
- Provides time series information to enable users to determine trends and make projections.

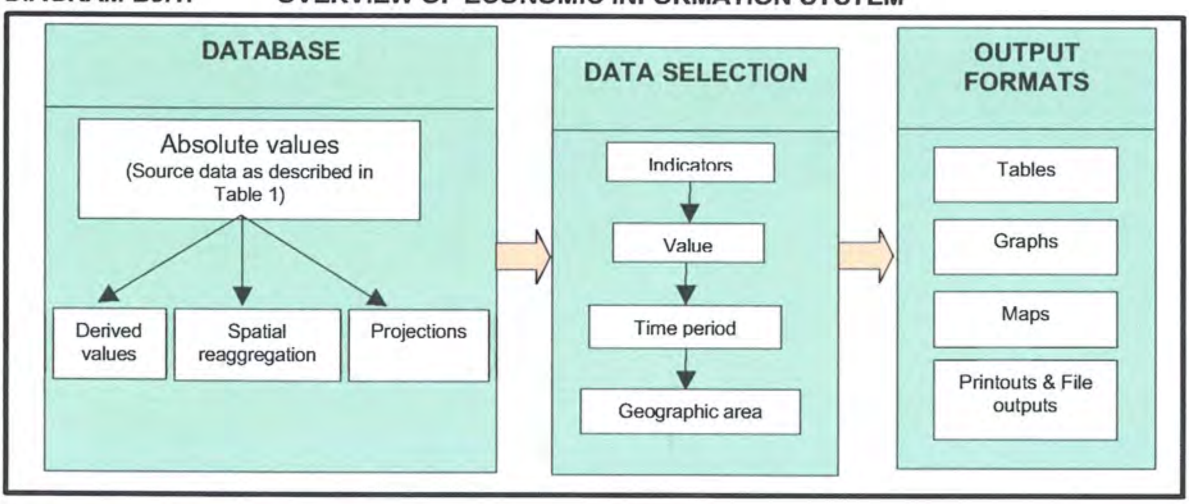
As part of the study, Urban-Econ collected the following economic data from a range of secondary sources. A prerequisite was that the data must be able to be freely distributed. This thus precluded certain sources, such as the 1996 population census. A summary of the data collected and included in the DWAF EIS is provided in Table B3.1.

TABLE B3.1: ECONOMIC INFORMATION COLLATED

Indicator	Time series	Geographic level available				Included in EIS
		Local Council	Magisterial District	District Council	Other	
Gross geographic Product (GGP)	1972,1975, 1978, 1981, 1984, 1988, 1991, 1993, 1994		✓			✓
Labour distribution	1980, 1991, 1994		✓			✓
Electricity consumption and connections	1988 – 1997	✓		✓	✓	✓
Services Council Levies	1993 – 1998		✓			✓
Buildings completed	1991 – 1996	✓		✓		✓
Telephone connections	1998		✓			✓
	1976 - 1997				✓	
Vehicle sales	1980 – 1997				✓	✓
Tax revenue	1992 -1997				✓	

The above information has been incorporated into the EIS, which provides a convenient means to query the database, perform basic economic analysis and projection functions and present the results. An overview of the EIS is provided in Diagram B3.1.

DIAGRAM B3.1: OVERVIEW OF ECONOMIC INFORMATION SYSTEM



The main features of the system include:

- ❑ incorporates all compatible data collected for the DMS;
- ❑ allows access to all indicators;
- ❑ provides background information on each indicator;
- ❑ determines percentage contributions and annual growth rates;
- ❑ calculates location quotients;
- ❑ allows projections of indicators;
- ❑ calculates ratios between two different variables;
- ❑ provides tools for spatial reaggregation;
- ❑ displays outputs in the form of tables, graphs and maps;

- allows outputs to be printed or saved as a file for further analysis.

On-line documentation is provided which gives information on:

- The definition of an indicator
- How the figures were obtained
- How reliable the figures are
- How complete the figures are
- To what detail the figures are available
- What the relevance or limitations of the figures are for analytical purposes.

3. EXAMPLES OF UTILISATION

- A user can select a main area for analysing the spatial variations of an indicator. Within that area, any level of geographic detail, i.e. magisterial district level or town level in the case of data relating to a local authority area can be assessed.
- It is possible to compare changes over time between different areas. This may indicate whether patterns of economic activity are changing, for example that it is growing in one area and declining in another area, which will have an impact on, for example, human settlement and the demand for water.
- A user can select more than one indicator to ascertain how the trends of the different indicators are correlated in different areas or over time. If indicators are correlated, there may be a causal relationship between the two, or it may reveal that changes in both indicators are a consequence of some other factor. If these causal relationships can be determined, it may also become known whether the causal factors are changing permanently or temporarily, which will inform the user whether there should be a long-term planning response or not.

APPENDIX B.4
ECONOMIC INFORMATION SYSTEM

B4: ECONOMIC SECTOR DESCRIPTION

A description of each of the major economic sectors is provided below:

- **Agriculture:** This sector includes agriculture, hunting and related services. It comprises activities such as growing of crops, market gardening, horticulture, mixed farming, production of organic fertiliser, forestry, logging and related services and fishing, operation of fish hatcheries and fish farms.
- **Mining:** This section entails the mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore, etc); extraction of crude petroleum and natural gas, service activities incidental to oil and gas extraction; stone quarrying; clay and sand pits; and the mining of diamonds and other minerals.
- **Manufacturing:** Manufacturing includes, inter alia, the manufacturing of food products, beverages and tobacco products; production, processing and preserving of meat, fish, fruit, vegetables, oils and fats, dairy products and grain mill products; textile and clothing; spinning and weaving; tanning and dressing of leather; footwear; wood and wood products; paper and paper products; printing and publishing; petroleum products; nuclear fuel; and other chemical substances.
- **Electricity, Water and Gas:** Utilities comprise mainly three elements, namely electricity, water and gas. The services rendered to the economy include the supply of electricity, gas and hot water, the production, collection and distribution of electricity, the manufacture of gas and distribution of gaseous fuels through mains, supply of steam and hot water, and the collection, purification and distribution of water.
- **Construction:** This sector includes construction; site preparation building of complete constructions or parts thereof; civil engineering; building installation; building completion; and the renting of construction or demolition equipment with operators all form part of the construction sector.
- **Trade:** Trade entails wholesale and commission trade; retail trade; repair of personal household goods; sale, maintenance and repair of motor vehicles and motor cycles; hotels, restaurants, bars canteens, camping sites and other provision of short-stay accommodation.
- **Transport:** The transportation sector comprises land transport; railway transport; water transport; transport via pipelines; air transport; activities of travel agencies; post and telecommunications; courier activities; and storage.
- **Business and Financial Services:** The economic activities under this category include, inter alia, financial intermediation; insurance and pension funding; real estate activities; renting of transport equipment; computer and related activities; research and development; legal; accounting, book-keeping and auditing activities; architectural, engineering and other technical activities; and business activities not classified elsewhere.
- **Government and Social services (Community Services)**: This sector includes public administration and defence, social and related community services (education, medical, welfare and religious organisations), recreational and cultural services and personal and household services.
- **Other:** Private households, extraterritorial organisations, representatives of foreign governments and other activities not adequately defined.

APPENDIX C

HYDROLOGY

HYROLOGICAL DATA

Quaternary catchment	Cactment area km2	Mean annual precipitation mm/a	Mean annual evaporation mm/a	Natual mean annual runoff (incremental) million m3/a	Natual mean annual runoff (accumulative) million m3/a
C31A	1402	577	1860	10.25	10.25
C31B	1743	553	1900	9.58	19.83
C31C	1635	566	1900	10.25	30.08
C31D	1494	530	1925	6.23	6.23
C31E	2960	506	1930	15.73	52.04
C31F	1789	477	1960	6.92	58.96
C32A	1405	449	1970	7.10	7.10
C32B	3002	434	2000	13.14	20.24
C32C	1658	460	1960	9.28	9.28
C32D	4140	442	2050	19.17	48.69
C33A	2859	432	2070	15.13	122.80
C33B	2835	422	2100	13.66	136.40
C33C	4149	397	2150	11.37	147.80
C91A	2546	464	1940	4.75	3315.00
C91B	4679	433	1950	6.41	3322.00
C91C	3135	430	1880	6.90	6.90
C91D	2697	397	2050	4.22	3333.00
C91E	1509	371	2140	1.82	3335.00
C92A	3923	367	2250	13.91	3496.00
C92B	1979	331	2225	5.02	3908.00
D41B	6164	443	1950	12.11	39.21
D41C	3919	396	2050	4.54	47.65
D41D	4380	380	2050	4.16	51.81
D41E	4497	334	2250	2.23	67.84
D41F	6011	332	2250	2.89	70.73
D41G	4312	366	2200	5.93	5.93
D41H	8657	324	2250	3.66	9.59
D41J	3878	358	2350	4.85	4.85
D41K	4216	344	2350	4.43	9.28
D41L	5383	391	2250	9.80	9.80
D41M	2628	305	2400	1.61	20.69
D42C	18110	216	2700	7.78	123.00
D42D	1621	151	2750	0.12	0.12
D73A	3238	323	2450	47.20	47.20
D73B	186	258	2450	0.00	0.00
D73C	3795	230	2450	18.30	18.30
D73D	429	185	2650	0.00	0.00
D73E	387	183	2650	0.00	0.00
Z10B	52280	228.8	2250	13.00	13.00
Z10C	3332	308.7	1950	3.90	43.11
Z10D	1701	228.8	2250	0.80	52.61
Z10E	44780	110.7	2900	9.60	9.60
Z10F	10720	201.5	2250	4.60	84.92
TOTAL	246163			352	

Notes

1 All shaded areas indicate values changed from those of the WSAM database

2 Surface areas and runoff apportioned

APPENDIX D

WATER ALLOCATIONS

ALLOCATIONS FROM THE VAAL-GAMAGARA GWS

User group	Amount allocated	Use
GJ Hoon (Yorks Handelshuis)	1,080	Domestic and stockwatering
SAS Administrasie – Hotazel (York Str)	19,440	Domestic and stockwatering
SAS Administrasie (Mamathwane Stasie)	4,800	Domestic and stockwatering
Mev GC Maritz (Rest Ged van Halifora)	4,500	Domestic and stockwatering
Mev GC Maritz (Chertsey)	4,500	Domestic and stockwatering
Mev GC Maritz (Elliesrus Ged 1 van Walton)	4,500	Domestic and stockwatering
SAS&H (Carter Block) (Silver Stream)	8,400	Domestic and stockwatering
Dept van Landbou (Koopmansfontein)	45,000	Domestic and stockwatering
Evkom	960	Domestic and stockwatering
PJ Swanepoel	20	Domestic and stockwatering
Mnr AB Cilliers	400	Domestic and stockwatering
Mnr JL Reynecke	1,200	Domestic and stockwatering
HJ Lamprecht	3,600	Domestic and stockwatering
JW Pretorius	3,600	Domestic and stockwatering
CJ van der Westhuizen	3,600	Domestic and stockwatering
CJ van der Westhuizen	3,600	Domestic and stockwatering
JH Theron	150	Domestic and stockwatering
CMGM Transvaal (Pty) Ltd	900	Domestic and stockwatering
PJ van den Berg	2,190	Domestic and stockwatering
CH Poolman	2,500	Domestic and stockwatering
Content Boerdery (MSE Doman)	3,650	Domestic and stockwatering
AWA Botma	3,600	Domestic and stockwatering
Koopmans Algemene Handelaar Mev. ME Combrink	1,200	Domestic and stockwatering
FH Swanepoel (Tafelkop)	1,500	Domestic and stockwatering
TA Burger	1,700	Domestic and stockwatering
HJ Steyn	3,650	Domestic and stockwatering
D+DH Fraser (Bpk) G van W Gagiano)	3,650	Domestic and stockwatering
Yskor Utiliteitswinkels: Onverwacht	2,800	Domestic and stockwatering
PJ Ludick	1,000	Domestic and stockwatering
JG van Zyl	3,600	Domestic and stockwatering
Mnr TR Terry	150	Domestic and stockwatering
Mnr RA Gous	1,000	Domestic and stockwatering
Mnr T Steyn	200	Domestic and stockwatering
Mnr JJP Spangenberg	200	Domestic and stockwatering
EC Langeveld	100	Domestic and stockwatering
JP Muller	120	Domestic and stockwatering
JL Reynecke	1,296	Domestic and stockwatering
RE Combrinck	1,000	Domestic and stockwatering
PJ van der B Lambrechts	200	Domestic and stockwatering
GJ Riecketts	250	Domestic and stockwatering
Ferroland Grondtrust	1,643	Domestic and stockwatering
Yskor (Sishen-Ystermyn)	7,200	Domestic and stockwatering
PH Mason	2,450	Domestic and stockwatering
N Fourie	3,500	Domestic and stockwatering
HJ Uys	1,000	Domestic and stockwatering
DF Marais	230	Domestic and stockwatering
J van der Merwe	3,600	Domestic and stockwatering
GP du Plessis	6,480	Domestic and stockwatering
WC van Zyl	1,800	Domestic and stockwatering
JJ Appelgryn	2,920	Domestic and stockwatering
TCB Vermeulen	1,290	Domestic and stockwatering
FE Jacobs	2,430	Domestic and stockwatering
JB le Grange	2,430	Domestic and stockwatering

JC Kruger	2,700	Domestic and stockwatering
HS Boerdery	3,240	Domestic and stockwatering
NGJ Markram	6,480	Domestic and stockwatering
AWA Maritz	4,500	Domestic and stockwatering
MA Kruger	6,480	Domestic and stockwatering
H Markram	5,364	Domestic and stockwatering
MJA Pretorius	2,000	Domestic and stockwatering
RJC Engel	330	Domestic and stockwatering
S Kloppers	2,600	Domestic and stockwatering
EE Reynecke	15,000	Domestic and stockwatering
JP de V Jansen	2,482	Domestic and stockwatering
AWA Maritz	3,285	Domestic and stockwatering
Yskor Prospekteerwerke (M Carney)	650	Domestic and stockwatering
I de Jager	30	Domestic and stockwatering
Yskor Plase	6,570	Domestic and stockwatering
AW Fourie	1,642	Domestic and stockwatering
CAJ Victor	6,570	Domestic and stockwatering
Rockies Drankwinkel	200	Domestic and stockwatering
CH Kotze	460	Domestic and stockwatering
CAJ Victor	6,570	Domestic and stockwatering
Kameelfontein Boerdery	4,927	Domestic and stockwatering
Langeberg Stene	10,000	Domestic and stockwatering
Mev GC Maritz	1,642	Domestic and stockwatering
Mnr AW Fourie	6,570	Domestic and stockwatering
Mnr JG Shaw	6,898	Domestic and stockwatering
JS Marais (Kameelfontein Boerdery)	5,256	Domestic and stockwatering
JS Marais (Kameelfontein Boerdery)	1,752	Domestic and stockwatering
Mnr AJ de Klerk	4500	Domestic and stockwatering
Samancor	750,000	Industrial
Tunnelcrete	6,000	Industrial
Ferroland Grond Trust (Edms) Bpk	9,600	Industrial
Kapstewel Enterprises	50,400	Industrial
Samancor Limited	40,000	Industrial
SAL Gevegsform	900,000	Industrial
FE Jacobs (Poen's Garage)	20,000	Industrial
Ferroland Trust	10000	Industrial
SAS&H Koopmansfonteinstasie	7,296	Industrial
Middelplaas Monganese	476,004	Mining
De Beers Consolidated Mines (Finsch Myn)	5,840,000	Mining
Associated Manganese Mines of SA Ltd (Devon)	72,000	Mining
Associated Manganese Mines (Gloria 2)	420,000	Mining
Associated Manganese Mines (Black Rock)	960,000	Mining
Associated Manganese Mines (Beeshoek)	1,200,000	Mining
Associated Manganese Mines (Gloria)	420,000	Mining
SA Mangaan Amcor BPk (Lohatla)	36,500	Mining
SA Mangaan Amcor Bpk Wessels 227	150,000	Mining
SA Mangaan Amcor Bpk (Manatwana)	300,000	Mining
The Associated Manganese Mines	1,200,000	Mining
The Associated Manganese Mines	100,000	Mining
De Beers Consolidated Mines Ltd (Finsch Mine)	2,500,000	Mining
Munisipaliteit Olifantshoek	2,300,000	Local Government
Kalahari Oos Waterraad	1,800,000	Local Government
Delportshoop Munisipaliteit	1,298	Local Government
(Vaal Gamagara) Streeksdiensteraad Kalahari	40,000	Local Government

APPENDIX E

WATER USE

URBAN DATA

Quaternary catchment	Direct urban use	Indirect urban use	Bulk loss factor	Distribution loss factor	Total losses	Total urban water use	Total return flows	Increased runoff due to urban areas	Return flows generated in the catchment	Urban population
	million m3/a	million m3/a	Factor	Factor	million m3/a	million m3/a	million m3/a	million m3/a	million m3/a	Number
C31A	2.010	1.317	0.080	0.125	0.731	4.058	0.000	0.000	0.000	61750
C31B	0.214	0.081	0.050	0.125	0.098	0.394	0.000	0.000	0.000	7100
C31C	0.242	0.092	0.050	0.125	0.111	0.446	0.000	0.000	0.000	11200
C31D	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
C31E	0.122	0.047	0.050	0.125	0.056	0.225	0.000	0.000	0.000	1850
C31F	0.266	0.187	0.080	0.125	0.176	0.628	0.000	0.000	0.000	29200
C32A	0.089	0.035	0.050	0.125	0.041	0.165	0.000	0.000	0.000	1100
C32B	3.071	0.767	0.080	0.125	0.843	4.681	0.000	0.000	0.000	34000
C32C	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
C32D	0.052	0.020	0.080	0.125	0.028	0.099	0.000	0.000	0.000	9400
C33A	2.379	1.396	0.080	0.125	1.468	5.243	0.000	0.000	0.000	47350
C33B	0.081	0.032	0.050	0.125	0.020	0.133	0.000	0.000	0.000	2450
C33C	0.136	0.053	0.050	0.125	0.063	0.251	0.000	0.000	0.000	1900
C91A	0.966	0.367	0.080	0.125	0.293	1.626	0.000	0.000	0.000	13950
C91B	0.655	0.250	0.080	0.125	0.352	1.257	0.000	0.000	0.000	21050
C91C	0.187	0.073	0.050	0.125	0.046	0.306	0.000	0.000	0.000	5550
C91D	0.847	0.322	0.080	0.125	0.455	1.624	0.000	0.000	0.000	23400
C91E	10.610	5.650	0.080	0.125	3.814	20.070	0.000	0.000	0.000	204000
C92A	0.756	0.287	0.080	0.125	0.406	1.450	0.000	0.000	0.000	18900
C92B	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41B	0.489	0.188	0.050	0.125	0.226	0.903	0.333	0.000	0.000	17600
D41C	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41D	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41E	0.017	0.007	0.050	0.125	0.008	0.031	0.014	0.000	0.000	400
D41F	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41G	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41H	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D41J	2.452	0.932	0.050	0.125	0.597	3.980	2.003	0.000	0.000	14950
D41K	0.198	0.075	0.050	0.125	0.091	0.364	0.132	0.000	0.000	4700
D41L	2.113	0.318	0.050	0.125	0.811	3.242	1.438	0.000	0.000	22700
D41M	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D42C	0.010	0.004	0.050	0.125	0.005	0.019	0.000	0.000	0.000	250
D42D	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D73A	1.018	0.744	0.050	0.125	0.587	2.349	1.053	0.000	0.000	18650
D73B	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D73C	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D73D	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
D73E	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
Z10B	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
Z10C	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
Z10D	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
Z10E	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
Z10F	0.000	0.000	0.050	0.125	0.000	0.000	0.000	0.000	0.000	0
TOTAL	28.979	13.243	2.450	5.375	11.324	53.542	4.973	0.000	0.000	573400

Notes

1 All shaded areas indicate values changed from those of the WSAM database

2 Urban use in D73D and D73E assumed to be in Lower Orange

3 It is assumed that there is no increase in runoff due to urban areas

4 Return flows from this WMA are assumed to be effectively zero.

IRRIGATION DATA

Quaternary catchment	Area under high category crops	Area under low category crops	Area under medium category crops	Green cover area	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Total water use by irrigators	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops
	km2	km2	km2	km2	Factor	Factor	Factor	million m3/a	Factor	Factor	Factor
C31A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31E	0.05	0.84	0.11	0.96	0.25	0.25	0.25	1.17	0.79	0.79	0.79
C31F	0.00	1.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32D	0.00	35.70	0.00	64.24	0.00	0.25	0.00	11.29	0.00	0.79	0.00
C33A	0.00	396.20	0.00	320.33	0.25	0.25	0.25	353.90	0.79	0.79	0.79
C33B	0.00	0.00	0.00	0.00	0.25	0.25	0.25	68.60	0.79	0.79	0.79
C33C	0.00	20.10	0.00	16.63	0.20	0.20	0.20	56.28	0.79	0.79	0.79
C91A	0.00	19.80	0.00	17.60	0.10	0.10	0.10	13.91	0.80	0.80	0.80
C91B	0.00	39.70	0.00	35.20	0.10	0.10	0.10	29.70	0.80	0.80	0.80
C91C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91D	0.00	0.00	2.00	0.00	0.10	0.10	0.10	18.19	0.79	0.79	0.79
C91E	0.00	80.40	0.00	65.41	0.10	0.10	0.10	18.29	0.79	0.79	0.79
C92A	0.00	0.00	0.00	0.00	0.10	0.10	0.10	18.06	0.79	0.79	0.79
C92B	0.00	0.00	0.00	0.00	0.10	0.10	0.10	18.42	0.79	0.79	0.79
D41B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41D	0.00	0.00	6.40	6.40	0.00	0.00	0.10	1.83	0.00	0.00	0.80
D41E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41H	0.00	0.00	16.10	16.10	0.00	0.00	0.10	4.73	0.00	0.00	0.80
D41J	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41L	0.00	0.00	1.20	1.20	0.00	0.00	0.00	0.31	0.00	0.00	0.65
D41M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D42C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D42D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73C	0.00	0.00	0.00	0.00	0.15	0.15	0.15	0.00	0.70	0.70	0.70
D73D	0.00	0.00	0.00	0.00	0.15	0.15	0.15	0.00	0.70	0.70	0.70
D73E	0.00	0.00	0.00	0.00	0.15	0.15	0.15	0.00	0.70	0.70	0.70
Z10B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.05	593.74	25.81	545.27				614.68			

Notes

1. All shaded areas indicate values changed from those of the WSAM database
2. Irrigation in D73C, D and E assumed to be in Lower Orange WMA
3. The breakdown of crops into high, low and medium categeory crops and into quaternary catchments is not accurate. However, this does not affect the water use by irrigation which is known from on-site recordings

BULK DATA

Quaternary catchment	On-site water use (strategic) million m3/a	On-site water use (mining) million m3/a	On-site water use (other) million m3/a	Loss factor (strategic) Factor	Loss factor (mining) Factor	Loss factor (other) Factor	Strategic water use million m3/a	Mining water use million m3/a	Other water use million m3/a	Return flow (strategic) million m3/a	Return flow (mining) million m3/a	Return flow (other) million m3/a	Return flow factor (mining) Factor	Return flow factor (other) Factor	Retrun flow factor (strategic) Factor	Groundwater decant/mine dewatering million m3/a
C31A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31E	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C31F	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C33A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C33B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C33C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C91E	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C92A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C92B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41B	0.00	0.50	0.00	0.05	0.10	0.10	0.00	0.55	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00
D41C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41E	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41F	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41G	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41H	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41J	0.00	1.00	0.75	0.05	0.10	0.10	0.00	1.10	0.83	0.00	0.30	0.15	0.00	0.00	0.00	0.00
D41K	0.00	3.00	0.00	0.05	0.10	0.10	0.00	3.30	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00
D41L	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D41M	0.00	0.30	0.00	0.05	0.10	0.10	0.00	0.33	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
D42C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D42D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73A	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73B	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73C	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D73E	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10D	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10E	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z10F	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0	5	0.75				0	5	0.83	0.00	1.44	0.15				0.00

RURAL DATA

Quaternary catchment	Rural population	Number of large stock units	Rural water consumption rate	Large stock units comsumption rate	Subsistance irrigation	Total rural water use	Rural loss factor	Rural return flow
	Number	Number	l/c/day	l/c/day	million m3/annum	million m3/annum		million m3/annum
C31A	7672	29700	25	45	0.00	0.70	0.2	0
C31B	11530	42630	25	45	0.00	1.01	0.2	0
C31C	9059	39950	25	45	0.00	0.92	0.2	0
C31D	30290	21160	25	45	0.00	0.78	0.2	0
C31E	18800	186900	25	45	0.00	4.06	0.2	0
C31F	43660	161500	25	45	0.00	3.82	0.2	0
C32A	5916	50910	25	45	0.00	1.11	0.2	0
C32B	10760	113500	25	45	0.00	2.46	0.2	0
C32C	6065	118400	25	45	0.00	2.50	0.2	0
C32D	55420	167000	25	45	0.00	4.06	0.2	0
C33A	65680	58800	25	45	0.00	1.96	0.2	0
C33B	19480	31650	25	45	0.00	0.87	0.2	0
C33C	3948	36750	25	45	0.00	0.80	0.2	0
C91A	8178	145200	25	45	0.00	3.08	0.2	0
C91B	24750	139100	25	45	0.00	3.14	0.2	0
C91C	4133	82050	25	45	0.00	1.73	0.2	0
C91D	6316	54010	25	45	0.00	1.18	0.2	0
C91E	7239	16010	25	45	0.00	0.41	0.2	0
C92A	2920	21000	25	45	0.00	0.46	0.2	0
C92B	5399	20050	25	45	0.00	0.47	0.2	0
D41B	110100	38620	35	45	1.01	4.35	0.3	0
D41C	12980	38620	35	45	0.12	1.31	0.3	0
D41D	36300	38620	35	45	- 0.33	2.04	0.3	0
D41E	4933	38620	35	45	0.05	1.06	0.3	0
D41F	30510	38620	35	45	0.28	1.86	0.3	0
D41G	45150	27560	35	45	0.41	2.06	0.3	0
D41H	26900	55340	35	45	0.25	2.14	0.3	0
D41J	1106	24790	35	45	0.01	0.62	0.3	0
D41K	5568	26950	35	45	0.05	0.81	0.3	0
D41L	79280	34410	35	45	0.72	3.29	0.3	0
D41M	1568	16800	35	45	0.01	0.44	0.3	0
D42C	3652	186400	45	45	0.01	3.92	0.2	0
D42D	242	3702	45	45	0.01	0.09	0.2	0
D73A	1833	37550	45	45	0.00	0.81	0.2	0
D73B	0	725	45	45	0.00	0.04	0.2	0
D73C	1825	31824	45	45	0.01	0.75	0.2	0
D73D	0	558	45	45	0.01	0.03	0.2	0
D73E	0	618	45	45	0.02	0.04	0.2	0
Z10B	0	0	30	45	0.00	0.00	0.2	0
Z10C	0	0	30	45	0.00	0.00	0.2	0
Z10D	0	0	30	45	0.00	0.00	0.2	0
Z10E	8000	15000	30	45	0.01	0.43	0.2	0
Z10F	1500	8000	30	45	0.00	0.19	0.2	0
TOTAL	718662	2199597			3.30	61.82		0

Notes

1 All shaded areas indicate values changed from those of the WSAM database
2 Rural population assumed to be zero in D73B, D and E. Apportioned for D42D and D73C
3 Ditto for stock numbers
4 Rural water use based on the above adjustments

APPENDIX E1

CONVERSION OF MATURE LIVESTOCK AND GAME POPULATIONS TO EQUIVALENT LARGE STOCK UNITS (ELSU)

Species	Number per ELSU
Livestock:	
Cattle	0.85
Sheep	6.5
Goats	5.8
Horses	1
Donkeys / mules	1.1
Pigs	4
Game:	
Black Wildebeeste	3.3
Blesbuck	5.1
Blou Wildebeeste	2.4
Buffalo	1
Eland	1
Elephant	0.3
Gemsbok	2.2
Giraffe	0.7
Hippopotamus	0.4
Impala	7
Kudu	2.2
Nyala	3.3
Ostrich	2.7
Red Hartebeest	2.8
Roan Antelope	2
Sable Antelope	2
Southern Reedbuck	7.7
Springbok	10.3
Tsessebe	2.8
Warthog	5
Waterbuck	2.4
Rhinoceros	0.4
Zebra	1.6

APPENDIX F

WATER TRANSFERS

WATER TRANSFERS

From	To	FromSect	ToSector	Description	Max	Actual	Losses
C91B	C32B	SRD	SSU	Transfer from Vaalharts to Vryburg via Pudimoe WTWs	3	2.79	0.07
C91B	C32D	SRD	SSI	Transfer from Vaalharts weir & Vaalharts GWS to Taung Irrigation Scheme [35 700ha]	18.32	18.6	0
C91B	C32D	SRD	SSU	Transfer from Vaalharts weir to Pudimoe TLC via government water supply network	0.14	0.09844	0.07
C91B	C33A	SRD	SSI	Transfer from Vaalharts Weir for Irrigation of Vaalharts north canal area [32000ha]	500	258	0
C91B	C33A	SRD	SSU	Vaalharts transfer from Vaalharts weir to Pampierstad	7.4	5.012	0.21
C91B	C91E	SRD	SSI	Transfer from Vaalharts weir to Vaalharts Barclay canal irrigation area [65 410ha]	34.8	51.4	0
C92A	D41J	SRD	SSM	Vaal-Gamagara transfer to ISCOR	1	1	0
C92A	D41J	SRD	SSO	Vaal-Gamagara transfer to small users and farmers in the area	0.75	0.75	0
C92A	D41J	SRD	SSU	Vaal Gamagara transfer to Olifantshoek TLC	0.3	0.3	0
C92A	D41K	SRD	SSM	Vaal-Gamagara transfer to manganese mines in the area	1.2	1.2	0
D33K	C92B	SRD	SRD	Orange to Vaal transfer from Marksdrift [6m^3/s] for irrigation [Orange-Vaal IB]	18.9	17.95	0.05
D41J	D42C	SRD	SRR	Transfer to the Kalahari East Stockwatering Scheme	1.3	1.3	0
D73E	D42C	SRD	SRR	Karos-Geelkoppan stock watering & rural supply	0.04	0.04	0
D73E	D42C	SRD	SRR	Kalahari West - rural area from Upington municipal potable reservoir	0.25	0.25	0
D73E	D42D	SRD	SRR	Kalahari West - rural area from Upington municipal potable reservoir	0.17	0.17	0

APPENDIX G

WATER QUALITY

Table 2.1.6 Drainage Region D4

Sampling Site	Description	Date from	Date to	Number of observation	Comments
D4H004-Q01	Grootfontein Eye (pipeline) at Valleifontein	1992-08-27	1999-07-26	11	Short
D4H005-Q01	Kuruman Eye at Kuruman	1993-07-14	1999-09-29	32	Good
D4H006-Q01	Kuruman Eye B at Kuruman/ Rensville	1992-02-03	1998-09-24	23	incomplete
D4H007-Q01	Manyeding Eye at Manyeding Reserve	1991-05-02	1999-09-29	40	inconsistent
D4H008-Q01	Klein-Koinig Eye at Kono reserve	1990-01-01	1994-05-26	12	incomplete
D4H009-Q01	Koning eye at Kono reserve	1992-03-13	1999-09-28	33	Short
D4H010-Q01	Bothethelesta Eye at Bothethelesta reserve	1992-09-15	1999-08-04	6	short
D4H011-Q01	Tsineng eye at lower Uruman 83 Tsineng	1992-09-15	1996-01-20	7	Short record
D4H012-Q01		1996-11-14	1999-08-17	82	Good
D4H013-Q01	Molopo river at Rietvallei	1990-06-01	1999-08-04	24	incomplete
D4H014-Q01	Molopo Eye at Mallespoos oog	1992-08-25	1999-08-04	24	Very short
D4H016-Q01	Welgedatch eye at Welgedatch	1990-06-01	1997-08-18	10	incomplete
D4H017-Q01	Olivendraai Eye at Olivendraai	1990-06-01	1999-08-04	22	incomplete
D4H019-Q01	Polfontein Eye at Matlabes loc	1990-01-03	1991-10-03	8	incomplete
D4H020-Q01	Temporary pump Station at Sishen Water Tower	1990-01-04	1996-09-27	38	Good
D4H021-Q01	Iscor Dewatering canal at Sacha	1990-01-01	1999-12-31	0	No record
D4H022-R01	Mafiking treatment- raw Grootfontein	1990-01-30	1998-07-03	54	Good
D4H022-S01	Mafiking treatment- treated water	1990-01-30	1998-04-06	51	Good
D4H026-Q01	Lake(Molopo river) at Mafikeng	1997-10-20	1999-07-27	19	Short
D4H036-R01		1990-01-01	1999-09-27	2	Two records
D4H036-S01		1997-01-20	1997-01-20	1	One record only
D4H037-Q01	Lotlamoreng dam on Molopo river: near dam wall	1995-10-09	1999-07-27	180	Good
D4H039-Q01	Mafikeng treatment works-raw water	1997-01-05	1999-01-28	37	incomplete
D4H039-S01	Mafikeng treatment works-treated water	1997-04-14	1998-02-11	9	Short
D4H004-Q01	Grootfontein Eye (pipeline) at Valleifontein	1992-08-27	1999-07-26	11	Short
D4H005-Q01	Kuruman Eye at Kuruman	1993-07-14	1999-09-29	32	Good
D4H006-Q01	Kuruman Eye B at Kuruman/ Rensville	1992-02-03	1998-09-24	23	incomplete
D4H007-Q01	Manyeding Eye at Manyeding Reserve	1991-05-02	1999-09-29	40	inconsistent
D4H008-Q01	Klein-Koinig Eye at Kono reserve	1990-01-01	1994-05-26	12	incomplete
D4H009-Q01	Koning eye at Kono reserve	1992-03-13	1999-09-28	33	Short
D4H010-Q01	Bothethelesta Eye at Bothethelesta reserve	1992-09-15	1999-08-04	6	short
D4H011-Q01	Tsineng eye at lower Uruman 83 Tsineng	1992-09-15	1996-01-20	7	Short record
D4H012-Q01		1996-11-14	1999-08-17	82	Good
D4H013-Q01	Molopo river at Rietvallei	1990-06-01	1999-08-04	24	incomplete
D4H014-Q01	Molopo Eye at Mallespoos oog	1992-08-25	1999-08-04	24	Very short
D4H016-Q01	Welgedatch eye at Welgedatch	1990-06-01	1997-08-18	10	incomplete
D4H017-Q01	Olivendraai Eye at Olivendraai	1990-06-01	1999-08-04	22	incomplete
D4H019-Q01	Polfontein Eye at Matlabes loc	1990-01-03	1991-10-03	8	incomplete
D4H020-Q01	Temporary pump Station at Sishen Water Tower	1990-01-04	1996-09-27	38	Good

D4H021-Q01	Iscor Dewatering canal at Sacha	1990-01-01	1999-12-31	0	No record
D4H022-R01	Mafiking treatment- raw Grootfontein	1990-01-30	1998-07-03	54	Good
D4H022-S01	Mafiking treatment- treated water	1990-01-30	1998-04-06	51	Good
D4H026-Q01	Lake(Molopo river) at Mafikeng	1997-10-20	1999-07-27	19	Short
D4H036-R01		1990-01-01	1999-09-27	2	Two records
D4H036-S01		1997-01-20	1997-01-20	1	One record only
D4H037-Q01	Lotlamoreng dam on Molopo river: near dam wall	1995-10-09	1999-07-27	180	Good
D4H039-Q01	Mafikeng treatment works-raw water	1997-01-05	1999-01-28	37	incomplete
D4H039-S01	Mafikeng treatment works-treated water	1997-04-14	1998-02-11	9	Short

APPENDIX H

SEDIMENTATION

SEDMENTATION POTENTIAL

KEY AREA	Quaternarty Catchment	WR90	WR90	Sediment yield	25 yr	MAR	%MAR
		sed. yield	catch area		sed. vol.	(net)	
		(t/a)	(km2)	t/km2/a	(Mm3/a)	(Mm3/a)	
					1	2	3 =1 /23
Harts River	C31A	90,000	1402	64	2.462	10.25	24.02
	C31B	72,000	1743	41	1.969	9.58	20.56
	C31C	51,000	1635	31	1.395	10.25	13.61
	C31D	50,000	1494	33	1.368	6.23	21.95
	C31E	104,000	2960	35	2.845	15.73	18.08
	C31F	81,000	1789	45	2.216	6.92	32.02
	Total	448,000	11,023	41	12.25	58.96	20.78
Dry Harts	C32A	41,000	1405	29	1.121	7.1	15.80
	C32B	90,000	3002	30	2.462	13.14	18.73
	C32C	59,000	1658	36	1.614	9.28	17.39
	C32D	181,000	4140	44	4.951	19.17	25.83
	Total	371,000	10,205	36	10.15	48.69	20.84
Vaalharts	C33A	118,000	2859	41	3.228	15.13	21.33
	C33B	112,000	2835	40	3.063	13.66	22.43
	C33C	153,000	4149	37	4.185	11.37	36.81
	Total	383,000	9,843	39	10.48	40.16	26.09
Vaal D/S of Bloemhof	C91A	76,000	2546	30	2.079	4.75	43.76
	C91B	157,000	4679	34	4.294	6.41	66.99
	C91C	229,000	3135	73	6.264	6.9	90.78
	C91D	124,000	2697	46	3.392	4.22	80.37
	C91E	46,000	1509	30	1.258	1.82	69.13
	C92A	126,000	3923	32	3.446	13.91	24.78
	C92B	57,000	1979	29	1.559	5.02	31.06
	Total	815,000	20,468	40	22.29	43.03	51.81
Molopo	D41B	0	6164		0.000	12.11	0.00
	D41C	0	3919		0.000	4.54	0.00
	D41D	0	4380		0.000	4.16	0.00
	D41E	0	4497		0.000	2.23	0.00
	D41F	0	6011		0.000	2.89	0.00
	D41G	0	4312		0.000	5.93	0.00
	D41H	0	8657		0.000	3.66	0.00
	D41J	0	3878		0.000	4.85	0.00
	D41K	0	4216		0.000	4.43	0.00
	D41L	0	5383		0.000	9.8	0.00
	D41M	0	2628		0.000	1.61	0.00
	D42C	0	18110		0.000	7.78	0.00
	D42D	0	16210		0.000	1.21	0.00
	D73A	0	3238		0.000	47.2	0.00
	D73B	0	3721		0.000	26.34	0.00
	D73C	0	6221		0.000	30.07	0.00
	D73D	0	4291		0.000	15.3	0.00
	Total	0	105,836		0.00	184.11	0.00

APPENDIX J

J.1 DATA TYPES AND RESPONSIBLE ORGANISATIONS
J.2 DEFAULT VALUES USED IN THE WRSA REPORTS

APPENDIX J1

Data type	Responsible organisation
Afforestation	CSIR
Alien vegetation	CSIR
Industrial, urban and strategic water use	WRSA consultants
Ground Water	WSM Consulting Engineers
Dams	DWAF
Transfer schemes	WRSA consultants
Run-of-river yields	Arcus Gibb
Population	Markdata
Ecological Reserve	IWR, Prof Hughes
Irrigation - Areas and crop types - Efficiency and losses - Evapotraspiration and crop factors	 WRSA consultant WRSA consultant WRP
Storage-draft-frequency curves	WRP

APPENDIX J2

Default values used in the WRSA reports

PARAMETER	Description	Default value
fBMLi	Mining losses (factor)	0.1
fBOLi	Other industrial losses (factor)	0.1
fBSLi	Strategic losses (factor)	0.05
fIHCi	Irrigation conveyance losses - High category irrigation (factor)	0.1
fIMCi	Irrigation conveyance losses - Medium category irrigation (factor)	0.1
fILCi	Irrigation conveyance losses - Low category irrigation (factor)	0.1
fIPLi	Irrigation efficiency – Low category irrigation (factor)	0.75
iIPMi	Irrigation efficiency – Medium category irrigation (factor)	0.75
iIPHi	Irrigation efficiency – High category irrigation (factor)	0.75
oRTLi	Rural losses (factor)	0.2

APPENDIX K

GROUNDWATER

GROUND WATER RESOURCES OF SOUTH AFRICA

1. BACKGROUND

The Department of Water Affairs and Forestry (DWAF) has decided to conduct a Water Situation Assessment Study for South Africa to give a broad overview of national water requirements and water resources. These studies will enable the DWAF to utilize the Water Situation Assessment Model (WSAM), to assist in the decision making process when doing long-term water resources planning.

WSM (Pty) Ltd was appointed to undertake the Situation Assessment Study of the Ground Water Resources of South Africa. This study took the form of a desk study evaluating all relevant existing data and reports at a reconnaissance level. The study area consists of all the quaternary sub-catchments of South Africa and the adjoining sub-catchments of the neighbouring states.

This report gives the findings of the study.

2. STUDY OBJECTIVES

The objective of the study is mainly to provide quantitative information on the Ground Water Resources on a quaternary catchment basis for the whole of South Africa for input into the WSAM. The information provided will consist of the following, viz: -

- ground water resource potential or harvest potential
- ground water resources available to be exploited or exploitation potential
- interaction between ground water and surface water ie the portion of ground water that contributes to stream flow (base flow)
- present ground water use
- a ground water balance identifying quaternary catchments where over exploitation occurs as well as catchments having a potential for increased ground water development
- ground water quality evaluation, determining the portion of ground water which is potable

3. METHODOLOGY

This study is a reconnaissance study making use of existing available information.

The quantification of the ground water resources is probably one of the most difficult aspects of ground water to access. Information on recharge to the ground water systems, storage capacity of the ground water systems, the hydraulic conductivity and thickness of these ground water systems, the interaction with surface water and water quality is required.

Once the ground water resources are quantified a ground water balance is set up, comparing the resource with the existing use, to determine areas of over exploitation and identify areas which have a potential for further ground water exploitation. These parameters have been evaluated and the methodology is given below.

3.1 Harvest Potential

The evaluation of the mean annual recharge and storage on a national scale has been done by Vegter, 1995. This information together with a rainfall reliability factor (20^{th} percentile precipitation divided by the median precipitation), which gives an indication of the possible drought length, has been utilized by Seward and Seymour, 1996, to produce the Harvest Potential of South Africa.

The Harvest Potential is defined as the maximum volume of ground water that may be abstracted per area without depleting the aquifers. The Harvest Potential as determined by Seward and Seymour, 1996 has been used as the starting point for the determination of the Ground Water Resources of South Africa.

3.2 Exploitation Potential

It is however not possible to abstract all the ground water available. This is mainly due to economic and/or environmental considerations. The main contributing factor is the hydraulic conductivity or transmissivity of the aquifer systems. As no regional information is available, a qualitative evaluation has been done using available borehole yield information, as there is a good relationship between borehole yield and transmissivity.

The average borehole yield was determined for each quaternary catchment using information available from the National Ground Water Database and the borehole database of the Chief Directorate Water Services. Where no information was available, the average of the tertiary catchment was used. The average yields were then divided into 5 groups and an exploitation factor allocated to each group as follows, viz: -

AVERAGE BOREHOLE YIELD	**EXPLOITATION FACTOR**
>3.0 P/s	0.7
1.5 - 3.0 P/s	0.6
0.7 - 1.5 P/s	0.5
0.3 - 0.7 P/s	0.4
<0.3 P/s	0.3

This factor was then multiplied by the Harvest Potential of each quaternary catchment to obtain the exploitation potential. The exploitation potential is considered to be a conservative estimate of the groundwater resources available for exploitation.

3.3 Ground Water, Surface Water Interaction

In order to avoid double counting the water resources, the interaction between Surface and Ground Water needs to be quantified. At a workshop held at the DWAF where ground and surface water specialists were represented, it was agreed that the baseflow, be regarded as the portion of water common to both ground and surface water for the purposes of this study.

- ***Baseflow***

  The baseflow has been considered as that portion of ground water which contributes to the low flow of streams. Baseflow can therefore be regarded as that portion of the total water resource that can either be abstracted as ground water or surface water. The baseflow in this study is defined as the annual equivalent of the average low flow that is equaled or exceeded 75% of the time during the 4 driest months of the year. The baseflow has been calculated by Schultz and Barnes, 2001.

- ***Baseflow factor***

  The baseflow factor gives an indication of the portion of ground water which contributes to base flow and has been calculated by dividing the baseflow by the Harvest Potential.

  If baseflow = 0, then ground water does not contribute to baseflow and the baseflow factor is therefore also = 0.

  If baseflow . harvest potential then all ground water can be abstracted as surface water and the baseflow factor is therefore . 1. As the contribution of the Harvest Potential to baseflow cannot be greater than the Harvest Potential, the baseflow factor has therefore been corrected to equal 1 where it was > 1.

- ***Impact of Ground Water Abstraction on Surface Water Resources***

  The impact that ground water abstraction will have on surface water resources has been evaluated qualitatively by using the corrected baseflow factor ie,

  X negligible where corrected baseflow factor is = 0
  X low where the corrected baseflow factors is # 0.3
  X moderate where the corrected baseflow factor is # 0.8
  X high where the corrected baseflow factor is > 0.8

- ***Contribution of Ground Water to the Total Utilization Water Resource***

  This assessment of the interaction of groundwater and the base flow component of the surface water can however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilizable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilizable groundwater not contributing to the base flow of the surface water that can be added to the utilizable surface water to estimate the total utilizable resources has therefore been ignored.

3.4 Existing Ground Water Use

Data on existing ground water use was not readily accessible especially the main use sectors, viz agriculture and mining. Available borehole information was thus utilized to give a first estimate.

This was done by adding all the estimated yields or blow yields of all the boreholes for an 8 hr/day pumping period, 365 days per year.

Ground Water use was also evaluated from work done by Jane Baron (Baron and Seward, 2000). The use was evaluated for the following sectors, ie:

- Municipal Use

  This data was obtained from a study done by DWAF in 1990 with additional information obtained from DWAF hydrogeologists and town clerk /engineers.

- Rural Use

  Rural use was estimated from the DWAF, Water Services Database linking water source to population and allowing for 25 P/capita/day.

- Livestock use

  The number of equivalent large livestock units per quaternary catchment was taken from the WSAM and multiplied by 45 P/day and then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

- Irrigation Use

  The total irrigation use per quaternary catchment was taken from the WSAM. This use was then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

The total use was determined by summation of the municipal, rural, livestock and irrigation use. It must be noted that information on mining and industrial use was not available and has not been included in the total use.

Workshops held in each of the Water Management Area's by the Water Resources Situation Assessment teams, provided local input to the water use numbers. These numbers were then adjusted by applying a factor to the Baron & Seward (2000) number to give the final ground water use figures.

3.5 **Ground Water Balance**

The Ground Water Balance was calculated for each quaternary catchment to determine the extent to which the ground water resources have been developed. This was done by means of comparing the values of Harvest Potential and Exploitation Potential with adjusted ground water use (as determined by Baron and Seward, 2000).

The following scenarios were mapped, viz: -

- If the total use was greater than the Harvest Potential then the catchment was considered to be over utilized.

- If the total use was greater than the Exploitation Potential but less than the Harvest Potential then the catchment was considered to be heavily utilized.

- If the total use was less than the Exploitation Potential but greater than 66% of the Exploitation Potential then the catchment was considered to be moderately utilized.

- If the total use was less than 66% of the Exploitation Potential the catchment was considered under utilized.

3.6 **Water Quality**

The ground water quality is one of the main factors affecting the development of available ground water resources. Although there are numerous problems associated with water quality, some of which are easily remediated, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (M Simonic 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegters Maps (Vegter, 1995). The potability evaluation done by Simonic (M Simonic, 2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

The TDS is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements of other uses. The South African Water Quality Guidelines for the Department of Water Affairs and Forestry (1996) for these two uses were combined into a single classification system as shown in Table 3.6.1

TABLE 3.6.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

Clas s	Colour Code	Description	TDS Range (mg/l)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 – 600
2	Yellow	Marginal water quality	601 – 1800
3	Red	Poor water quality	1801 – 3400
4	Purple	Completely unacceptable water quality	>3400

The portion of the ground water resources considered potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the Quality of Domestic Water Supplies, Volume I (DWAF, 1998). Water classified as poor and unacceptable has been considered **not** potable.

In catchments where no information was available estimates of the portion potable were made using Vegters maps (Vegter 1995).

4. DATA LIMITATIONS

It must be noted that this evaluation was done using existing available information. The evaluation is based on the harvest potential map which was derived from interpretations of limited existing information on recharge and a very broad qualitative assessment of storage capacity. The comparison of base flow with the harvest potential indicates that the harvest potential could be significantly underestimated in the wetter parts of the country. It is thought that this is due to an under estimation of the storage capacity.

Although yield data on some 91000 boreholes was used the accuracy of this data in some instances is questionable, as it was not known whether the yield was a blow yield estimated during drilling, or a yield recommended by a hydrogeologist from detailed pumping test results. In general, however, the yields do highlight areas of higher and lower yield potential such as the dolomite areas but in some areas such as catchment W70 appear to grossly underestimate the yield. Underestimation of the yield would negatively impact on the calculation of exploitation potential.

Information on ground water use was obtained mainly from indirect qualitative evaluations. Further, mining and industrial use was not available and was therefore not included in the total usage. This could have a significant effect on the ground water balance in specifically the gold mining areas.

Water quality data should also only be used to give regional trends. In many catchments data at only a few sample points were available. As a catchment could be underlain by numerous different lithologies, a large range in water quality can occur. The samples used in the analysis could thus be non-representative of the catchment as a whole.

In general this study should be seen as a first quantitative estimate of the ground water resources of South Africa.

5. OVERVIEW OF THE GROUND WATER RESOURCES OF SOUTH AFRICA

In over 90% of the surface area of South Africa, ground water occurs in secondary openings such as pores in weathered rock and faults, fractures, fissures and dissolution channels in so-called hard rock. These rocks consist of igneous, metamorphic and sedimentary rocks and range in age from Jurassic (± 140 x 10^6 yrs) to Swazian (3750 x 10^6 yrs).

In the remaining 10% of the surface area of South Africa ground water occurs in primary openings ie intergranular pores in mainly unconsolidated classic rocks. These rocks are generally recent in age (< 65 x 10^6 yrs) and consist of the Kalahari beds, the alluvial strip along some rivers and cenozoic deposits fringing the coast line, mainly in Northern Kwa Zulu Natal and the Southern and Western Cape.

The total Harvest Potential for South Africa has been calculated as 19100 x $10^6 m^3$/annum and varies from less than 0.5 mm/annum in quaternary catchment D82J to more than 352 mm/annum in quaternary catchment W12J.

Borehole yields vary considerably. The highest boreholes yields (up to 100 P/s) have been found in the Malmani Dolomites. Other high borehole yielding (> 10 P/s) lithostratigraphic units include the Table Mountain Quartsites of the Southern Cape, Basement Granites in the Pietersburg Dendron and Coetzerdam area, coastal deposits along Northern Natal, the eastern southern and western Cape, and alluvial deposits along certain sections of some of the major rivers such as the Limpopo River.

Moderate to good yields (> 5 P/s) are found in the Letaba Basalt formation and where the Ecca has been intruded by dolerite dykes and sheets.

The total exploitation potential for South Africa has been calculated as 10100 x $10^6 m^3$/annum and varies from less than 0.2 mm/annum in quaternary catchment D82G to more than 211 mm/annum in quaternary catchment W12J.

The ground water use, excluding mines and industries, has been estimated to be some 1040 x $10^6 m^3$/annum and is concentrated in a few isolated areas.

The ground water balance shows that in general ground water is underutilized except for a few areas where over or heavy utilization occurs.

The extreme north western parts of South Africa show the poorest quality with TDS > 20000 mg/P. The higher rainfall eastern parts have the best water quality, TDS < 100 mg/P. The potability ranges between 0% in the extreme north-western parts of South Africa and 100% in the central and eastern areas. The main problems being brackish water and high nitrates and fluorides.

THE DATA AT QUATERNARY CATCHMENT RESOLUTION

For the record – not part of appendix

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D11A	278	278	7	10	203	56434	0.0565	0.0426	255	71024	0.0712	0.0536
D11B	236	236	7	10	203	47908	0.0480	0.0589	255	60294	0.0604	0.0741
D11C	292	292	7	10	203	59276	0.0594	0.0549	255	74601	0.0748	0.0691
D11D	319	319	7	10	203	64757	0.0649	0.0774	255	81499	0.0817	0.0975
D11E	322	322	7	10	203	65366	0.0655	0.1018	255	82266	0.0824	0.1281
D11F	413	413	7	10	203	83839	0.0840	0.0749	255	105514	0.1057	0.0943
D11G	320	320	7	10	203	64960	0.0651	0.1368	255	81755	0.0819	0.1722
D11H	359	359	7	10	203	72877	0.0730	0.1420	255	91718	0.0919	0.1787
D11J	440	440	7	10	203	89320	0.0895	0.1485	255	112412	0.1126	0.1869
D11K	381	381	7	10	203	77343	0.0775	0.1565	255	97339	0.0975	0.1970
0	**3360**	**3360**				**682080**	**0.6834**	**0.0863**		**858423**	**0.8601**	**0.1087**
D12A	369	369	6	13	335	123615	0.1239	0.2878	422	155574	0.1559	0.3622
D12B	385	385	6	13	335	128975	0.1292	0.1969	422	162320	0.1626	0.2478
D12C	343	343	6	13	335	114905	0.1151	0.5597	422	144612	0.1449	0.7044
D12D	355	355	6	12	335	118925	0.1192	0.6649	422	149671	0.1500	0.8368
D12E	712	712	6	12	335	238520	0.2390	0.7200	422	300186	0.3008	0.9062
D12F	803	803	6	13	335	269005	0.2695	0.9797	422	338553	0.3392	1.2330
0	**2967**	**2967**				**993945**	**0.9959**	**0.4791**		**1250916**	**1.2534**	**0.6030**
D13A	475	475	6	13	335	159125	0.1594	0.2239	422	200265	0.2007	0.2817
D13B	533	533	6	13	335	178555	0.1789	0.2420	422	224718	0.2252	0.3046
D13C	517	517	6	13	335	173195	0.1735	0.3160	422	217972	0.2184	0.3977
D13D	635	635	6	13	335	212725	0.2132	0.3679	422	267722	0.2683	0.4630
D13E	1031	1031	6	13	335	345385	0.3461	0.2673	422	434680	0.4355	0.3364
D13F	970	970	6	13	335	324950	0.3256	0.3358	422	408961	0.4098	0.4226
D13G	1125	1125	6	13	335	376875	0.3776	0.7118	422	474311	0.4753	0.8958
D13H	1144	1144	6	13	335	383240	0.3840	1.2843	422	482322	0.4833	1.6163
D13J	1167	1167	6	13	335	390945	0.3917	1.1828	422	492019	0.4930	1.4886

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D13K	397	397	6	13	335	132995	0.1333	0.2641	422	167379	0.1677	0.3324
D13L	682	682	6	13	335	228470	0.2289	0.9037	422	287538	0.2881	1.1373
D13M	678	678	6	13	335	227130	0.2276	1.0546	422	285851	0.2864	1.3272
0	**9354**	**9354**				**3133590**	**3.1399**	**0.4499**		**3943737.7**	**3.9516**	**0.5662**
D14A	764	764	6	12	335	255940	0.2565	1.0205	422	322110	0.3228	1.2843
D14B	324	324	6	13	335	108540	0.1088	1.3492	422	136602	0.1369	1.6981
D14C	722	722	6	13	335	241870	0.2424	1.3106	422	304402	0.3050	1.6494
D14D	680	680	6	13	335	227800	0.2283	1.9450	422	286695	0.2873	2.4479
D14E	663	663	6	13	335	222105	0.2225	2.1580	422	279527	0.2801	2.7159
D14F	541	541	6	13	335	181235	0.1816	1.2767	422	228091	0.2285	1.6067
D14G	605	605	6	13	335	202675	0.2031	1.0383	422	255074	0.2556	1.3068
D14H	697	697	6	13	335	233495	0.2340	1.5790	422	293862	0.2944	1.9872
D14J	515	515	6	13	335	172525	0.1729	1.5681	422	217129	0.2176	1.9735
D14K	634	634	6	13	335	212390	0.2128	1.6937	422	267301	0.2678	2.1316
0	**6145**	**6145**				**2058575**	**2.0627**	**1.4136**		**2590792**	**2.5960**	**1.7790**
D15A	437	437	7	10	203	88711	0.0889	0.0749	255	111646	0.1119	0.0942
D15B	393	393	7	10	203	79779	0.0799	0.0773	255	100405	0.1006	0.0973
D15C	276	276	7	10	203	56028	0.0561	0.1036	255	70513	0.0707	0.1304
D15D	437	437	7	12	203	88711	0.0889	0.0842	255	111646	0.1119	0.1060
D15E	619	619	7	12	203	125657	0.1259	0.1097	255	158144	0.1585	0.1380
D15F	352	352	7	12	203	71456	0.0716	0.2366	255	89930	0.0901	0.2978
D15G	485	485	7	12	203	98455	0.0987	0.3474	255	123909	0.1242	0.4372
D15H	361	361	7	12	203	73283	0.0734	0.4943	255	92229	0.0924	0.6221
0	**3360**	**3360**				**682080**	**0.6834**	**0.1199**		**858422.63**	**0.8601**	**0.1509**
D16A	159	159	7	10	203	32277	0.0323	0.0762	255	40622	0.0407	0.0960
D16B	249	249	7	10	203	50547	0.0506	0.0925	255	63615	0.0637	0.1164
D16C	438	438	7	10	203	88914	0.0891	0.2732	255	111902	0.1121	0.3438
D16D	339	339	7	10	203	68817	0.0690	0.1114	255	86609	0.0868	0.1402
D16E	434	434	7	10	203	88102	0.0883	0.1763	255	110880	0.1111	0.2219
D16F	277	277	7	10	203	56231	0.0563	0.1105	255	70769	0.0709	0.1391
D16G	290	290	7	10	203	58870	0.0590	0.1269	255	74090	0.0742	0.1597
D16H	345	345	7	10	203	70035	0.0702	0.2191	255	88142	0.0883	0.2758

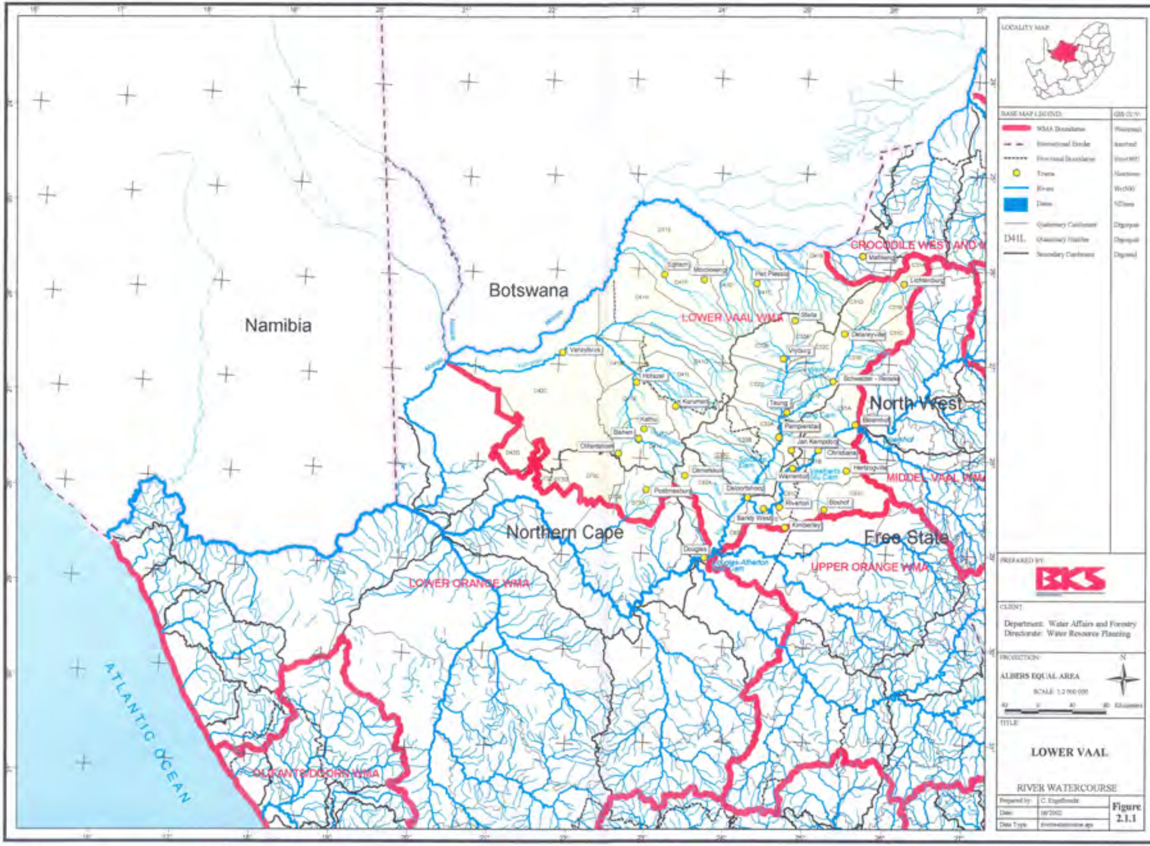
Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D16J	374	374	7	10	203	75922	0.0761	0.1584	255	95551	0.0957	0.1993
D16K	329	329	7	10	203	66787	0.0669	0.1116	255	84054	0.0842	0.1404
D16L	533	533	7	10	203	108199	0.1084	0.1819	255	136172	0.1364	0.2290
D16M	753	753	7	10	203	152859	0.1532	0.1152	255	192379	0.1928	0.1450
0	**4520**	**4520**				**917560**	**0.9194**	**0.1369**		**1154782.8**	**1.1571**	**0.1722**
D17A	638	638	7	10	203	129514	0.1298	0.0629	255	162998	0.1633	0.0791
D17B	442	442	7	10	203	89726	0.0899	0.0710	255	112923	0.1131	0.0894
D17C	525	525	7	10	203	106575	0.1068	0.1379	255	134129	0.1344	0.1735
D17D	748	748	7	10	203	151844	0.1521	0.1356	255	191101	0.1915	0.1707
D17E	605	605	7	10	203	122815	0.1231	0.1276	255	154567	0.1549	0.1606
D17F	582	582	7	10	203	118146	0.1184	0.2451	255	148691	0.1490	0.3084
D17G	849	849	7	10	203	172347	0.1727	0.1584	255	216905	0.2173	0.1994
D17H	852	852	7	10	203	172956	0.1733	0.1701	255	217671	0.2181	0.2140
D17J	437	437	7	10	203	88711	0.0889	0.0890	255	111646	0.1119	0.1120
D17K	383	383	7	10	203	77749	0.0779	0.1533	255	97850	0.0980	0.1929
D17L	590	590	7	10	203	119770	0.1200	0.1611	255	150735	0.1510	0.2027
D17M	528	528	7	10	203	107184	0.1074	0.1475	255	134895	0.1352	0.1857
0	**7179**	**7179**				**1457337**	**1.4603**	**0.1241**		**1834111.9**	**1.8378**	**0.1562**
D18A	599	599	7	10	203	121597	0.1218	0.1259	255	153034	0.1533	0.1584
D18B	327	327	7	10	203	66381	0.0665	0.1668	255	83543	0.0837	0.2100
D18C	466	466	7	12	203	94598	0.0948	0.1972	255	119055	0.1193	0.2482
D18D	766	766	7	10	203	155498	0.1558	0.1393	255	195700	0.1961	0.1753
D18E	376	376	7	10	203	76328	0.0765	0.1376	255	96062	0.0963	0.1731
D18F	446	446	7	12	203	90538	0.0907	0.2071	255	113945	0.1142	0.2607
D18G	492	492	7	13	203	99876	0.1001	0.1160	255	125698	0.1259	0.1460
D18H	384	384	7	13	203	77952	0.0781	0.1551	255	98105	0.0983	0.1952
D18J	859	859	7	12	203	174377	0.1747	0.1561	255	219460	0.2199	0.1964
D18K	935	935	7	13	203	189805	0.1902	0.1290	255	238877	0.2394	0.1623
D18L	610	610	7	12	203	123830	0.1241	0.1919	255	155845	0.1562	0.2415
0	**6260**	**6260**				**1270780**	**1.2733**	**0.1486**		**1599323.1**	**1.6025**	**0.1871**
D21A	309	309	6	10	335	103515	0.1037	0.1688	422	130277	0.1305	0.2124
D21B	394	394	6	10	335	131990	0.1323	0.1495	422	166114	0.1664	0.1882

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D21C	212	212	6	9	335	71020	0.0712	0.2287	422	89381	0.0896	0.2878
D21D	252	252	6	9	335	84420	0.0846	0.2762	422	106246	0.1065	0.3476
D21E	268	268	6	9	335	89780	0.0900	0.3430	422	112991	0.1132	0.4317
D21F	480	480	6	9	335	160800	0.1611	0.4945	422	202373	0.2028	0.6223
D21G	278	278	6	9	335	93130	0.0933	0.4354	422	117208	0.1174	0.5480
D21H	381	381	6	9	335	127635	0.1279	0.3292	422	160633	0.1610	0.4143
D21J	359	359	6	10	335	120265	0.1205	0.1620	422	151358	0.1517	0.2039
D21K	326	326	6	10	335	109210	0.1094	0.1772	422	137445	0.1377	0.2230
D21L	304	304	6	9	335	101840	0.1020	0.2519	422	128169	0.1284	0.3170
0	**3563**	**3563**				**1193605**	**1.1960**	**0.2357**		**1502195.6**	**1.5052**	**0.2967**
D22A	636	636	6	9	335	213060	0.2135	0.5977	422	268144	0.2687	0.7522
D22B	457	457	6	9	335	153095	0.1534	0.4794	422	192676	0.1931	0.6033
D22C	486	486	6	9	335	162810	0.1631	0.3321	422	204902	0.2053	0.4180
D22D	628	628	6	9	335	210380	0.2108	0.5729	422	264771	0.2653	0.7211
D22E	498	498	6	10	335	166830	0.1672	0.3266	422	209962	0.2104	0.4111
D22F	633	633	6	9	335	212055	0.2125	0.4105	422	266879	0.2674	0.5166
D22G	969	969	6	9	335	324615	0.3253	0.6144	422	408540	0.4094	0.7733
D22H	541	541	6	9	335	181235	0.1816	0.5043	422	228091	0.2285	0.6347
D22J	652	652	6	10	335	218420	0.2189	0.3533	422	274890	0.2754	0.4447
D22K	324	324	6	10	335	108540	0.1088	0.3859	422	136602	0.1369	0.4857
D22L	376	376	6	11	335	125960	0.1262	0.5836	422	158525	0.1588	0.7345
0	**6200**	**6200**				**2077000**	**2.0812**	**0.4551**		**2613980.5**	**2.6192**	**0.5728**
D23A	608	608	6	12	335	203680	0.2041	0.5334	422	256339	0.2569	0.6713
D23B	597	597	6	12	335	199995	0.2004	0.4911	422	251701	0.2522	0.6181
D23C	861	861	3	12	82	70602	0.0707	0.1730	103	88855	0.0890	0.2177
D23D	565	565	6	12	335	189275	0.1897	0.8614	422	238210	0.2387	1.0841
D23E	702	702	6	12	335	235170	0.2356	0.8219	422	295970	0.2966	1.0343
D23F	352	352	6	12	335	117920	0.1182	0.6037	422	148407	0.1487	0.7598
D23G	512	512	6	12	335	171520	0.1719	0.6553	422	215864	0.2163	0.8248
D23H	776	776	6	12	335	259960	0.2605	1.3243	422	327169	0.3278	1.6667
D23J	534	534	6	12	335	178890	0.1792	1.1169	422	225140	0.2256	1.4057

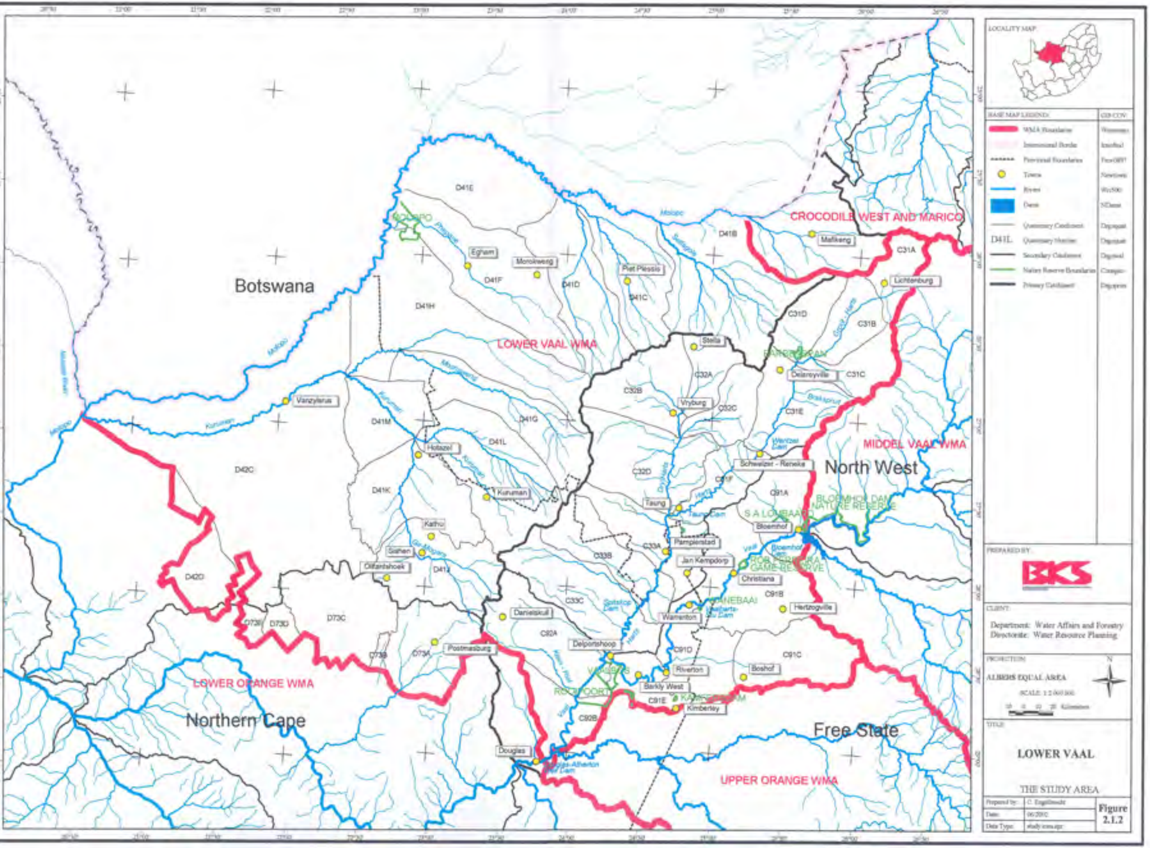
Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
0	**5507**	**5507**				**1627012**	**1.6303**	**0.6465**		**2047654.1**	**2.0517**	**0.8136**
D24A	310	310	6	12	335	103850	0.1041	0.5452	422	130699	0.1310	0.6862
D24B	470	470	6	12	335	157450	0.1578	0.6896	422	198157	0.1986	0.8679
D24C	398	398	6	12	335	133330	0.1336	0.9886	422	167801	0.1681	1.2442
D24D	598	598	6	12	335	200330	0.2007	1.3334	422	252123	0.2526	1.6781
D24E	489	489	6	12	335	163815	0.1641	1.3315	422	206167	0.2066	1.6757
D24F	567	567	6	12	335	189945	0.1903	1.0849	422	239053	0.2395	1.3653
D24G	626	626	6	13	335	209710	0.2101	0.9379	422	263928	0.2645	1.1804
D24H	736	736	6	12	335	246560	0.2471	1.3026	422	310305	0.3109	1.6394
D24J	1032	1032	6	12	335	345720	0.3464	1.6795	422	435101	0.4360	2.1137
D24K	877	877	6	12	335	293795	0.2944	1.7489	422	369752	0.3705	2.2011
D24L	511	511	6	12	335	171185	0.1715	1.8793	422	215443	0.2159	2.3651
0	**6614**	**6614**				**2215690**	**2.2201**	**1.1787**		**2788526.9**	**2.7941**	**1.4834**
D31A	1160	1160	5	12	30	34800	0.0349	0.2128	38	43797	0.0439	0.2678
D31B	996	757	5	13	30	22710	0.0228	0.5438	38	28581	0.0286	0.6844
D31C	677	677	5	12	30	20310	0.0204	0.4541	38	25561	0.0256	0.5715
D31D	1108	833	5	12	30	24990	0.0250	0.2575	38	31451	0.0315	0.3241
D31E	969	969	5	12	30	29070	0.0291	0.3395	38	36586	0.0367	0.4273
0	**4910**	**4396**				**131880**	**0.1321**	**0.3048**		**165975.8**	**0.1663**	**0.3836**
D32A	716	716	5	12	30	21480	0.0215	0.5253	38	27033	0.0271	0.6611
D32B	582	582	5	13	30	17460	0.0175	0.3693	38	21974	0.0220	0.4648
D32C	850	850	5	12	30	25500	0.0256	0.5117	38	32093	0.0322	0.6440
D32D	851	851	5	12	30	25530	0.0256	0.5400	38	32130	0.0322	0.6796
D32E	1157	1157	5	13	30	34710	0.0348	0.9054	38	43684	0.0438	1.1395
D32F	1443	1443	5	13	30	43290	0.0434	0.5841	38	54482	0.0546	0.7351
D32G	1045	1045	5	12	30	31350	0.0314	0.4304	38	39455	0.0395	0.5417
D32H	572	572	5	12	30	17160	0.0172	0.4476	38	21596	0.0216	0.5634
D32J	1114	1041	5	12	30	31230	0.0313	0.5128	38	39304	0.0394	0.6454
D32K	824	824	5	12	30	24720	0.0248	0.4606	38	31111	0.0312	0.5797
0	**9154**	**9081**				**272430**	**0.2730**	**0.5204**		**342863.12**	**0.3435**	**0.6550**
D33A	593	472	5	12	30	14160	0.0142	0.9903	38	17821	0.0179	1.2463
D33B	1018	323	5	12	30	9690	0.0097	1.1770	38	12195	0.0122	1.4813

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D33C	805	520	5	12	30	15600	0.0156	0.9679	38	19633	0.0197	1.2182
D33D	952	311	5	12	30	9330	0.0093	1.4309	38	11742	0.0118	1.8008
D33E	1554	343	5	12	30	10290	0.0103	1.3347	38	12950	0.0130	1.6797
D33F	863	77	5	12	30	2310	0.0023	1.7295	38	2907	0.0029	2.1766
D33G	1406	400	5	12	30	12000	0.0120	1.7610	38	15102	0.0151	2.2163
D33H	1054	468	5	7	80.7	37767.6	0.0378	4.0585	102	47532	0.0476	5.1077
D33J	865	200	5	12	30	6000	0.0060	2.1668	38	7551	0.0076	2.7270
D33K	488	290	5	12	30	8700	0.0087	1.6299	38	10949	0.0110	2.0513
0	**9598**	**3404**				**125847.6**	**0.1261**	**1.6044**		**158383.81**	**0.1587**	**2.0191**
D34A	794	794	5	12	30	23820	0.0239	0.2193	38	29978	0.0300	0.2760
D34B	706	706	5	12	30	21180	0.0212	0.2960	38	26656	0.0267	0.3725
D34C	760	760	5	12	30	22800	0.0228	0.3641	38	28695	0.0288	0.4583
D34D	599	599	5	12	30	17970	0.0180	0.3348	38	22616	0.0227	0.4214
D34E	519	519	5	12	30	15570	0.0156	0.2834	38	19595	0.0196	0.3566
D34F	692	692	5	12	30	20760	0.0208	0.3868	38	26127	0.0262	0.4868
D34G	950	950	5	12	30	28500	0.0286	0.2593	38	35868	0.0359	0.3264
0	**5020**	**5020**				**150600**	**0.1509**	**0.2924**		**189535.61**	**0.1899**	**0.3680**
D35A	254	254	6	12	335	85090	0.0853	1.9440	422	107089	0.1073	2.4465
D35B	260	260	6	13	335	87100	0.0873	2.1655	422	109619	0.1098	2.7253
D35C	943	943	6	13	335	315905	0.3165	2.9344	422	397578	0.3984	3.6931
D35D	586	586	6	13	335	196310	0.1967	3.5307	422	247063	0.2476	4.4435
D35E	312	312	6	13	335	104520	0.1047	2.6773	422	131542	0.1318	3.3695
D35F	557	557	6	12	335	186595	0.1870	2.1607	422	234837	0.2353	2.7193
D35G	552	552	6	13	335	184920	0.1853	3.7217	422	232729	0.2332	4.6839
D35H	498	498	6	12	335	166830	0.1672	2.7651	422	209962	0.2104	3.4800
D35J	1002	1002	5	12	30	30060	0.0301	0.3909	38	37832	0.0379	0.4920
D35K	674	674	5	12	30	20220	0.0203	0.2947	38	25448	0.0255	0.3709
0	**5638**	**5638**				**1377550**	**1.3803**	**2.1929**		**1733697.1**	**1.7372**	**2.7599**
0	0	0										
TOTALS	**99349**	**92568**				**20367562**	**20.4083**	**0.3027**		**25633321**	**25.6846**	**0.3810**

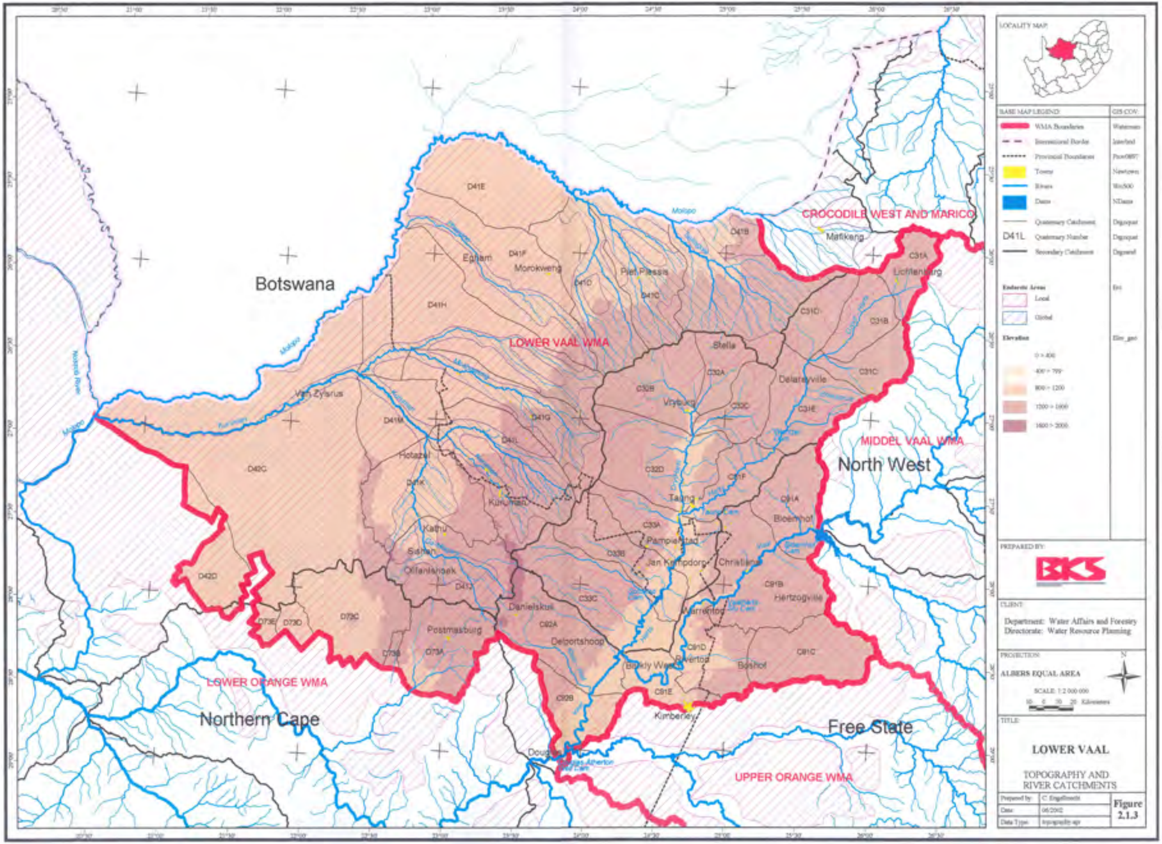
FIGURES



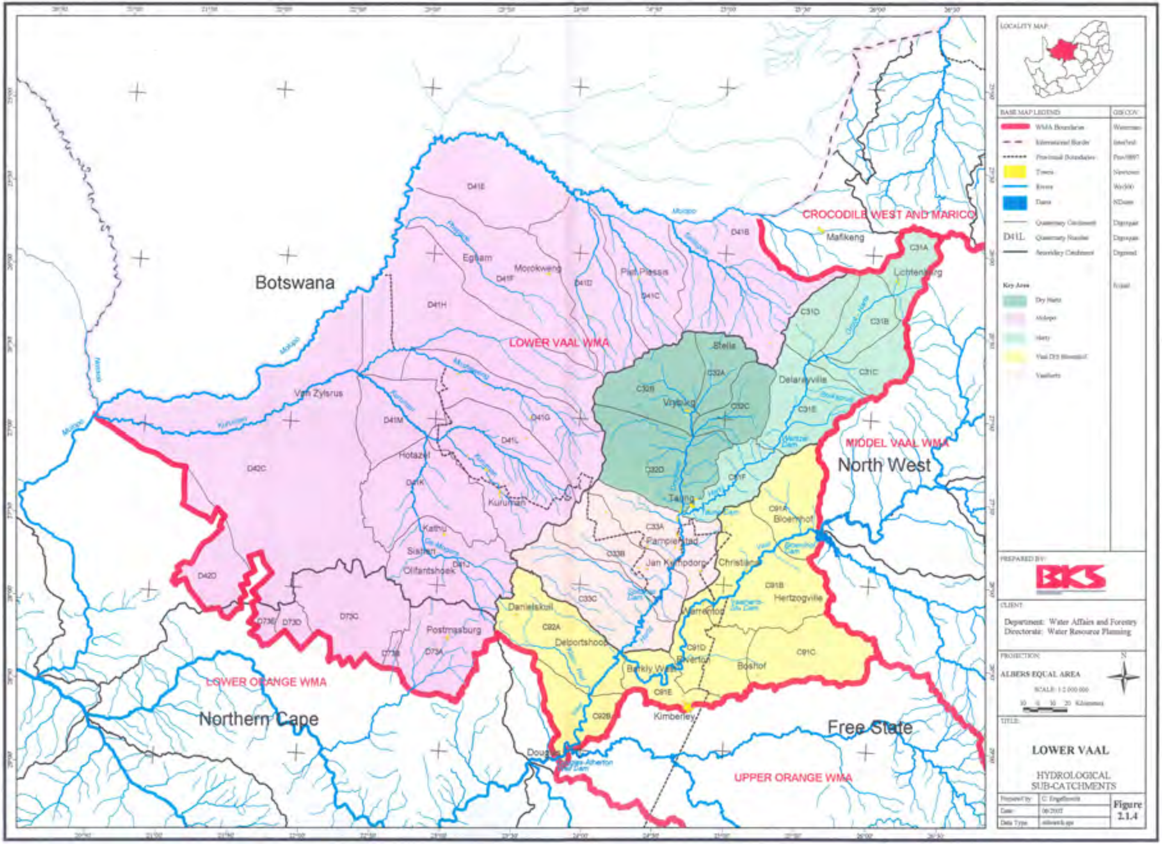
Namibia
Botswana
Northern Cape
North West
Free State
ATLANTIC OCEAN
LOWER VAAL WMA
CROCODILE WEST AND
MIDDEL VAAL WMA
UPPER ORANGE WMA
LOWER ORANGE WMA
OLIFANTS/DOORN WMA
Mafikeng
Lichtenburg
Ganyesa
Stella
Delareyville
Vryburg
Schweizer - Reneke
Vanzylsrus
Hotazel
Kuruman
Taung
Bloemhof
Kathu
Sishen
Pampierstad
Jan Kempdorp
Christiana
Olifantshoek
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Riverton
Boshof
Barkly West
Kimberley
Douglas
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
D41L
Secondary Catchments
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
LOWER VAAL
RIVER WATERCOURSE
Prepared by:
Date:
Data Type
Figure 2.1.1



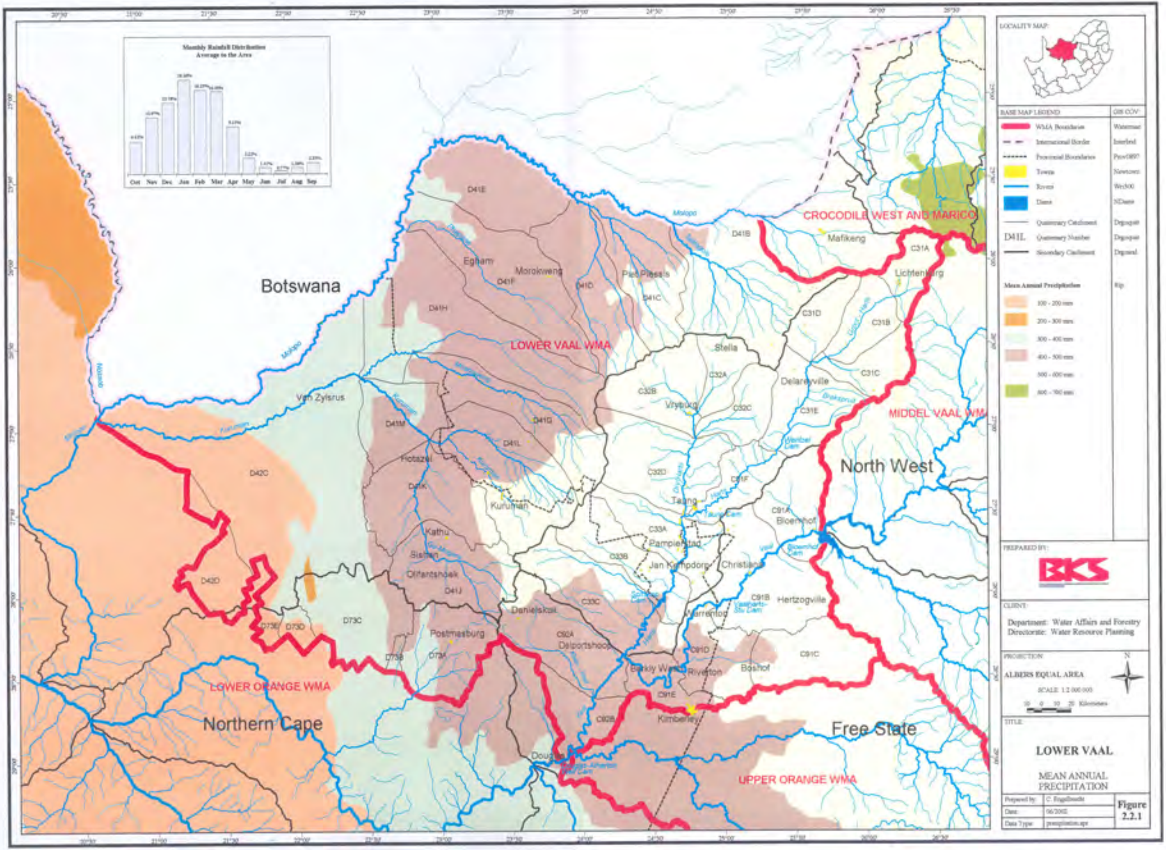
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Vanzylsrus
Hotazel
Kuruman
Schweizer - Reneke
Taung
Bloemhof
Kathu
Sishen
Olifantshoek
Pampierstad
Jan Kempdorp
Christiana
Warrenton
Hertzogville
Danielskuil
Delportshoop
Postmasburg
Riverton
Boshof
Barkly West
Kimberley
Douglas
BLOEMHOF DAM NATURE RESERVE
S A LOMBAARD
LOCALITY MAP
BASE MAP LEGEND
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
LOWER VAAL
THE STUDY AREA
Figure 2.1.2



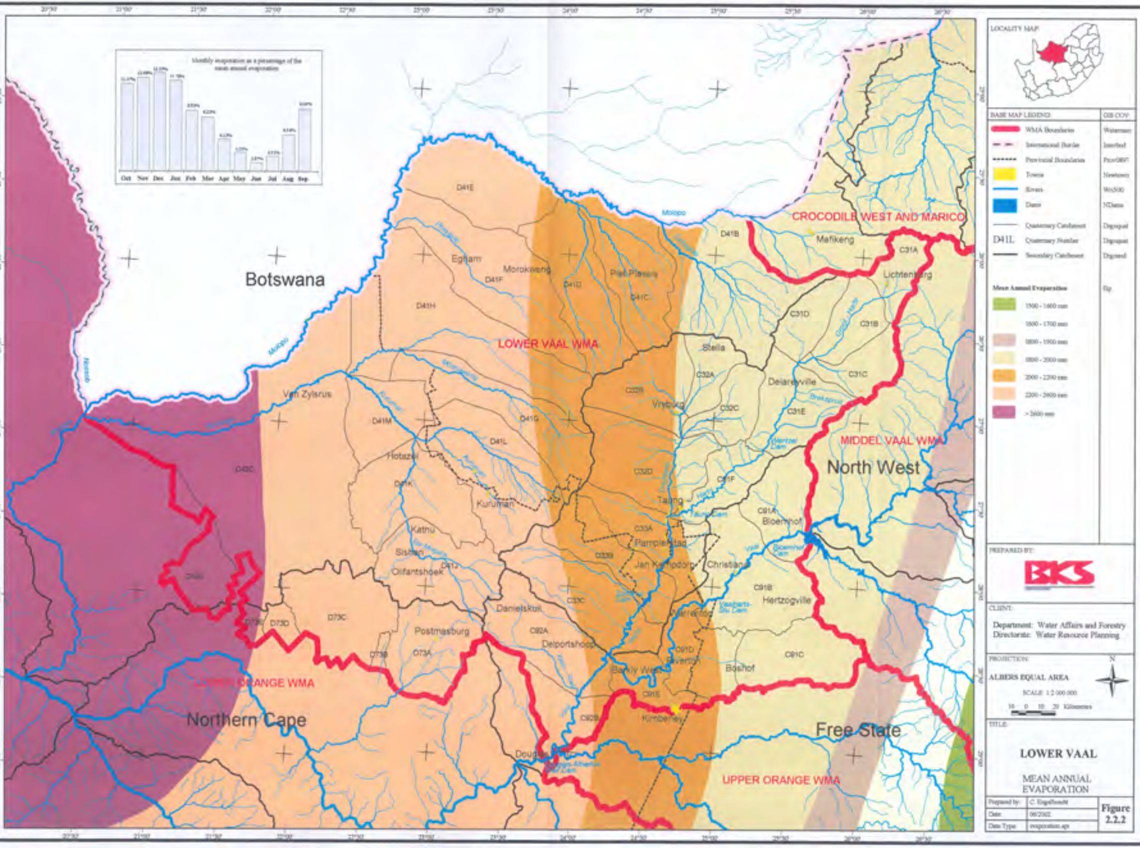
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Molopo
Nossob River
Kuruman
Vaal
Mafikeng
Lichtenburg
Piet Plessis
Morokweng
Egham
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Stella
Vryburg
Delareyville
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Barkly West
Riverton
Boshof
Kimberley
Douglas
D41E
D41F
D41H
D41D
D41C
D41B
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Endoreic Areas
Local
Global
Elevation
0 > 400
400 > 799
800 > 1200
1200 > 1600
1600 > 2000
Elev_geo
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:2 000 000
Kilometers
N
TITLE:
LOWER VAAL
TOPOGRAPHY AND
RIVER CATCHMENTS
Prepared by:
Date:
Data Type:
Figure 2.1.3



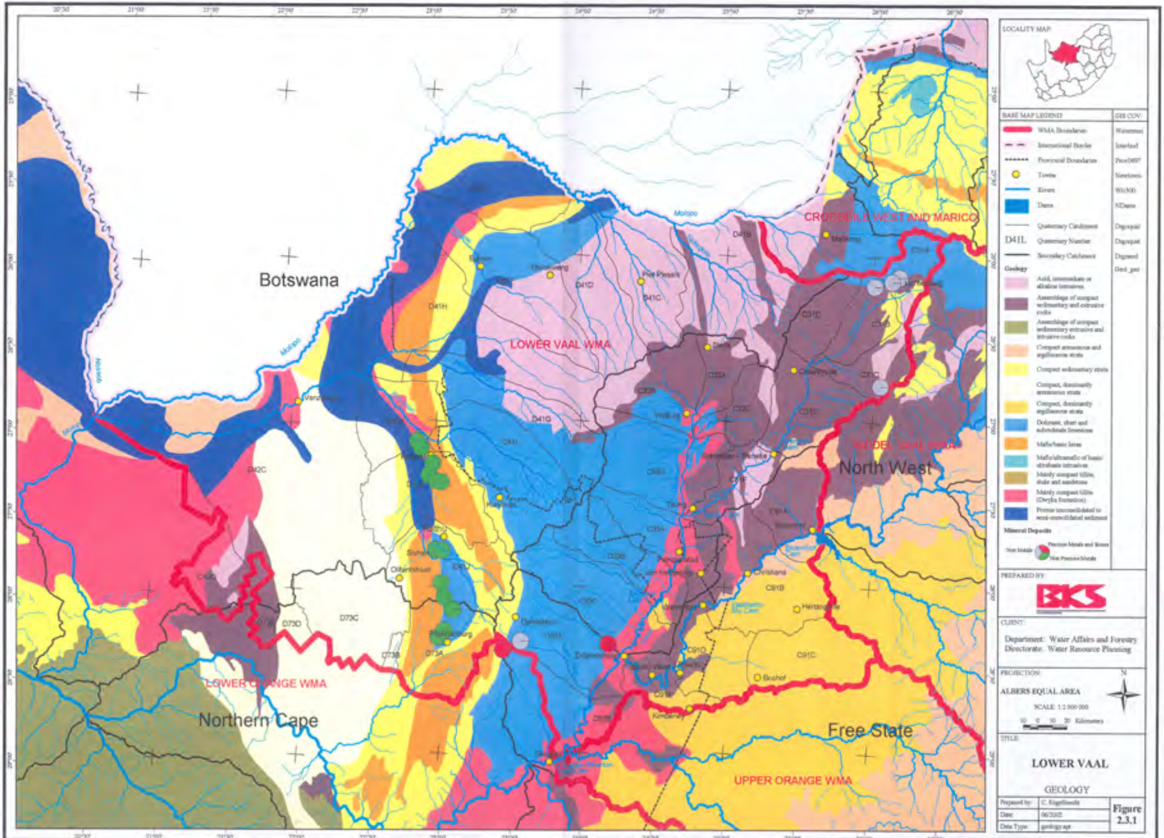
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
Towns
Rivers
Dams
D41L
Key Area
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
HYDROLOGICAL SUB-CATCHMENTS
Figure 2.1.4
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Delareyville
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Danielskuil
Delportshoop
Barkly West
Riverton
Boshof
Kimberley
Douglas
Molopo
Kuruman
D41E
D41B
D41F
D41D
D41C
D41H
D41G
D41M
D41L
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B



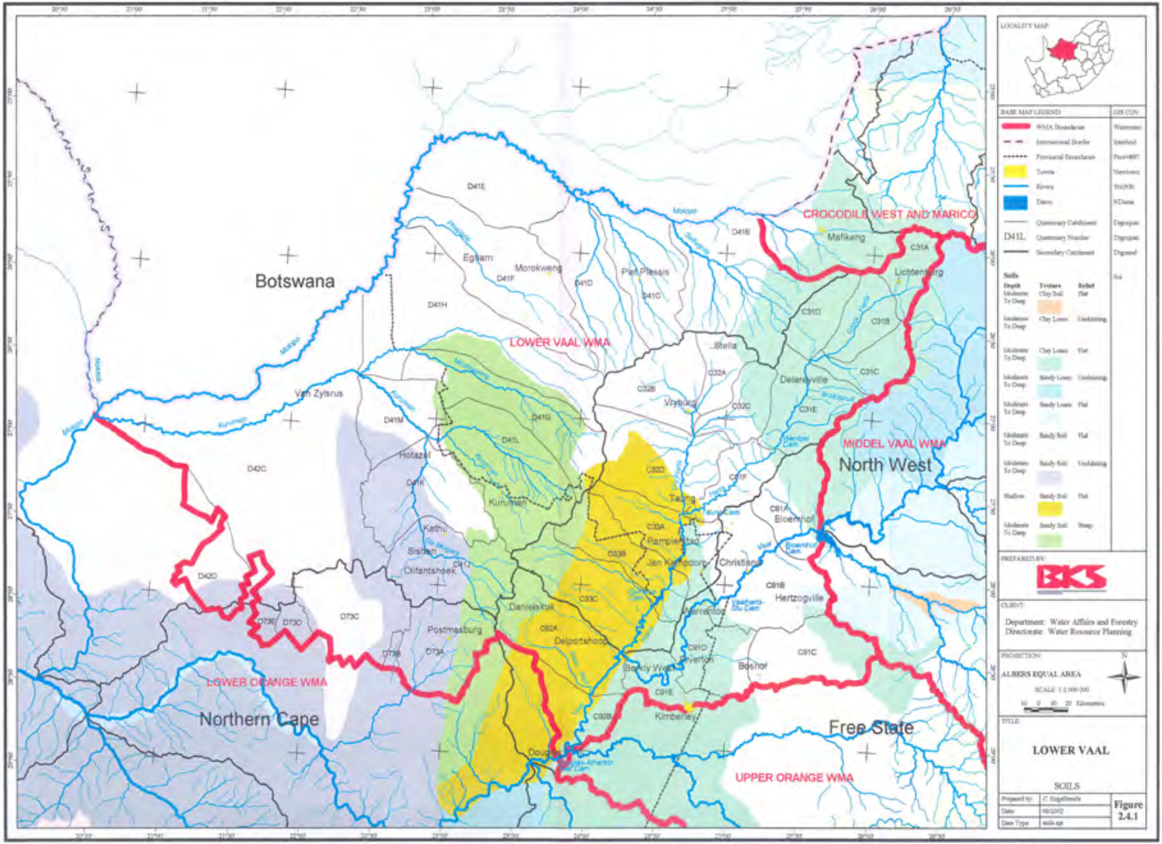
Monthly Rainfall Distribution
Average to the Area
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Botswana
Molopo
Nossob
Van Zylsrus
Egham
Morokweng
Piet Plessis
LOWER VAAL WMA
CROCODILE WEST AND MARICO
Mafikeng
Lichtenburg
Stella
Vryburg
Delareyville
MIDDEL VAAL WMA
North West
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Hertzogville
Danielskuil
Postmasburg
Warrenton
Dalportshoop
Barkly West
Riverton
Boshof
Kimberley
LOWER ORANGE WMA
Northern Cape
Free State
Douglas
UPPER ORANGE WMA
LOCALITY MAP:
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Mean Annual Precipitation
100 - 200 mm
200 - 300 mm
300 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
MEAN ANNUAL PRECIPITATION
Figure 2.2.1



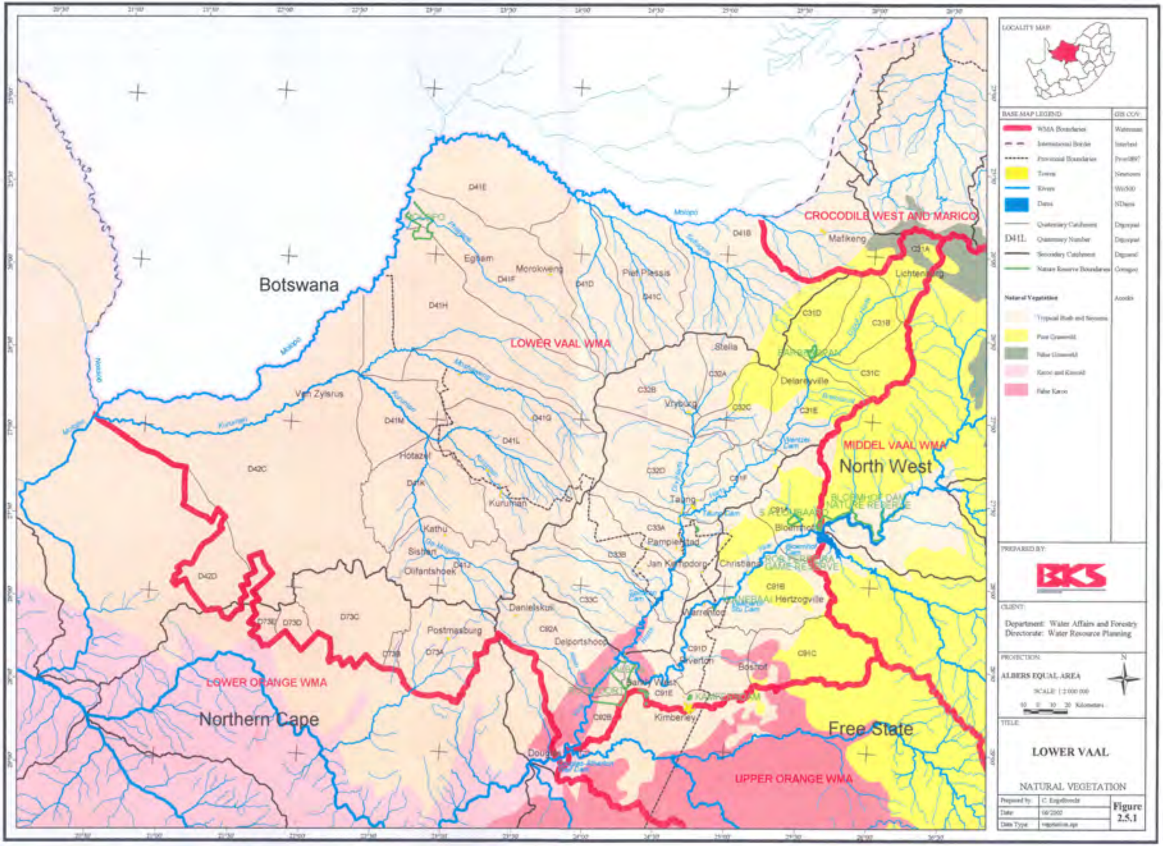
Monthly evaporation as a percentage of the mean annual evaporation
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Botswana
Molopo
Nossob
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Barkly West
Riverton
Boshof
Kimberley
Douglas
D41E
D41F
D41D
D41C
D41B
D41H
D41M
D41G
D41L
D41K
D41J
D42C
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Mean Annual Evaporation
1500 - 1600 mm
1600 - 1700 mm
1800 - 1900 mm
1800 - 2000 mm
2000 - 2200 mm
2200 - 2600 mm
> 2600 mm
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:2 000 000
10 0 10 20 Kilometers
N
TITLE:
LOWER VAAL
MEAN ANNUAL EVAPORATION
Prepared by:
C. Engelbrecht
Date:
06/2002
Figure 2.2.2



Botswana
Northern Cape
North West
Free State
LOWER VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
MIDDLE VAAL WMA
CROCODILE WEST AND MARICO
Molopo
Kimberley
Boshof
Christiana
Hertzogville
Taung
Vryburg
Mafikeng
Piet Plessis
Schmidtsdrif
Postmasburg
Olifantshoek
Kuruman
D41L
LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Geology
Acid, intermediate or alkaline intrusives
Assemblage of compact sedimentary and extrusive rocks
Assemblage of compact sedimentary extrusive and intrusive rocks
Compact arenaceous and argillaceous strata
Compact sedimentary strata
Compact, dominantly arenaceous strata
Compact, dominantly argillaceous strata
Dolomite, chert and subordinate limestone
Mafic/basic lavas
Mafic/ultramafic of basic/ultrabasic intrusives
Mainly compact tillite, shale and sandstone
Mainly compact tillite (Dwyka formation)
Porous unconsolidated to semi-consolidated sediment
Mineral Deposits
Non Metals
Precious Metals and Stones
Non Precious Metals
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
Kilometers
TITLE:
LOWER VAAL
GEOLOGY
Prepared by:
Date:
06/2005
Data Type:
Figure 2.3.1

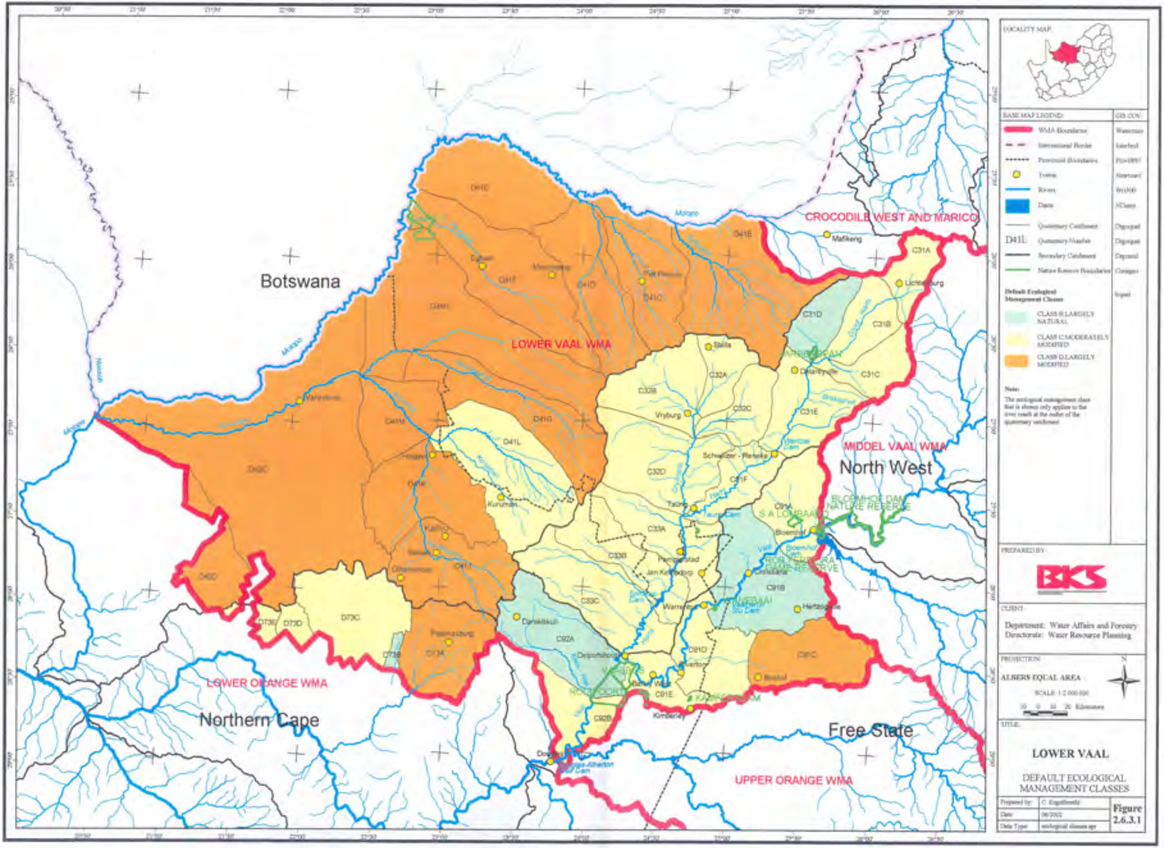


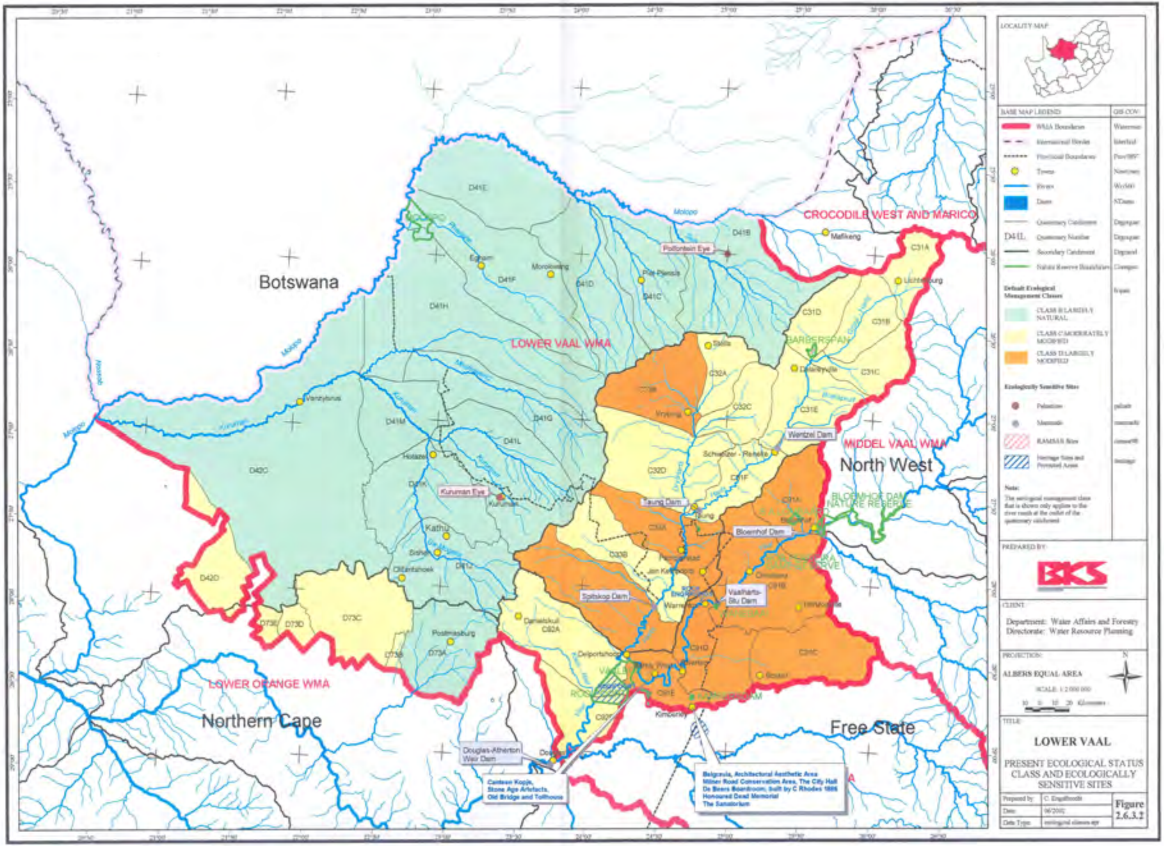
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Douglas
Barkly West
Kimberley
Warrenton
Christiana
Jan Kempdorp
Pampierstad
Taung
Vryburg
Stella
Delareyville
Mafikeng
Lichtenburg
Bloemhof
Hertzogville
Boshof
Egham
Morokweng
Piet Plessis
Molopo
Kuruman
Vaal
Harts
Bloemhof Dam
Vaalharts-Stu Dam
D41E
D41F
D41D
D41C
D41B
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73C
D73D
D73E
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Soils
Depth
Texture
Relief
Moderate To Deep
Clay Soil
Flat
Clay Loam
Undulating
Sandy Loam
Sandy Soil
Shallow
Steep
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
10 0 10 20 Kilometres
N
TITLE:
LOWER VAAL
SOILS
Prepared by:
Date:
Data Type
Figure 2.4.1



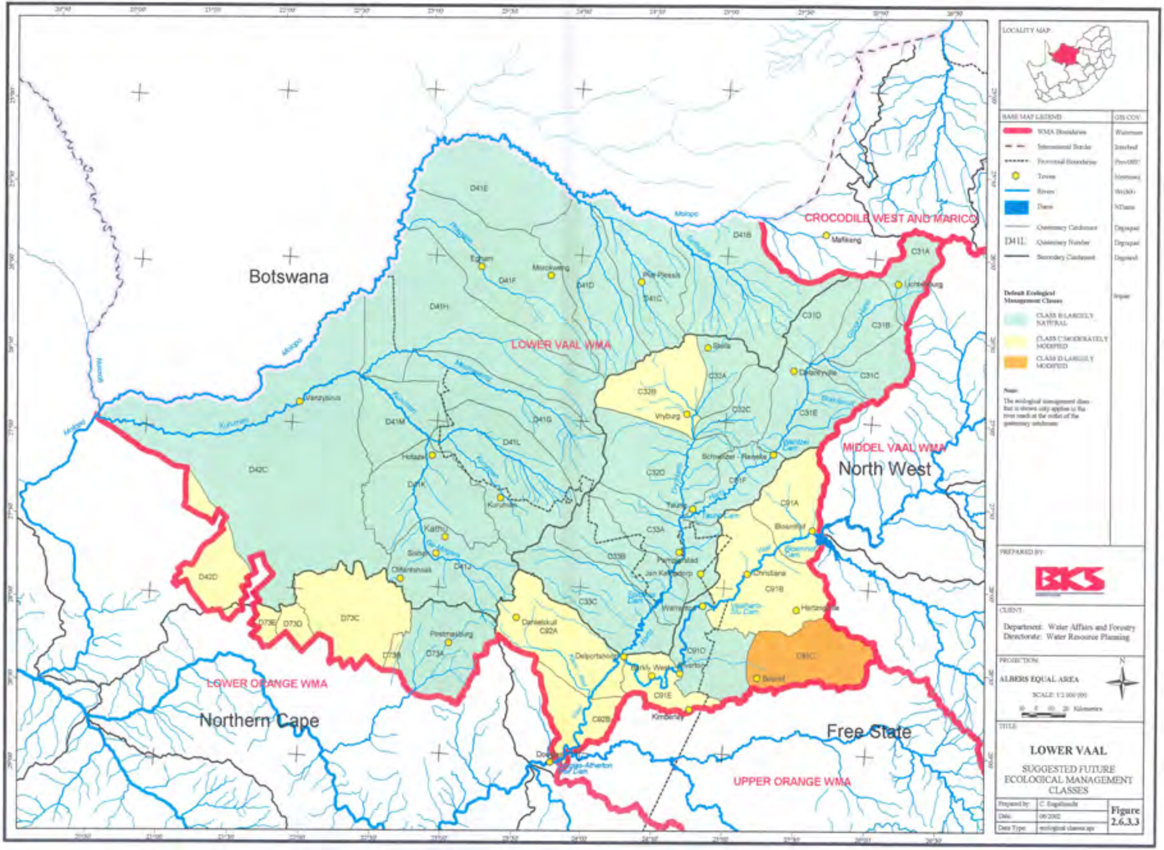
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
UPPER ORANGE WMA
Free State
Molopo
Kuruman
Vryburg
Mafikeng
Lichtenburg
Delareyville
Stella
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Windsorton
Boshof
Barkly West
Kimberley
Douglas
Delportshoop
Postmasburg
Danielskuil
Olifantshoek
Kathu
Sishen
Hotazel
Van Zylsrus
Morokweng
Piet Plessis
Ganyesa
BLOEMHOF DAM NATURE RESERVE
LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Natural Vegetation
Tropical Bush and Savanna
Pure Grassveld
False Grassveld
Karoo and Karoid
False Karoo
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
NATURAL VEGETATION

Figure 2.5.1

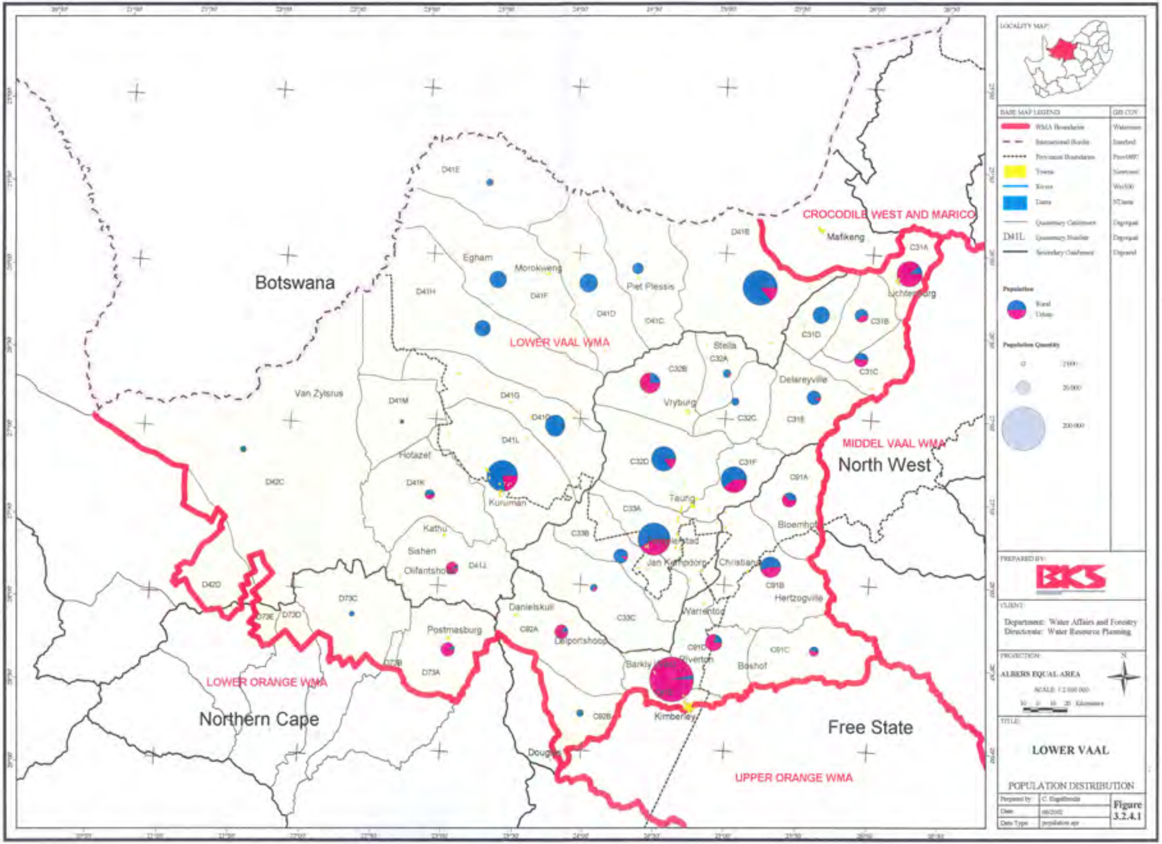

Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Vryburg
Kuruman
Kimberley
Bloemhof
Christiana
Hartswater
Warrenton
Delportshoop
Barkly West
Douglas
Boshof
Danielskuil
Postmasburg
Taung
Stella
Delareyville
Schweizer - Reneke
Jan Kempdorp
Hampton
Pampierstad
S A LOMBAARD
BLOEMHOF DAM NATURE RESERVE
C31A
C31B
C31C
C31D
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
D41B
D41C
D41D
D41E
D41G
D41J
D41L
D41M
D42C
D42D
D73B
D73C
D73D
D73E
LOCALITY MAP
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Default Ecological Management Classes
CLASS B LARGELY NATURAL
CLASS C MODERATELY MODIFIED
CLASS D LARGELY MODIFIED
Note:
The ecological management class that is shown only applies to the river reach at the outlet of the quaternary catchment
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
LOWER VAAL
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Prepared by:
Date:
Data Type:
Figure 2.6.3.1



LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Default Ecological Management Classes
CLASS B LARGELY NATURAL
CLASS C MODERATELY MODIFIED
CLASS D LARGELY MODIFIED
Ecologically Sensitive Sites
RAMSAR Sites
Heritage Sites and Protected Areas
Note:
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES
Figure 2.6.3.2
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
Molopo
Kuruman
Mafikeng
Lichtenburg
Delareyville
Vryburg
Schweizer - Reneke
Wentzel Dam
Taung Dam
Bloemhof Dam
Spitskop Dam
Vaalharts-Blu Dam
Douglas-Atherton Weir Dam
Pollfontein Eye
Kuruman Eye
Hotazel
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Warrenton
Christiana
Bloemhof
Boshof
Kimberley
Douglas
Vanzylsrus
Stella
BARBERSPAN
Canteen Kopje, Stone Age Artefacts, Old Bridge and Tollhouse
Belgravia, Architectural Aesthetic Area
Milner Road Conservation Area, The City Hall
De Beers Boardroom; built by C Rhodes 1888
Honoured Dead Memorial
The Sanatorium
D41E
D41F
D41H
D41D
D41C
D41B
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32C
C32D
C32B
C33B
C92A
C92B
C91E
C91D
C91B
C91C



LOCALITY MAP:
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Default Ecological Management Classes
CLASS B LARGELY NATURAL
CLASS C MODERATELY MODIFIED
CLASS D LARGELY MODIFIED
Note:
The ecological management class that is shown only applies to the river reach at the outlet of the quaternary catchment
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Mafikeng
Lichtenburg
Stella
Delareyville
Vryburg
Schweizer - Reneke
Taung
Bloemhof
Christiana
Hertzogville
Boshof
Kimberley
Barkly West
Delportshoop
Danielskuil
Postmasburg
Olifantshoek
Kathu
Sishen
Kuruman
Hotazel
Vanzylsrus
Warrenton
Jan Kempdorp
Pampierstad
Piet Plessis
Morokweng
Ganyesa
D41E
D41F
D41H
D41D
D41C
D41B
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C92A
C92B
C91E
C91D
C91A
C91B
C91C
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSES
Prepared by:
C. Engelbrecht
Date:
06/2002
Figure 2.6.3.3



LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
Towns
Rivers
Dams
D41L
Population
Rural
Urban
Population Quantity
2 000
20 000
200 000
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
LOWER VAAL
POPULATION DISTRIBUTION
Figure 3.2.4.1
Botswana
North West
Northern Cape
Free State
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Delareyville
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Taung
Bloemhof
Jan Kempdorp
Christiana
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Barkly West
Windsorton
Boshof
Kimberley
Douglas
D41E
D41B
D41H
D41F
D41D
D41C
D41G
D41M
D41L
D41K
D41J
D42C
D42D
D73C
D73E
D73D
D73B
D73A
C31A
C31B
C31C
C31D
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C92A
C92B

FIGURE 3.3.1: CONTRIBUTION BY SECTOR TO THE ECONOMY OF LOWER VAAL WATER MANAGEMENT AREA, 1988 AND 1997 (%)

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DIRECTORATE: WATER RESOURCES PLANNING

FIGURE 3.3.2: COMPUND ANNUAL ECONOMIC GROWTH BY SECTION OF THE LOWER VAAL

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FIGURE 3.3.3: WATER MANAGEMENT AREA AND SOUTH AFRICA
1988 - 1997

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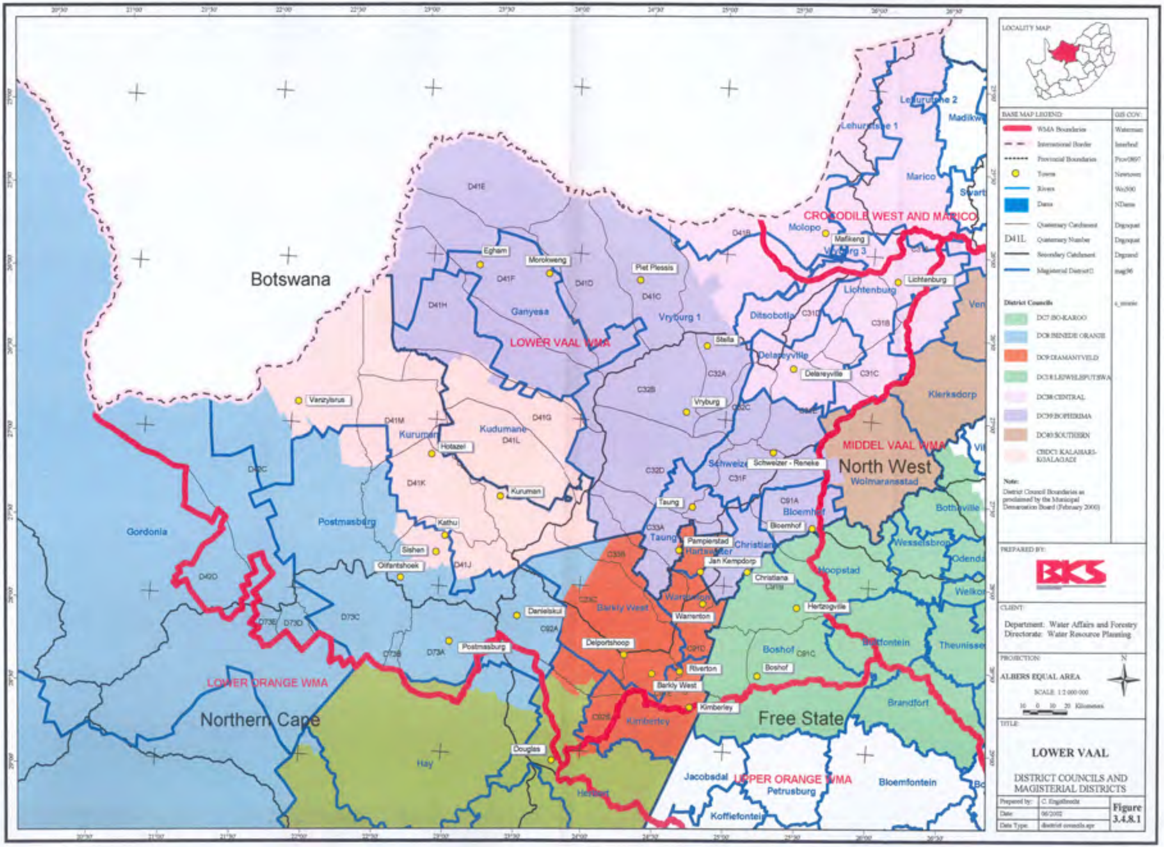
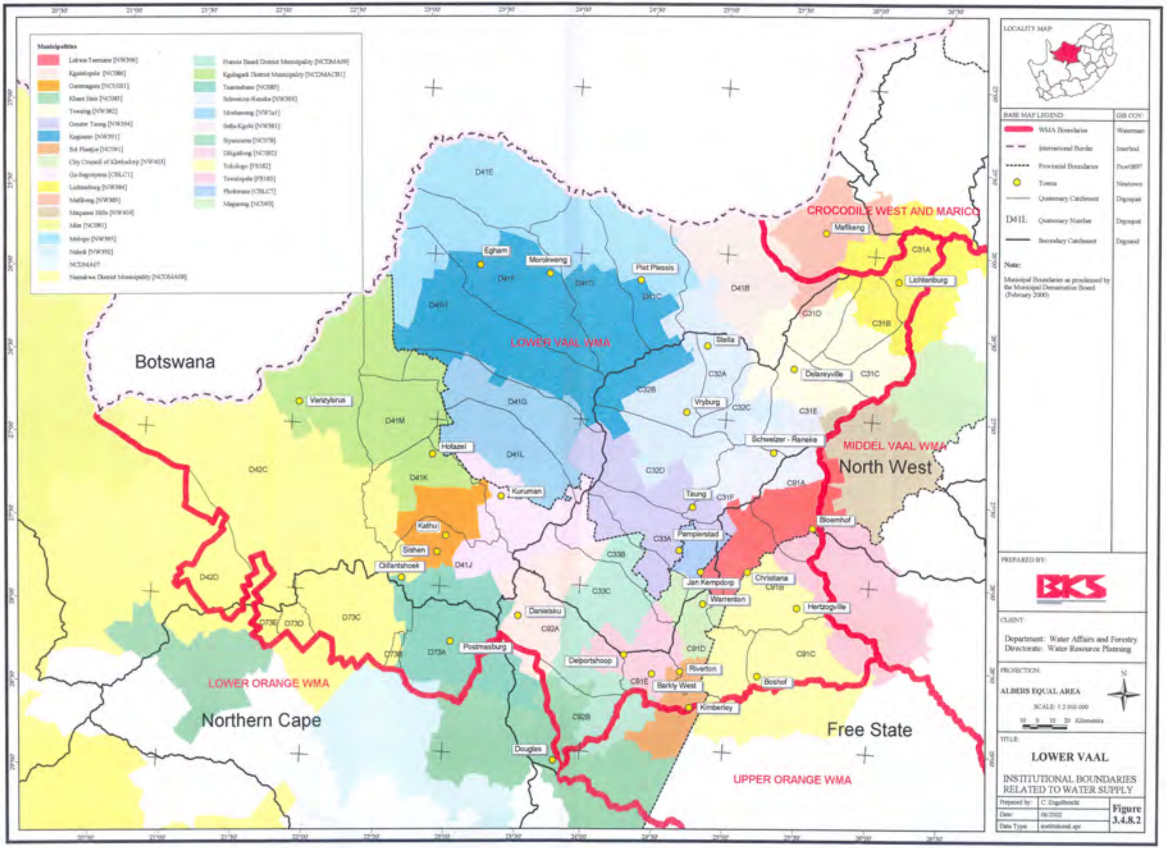
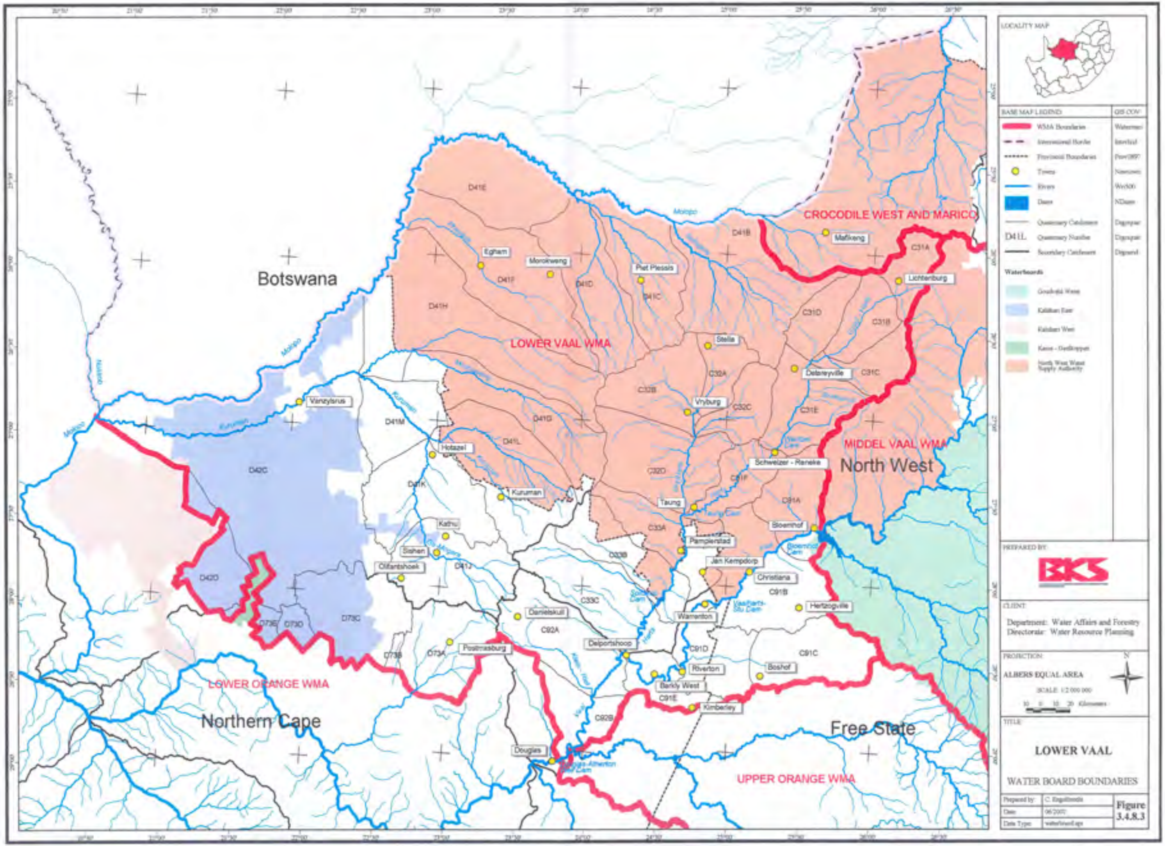


Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Gordonia
Postmasburg
Kuruman
Kudumane
Ganyesa
Vryburg 1
Lehurutshe 1
Lehurutshe 2
Marico
Molopo
Mafikeng
Lichtenburg
Ditsobotla
Delareyville
Schweizer - Reneke
Taung
Christiana
Bloemhof
Wolmaransstad
Klerksdorp
Hartswater
Jan Kempdorp
Warrenton
Barkly West
Kimberley
Delportshoop
Riverton
Boshof
Hertzogville
Hoopstad
Wesselsbron
Bothaville
Brandfort
Theunissen
Jacobsdal
Petrusburg
Koffiefontein
Bloemfontein
Hay
Herbert
Douglas
Danielskuil
Olifantshoek
Sishen
Kathu
Hotazel
Vanzylsrus
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Pampierstad
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Magisterial District
District Councils
DC7 BO-KAROO
DC8 BENEDE ORANJE
DC9 DIAMANTVELD
DC18 LEJWELEPUTSWA
DC38 CENTRAL
DC39 BOPHIRIMA
DC40 SOUTHERN
CBDC1 KALAHARI-KGALAGADI
Note:
District Council Boundaries as proclaimed by the Municipal Demarcation Board (February 2000)
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
10 0 10 20 Kilometers
N
TITLE:
LOWER VAAL
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS
Prepared by: C. Engelbrecht
Date: 06/2002
Data Type: district councils.apr

Figure 3.4.8.1

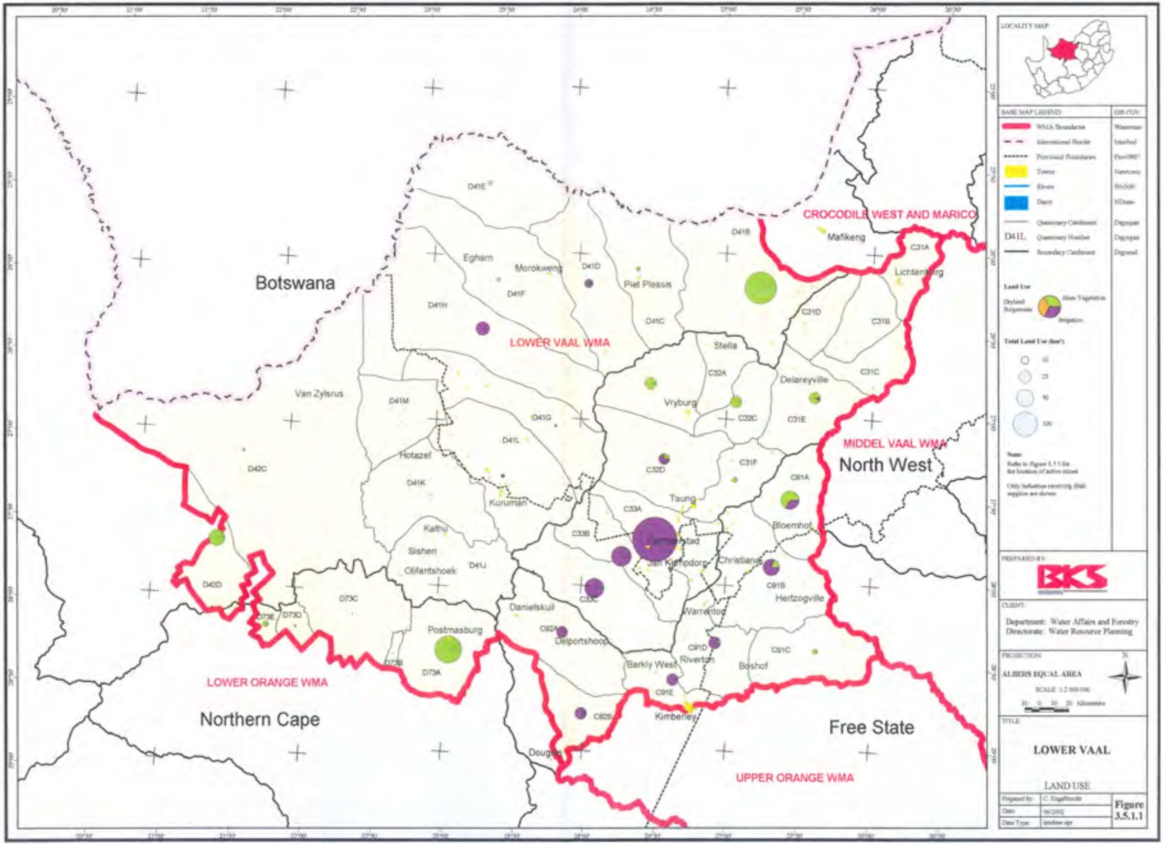


Municipalities
Botswana
Northern Cape
North West
Free State
LOWER VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
MIDDEL VAAL WMA
CROCODILE WEST AND MARICO
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Schweizer - Reneke
Vanzylsrus
Hotazel
Kuruman
Taung
Bloemhof
Kathu
Sishen
Pampierstad
Olifantshoek
Jan Kempdorp
Christiana
Warrenton
Hertzogville
Danielsku
Postmasburg
Delportshoop
Riverton
Barkly West
Boshof
Kimberley
Douglas
D41E
D41F
D41D
D41C
D41H
D41B
C31A
C31D
C31B
C31C
C32A
C32B
C32C
C31E
D41G
D41M
D41L
D41K
C32D
C31F
C91A
D42C
D41J
C33A
C33B
C33C
C91B
D42D
D73E
D73D
D73C
D73B
D73A
C92A
C91D
C91C
C91E
C92B
LOCALITY MAP
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Note:
Municipal Boundaries as proclaimed by the Municipal Demarcation Board (February 2000)
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:2 000 000
10 0 10 20 Kilometers
N
TITLE:
LOWER VAAL
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Prepared by: C. Engelbrecht
Date: 06/2002
Figure 3.4.8.2

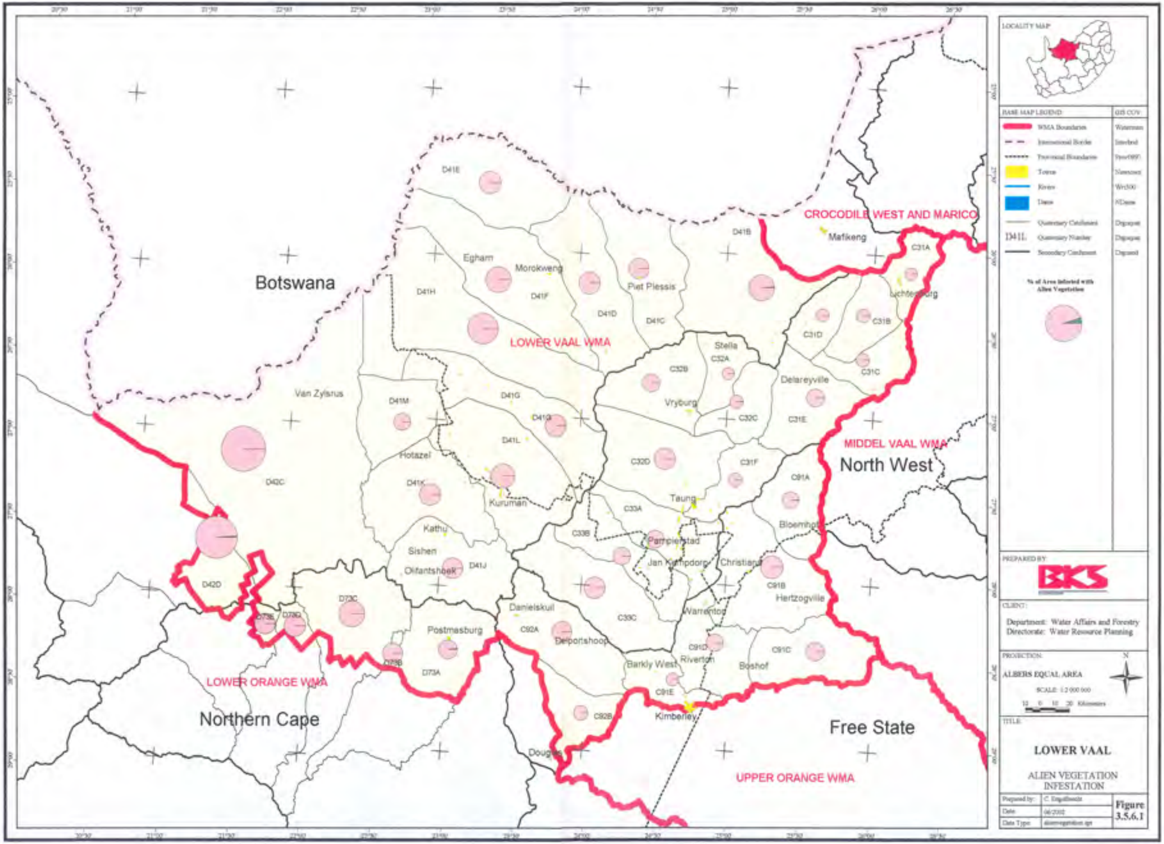


LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Waterboards
Kalahari East
Kalahari West
North West Water Supply Authority
Botswana
North West
Northern Cape
Free State
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
Molopo
Kuruman
Harts
Vaal
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Schweizer - Reneke
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Hertzogville
Warrenton
Vanzylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Danielskuil
Postmasburg
Delportshoop
Riverton
Barkly West
Boshof
Kimberley
Douglas
D41E
D41F
D41D
D41B
D41C
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73C
D73D
C31A
C31B
C31C
C31D
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
TITLE:
LOWER VAAL
WATER BOARD BOUNDARIES
Prepared by:
Date:
Data Type:

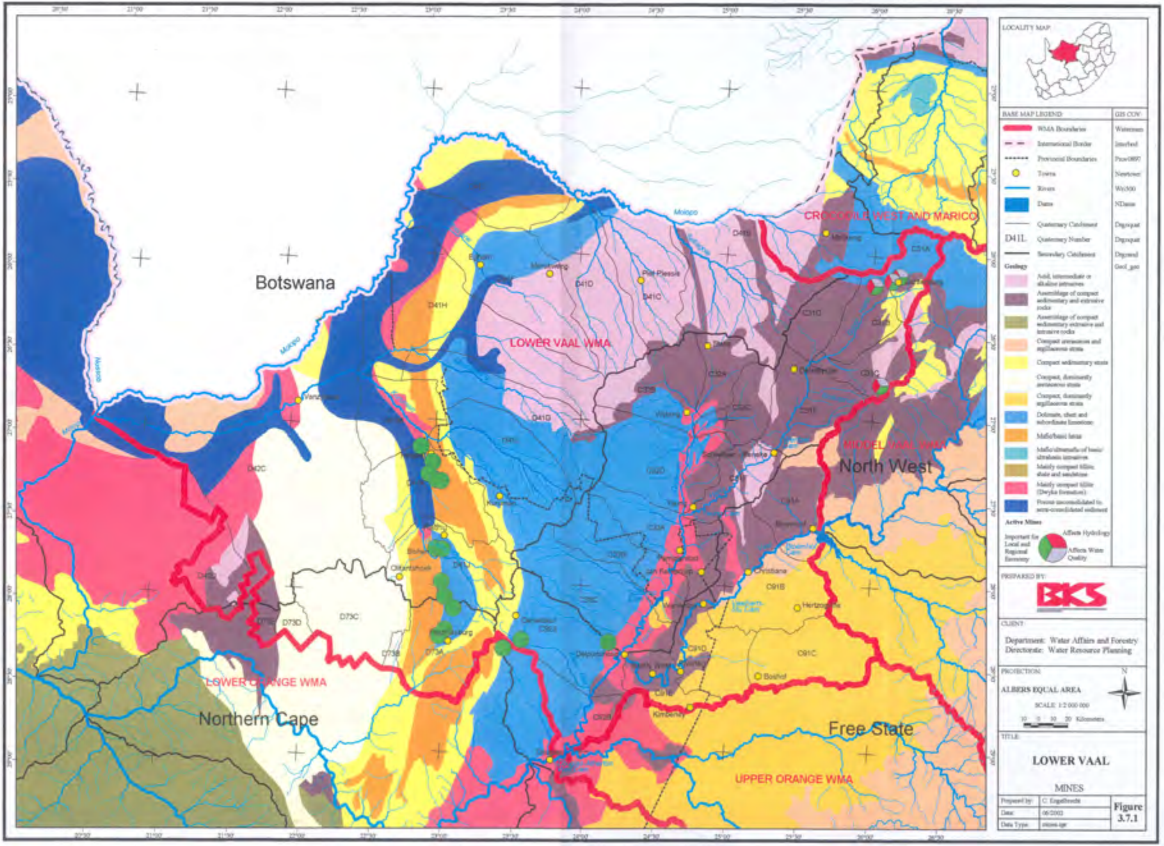
Figure 3.4.8.3



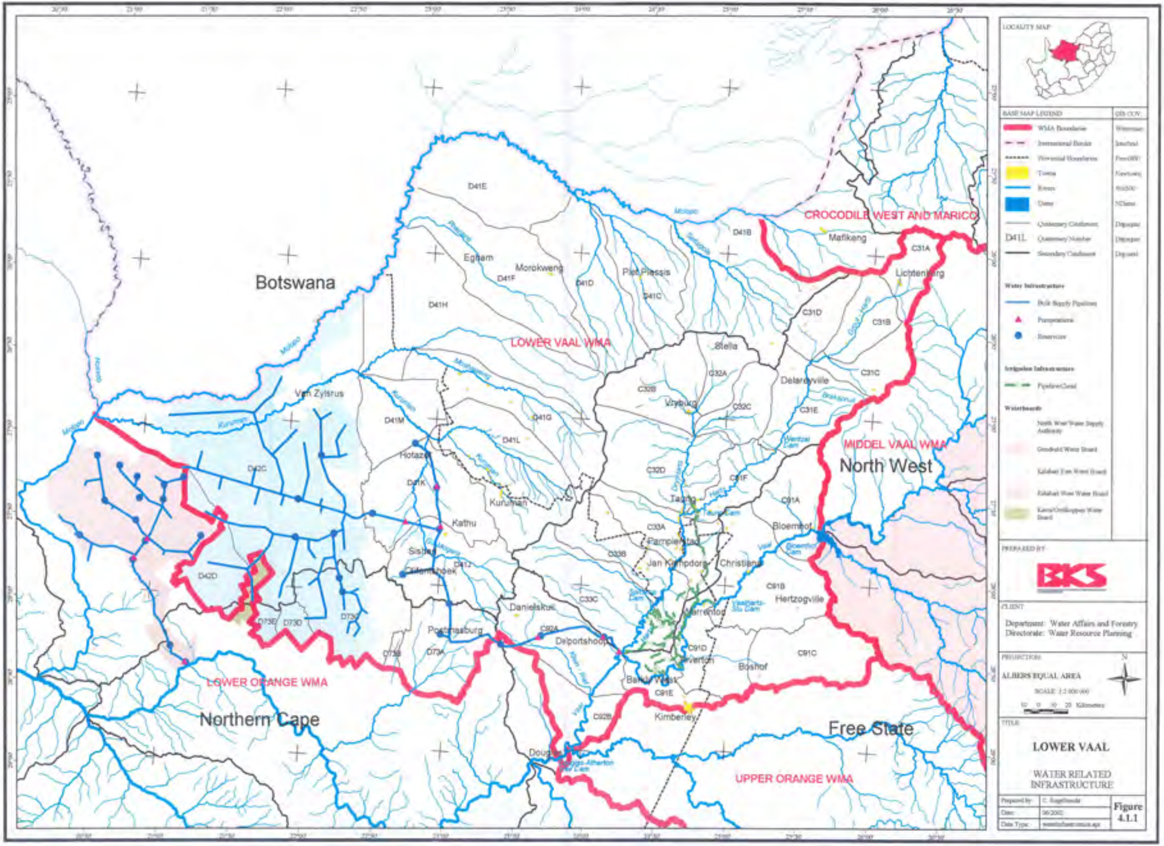
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Delareyville
Van Zylsrus
Hotazel
Kuruman
Taung
Kathu
Sishen
Olifantshoek
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Danielskuil
Delportshoop
Barkly West
Riverton
Boshof
Kimberley
Postmasburg
Douglas
D41E
D41B
D41D
D41F
D41H
D41C
D41M
D41G
D41L
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Land Use
Dryland Sugarcane
Alien Vegetation
Irrigation
Total Land Use (km²)
10
25
50
100
Note:
Refer to Figure 3.7.1 for the location of active mines
Only Industries receiving bulk supplies are shown
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
SCALE 1:2 000 000
10 0 10 20 Kilometers
TITLE:
LOWER VAAL
LAND USE
Prepared by:
C. Engelbrecht
Date:
Data Type:
Figure 3.5.1.1



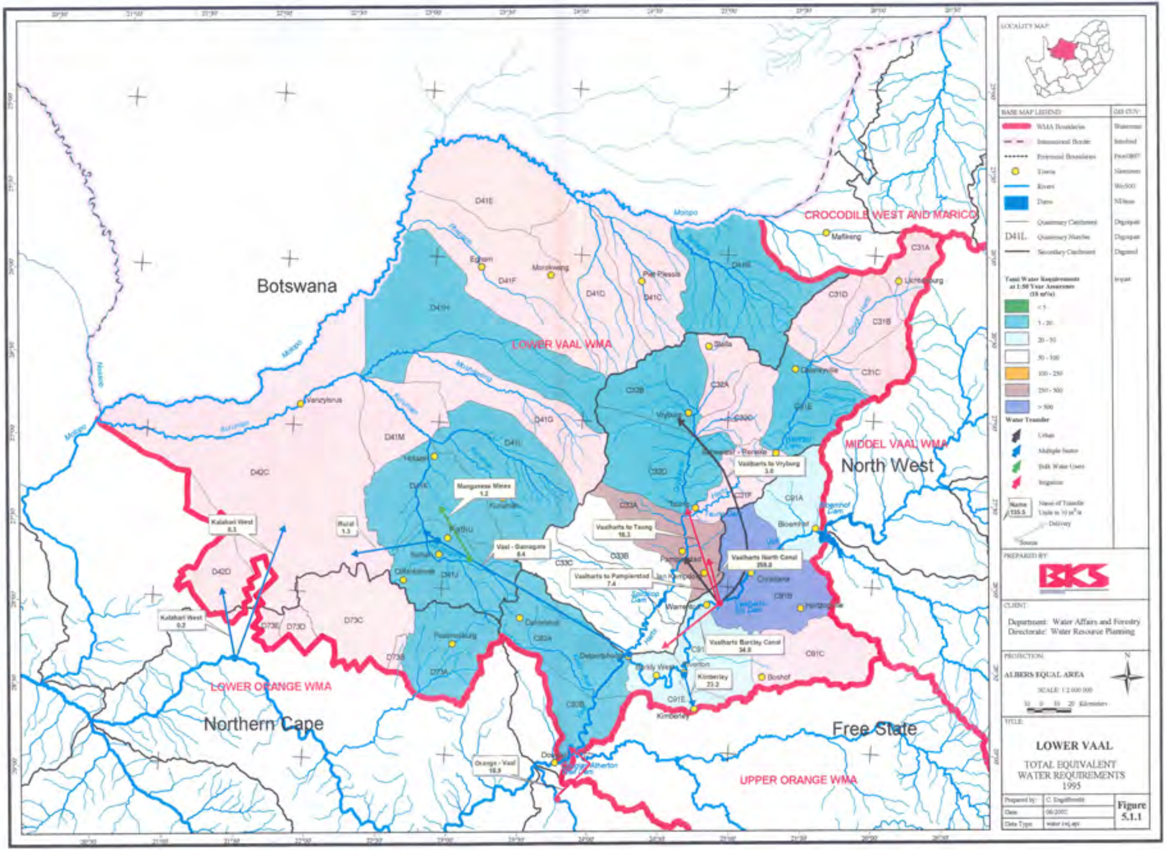
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Delareyville
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Barkly West
Riverton
Boshof
Kimberley
Douglas
D41E
D41B
D41H
D41F
D41D
D41C
C31A
C31B
C31D
C31C
C32B
C32A
C32C
C31E
D41M
D41G
D42C
D41L
C32D
C31F
C91A
D41K
C33A
C33B
D41J
D42D
D73E
D73D
D73C
C33C
C92A
C91B
C91D
C91C
D73B
D73A
C91E
C92B
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
% of Area Infested with Alien Vegetation
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
ALIEN VEGETATION INFESTATION
Prepared by:
Date:
Data Type:
Figure 3.5.6.1



LOCALITY MAP
BASE MAP LEGEND
GIS COV
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Geology
Acid, intermediate or alkaline intrusives
Assemblage of compact sedimentary and extrusive rocks
Assemblage of compact sedimentary extrusive and intrusive rocks
Compact arenaceous and argillaceous strata
Compact sedimentary strata
Compact, dominantly arenaceous strata
Compact, dominantly argillaceous strata
Dolomite, chert and subordinate limestone
Mafic/basic lavas
Mafic/ultramafic of basic/ultrabasic intrusives
Mainly compact tillite, shale and sandstone
Mainly compact tillite (Dwyka formation)
Porous unconsolidated to semi-consolidated sediment
Active Mines
Important for Local and Regional Economy
Affects Hydrology
Affects Water Quality
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:2 000 000
10 0 10 20 Kilometers
N
TITLE:
LOWER VAAL
MINES
Prepared by: C. Engelbrecht
Date: 06/2002
Figure 3.7.1
Botswana
Molopo
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
D41H
D41D
D41C
D41G
D42C
D73D
D73C
D73B
D73A
C31D
C32A
C31C
C91B
C91C
C91D
Mafikeng
Kimberley
Christiana
Hertzogville
Boshof
Vanzylsrus
Olifantshoek
Postmasburg
Douglas
Danielskuil
Kuruman
Vryburg
Schweizer-Reneke
Bloemhof
Delportshoop
Warrenton
Jan Kempdorp
Hartswater
Taung
Bloemhof Dam
Vaalharts Weir

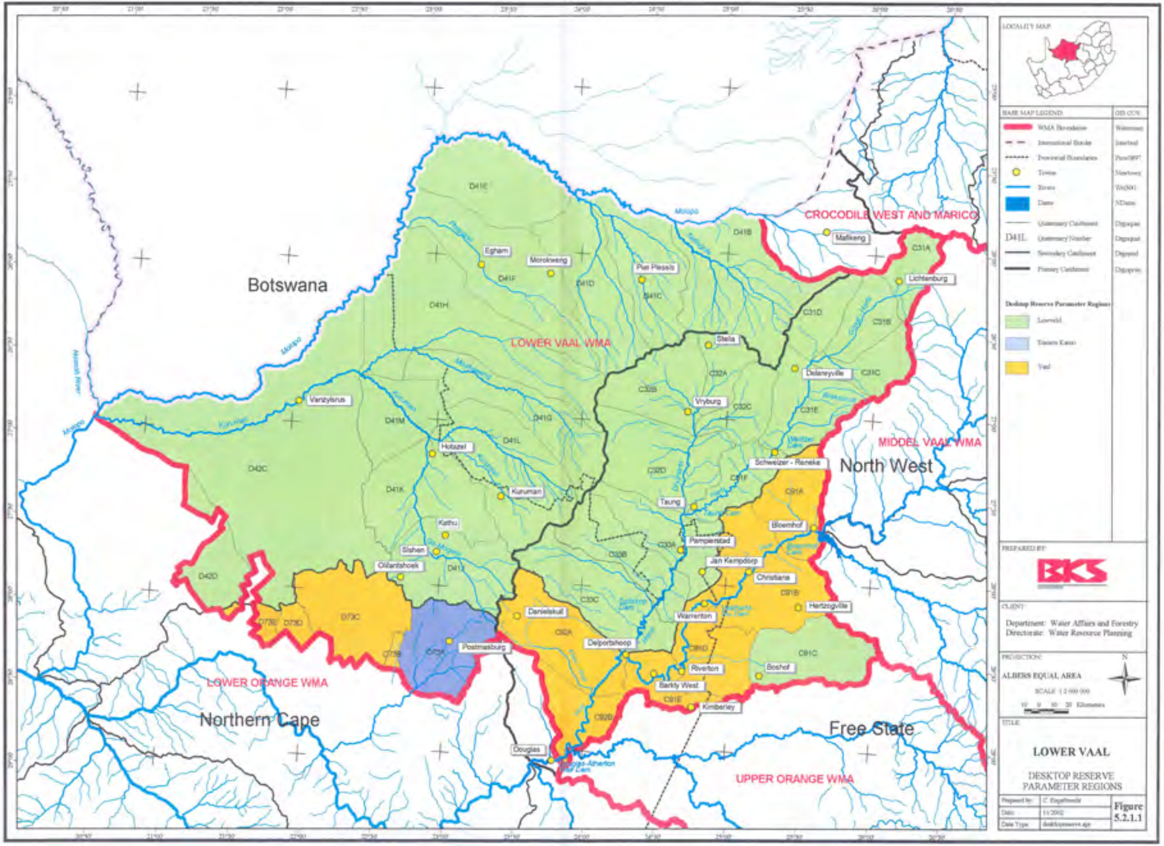


LOCALITY MAP
BASE MAP LEGEND
D41L
PREPARED BY
BKS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
LOWER VAAL
WATER RELATED INFRASTRUCTURE
Figure 4.1.1
Botswana
North West
Northern Cape
Free State
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
Molopo
Kuruman
Vaal
Harts
Van Zylsrus
Egham
Morokweng
Piet Plessis
Mafikeng
Lichtenburg
Stella
Vryburg
Delareyville
Hotazel
Kathu
Kuruman
Sishen
Postmasburg
Danielskuil
Delportshoop
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Boshof
Barkly West
Kimberley
Douglas
Taung Dam
Bloemhof Dam
Vaalharts Dam
Wentzel Dam
D41E
D41B
D41F
D41D
D41C
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73A
C31A
C31D
C31B
C31C
C31E
C32A
C32B
C32C
C32D
C31F
C91A
C33A
C33B
C33C
C91B
C91D
C91C
C91E
C92A
C92B



Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Molopo
Kuruman
Mafikeng
Lichtenburg
Vryburg
Stella
Delareyville
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Warrenton
Hertzogville
Barkly West
Kimberley
Boshof
Douglas
Delportshoop
Danielskuil
Postmasburg
Kathu
Kuruman
Hotazel
Olifantshoek
Vanzylsrus
Ganyesa
Morokweng
Piet Plessis
Bloemhof Dam
Spitskop Dam
Vaalharts Weir
Manganese Mines 1.2
Kalahari West 0.1
Kalahari West 0.2
Rural 1.1
Vaal - Gamagara 8.4
Vaalharts to Vryburg 3.0
Vaalharts to Taung 16.3
Vaalharts North Canal 259.0
Vaalharts to Pampierstad 7.4
Vaalharts Barclay Canal 34.0
Kimberley 23.2
Orange - Vaal 18.9
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Total Water Requirements at 1:50 Year Assurance
< 5
5 - 20
20 - 50
50 - 100
100 - 250
250 - 500
> 500
Water Transfer
Urban
Multiple Sector
Bulk Water Users
Irrigation
Name 135.5
Name of Transfer
Delivery
Source
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:2 000 000
TITLE:
LOWER VAAL
TOTAL EQUIVALENT WATER REQUIREMENTS 1995
Prepared by:
Date
Data Type
Figure 5.1.1

Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
D41E
D41B
D41F
D41D
D41C
D41H
D41M
D41G
D41L
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
Egham
Morokweng
Piet Plessis
Mafikeng
Lichtenburg
Stella
Delareyville
Vryburg
Schweizer - Reneke
Taung
Bloemhof
Jan Kempdorp
Warrenton
Hertzogville
Boshof
Vanzylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Barkly West
Riverton
Kimberley
Douglas
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
User Groups
Afforestation
Alien Vegetation
Urban
Irrigation
Rural
Bulk
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
WATER REQUIREMENTS
AT 1:50 YEAR ASSURANCE
PER USER SECTOR 1995
Prepared by:
Date:
06/2002
Data Type:
Figure
5.1.2


LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Primary Catchment
Desktop Reserve Parameter Regions
Lowveld
Eastern Karoo
Vaal
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
Kilometers
TITLE:
LOWER VAAL
DESKTOP RESERVE PARAMETER REGIONS
Prepared by:
Date:
11/2002
Data Type:
Figure 5.2.1.1
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Vanzylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Schweizer - Reneke
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Warrenton
Hertzogville
Riverton
Barkly West
Boshof
Kimberley
Douglas
D41E
D41B
D41F
D41D
D41C
D41H
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
D41G
D41L
D41M
D41K
D41J
D42C
D42D
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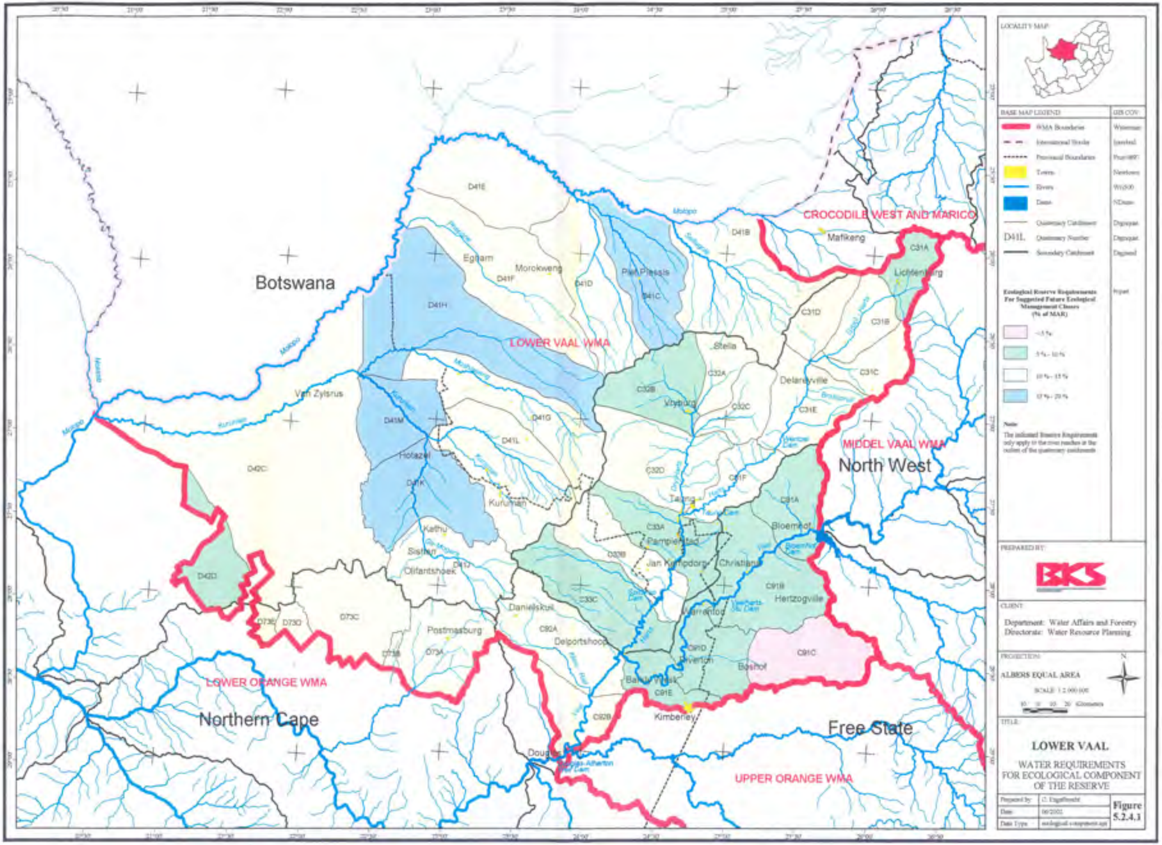
C91C
C91D
C91E


LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
Towns
Rivers
Dams
Quaternary Number
Ecological Reserve Requirements For Suggested Future Ecological Management Classes (% of MAR)
Note
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Prepared by:
Date:
Data Type:
Figure 5.2.4.1
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Stella
Vryburg
Delareyville
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Hertzogville
Warrenton
Boshof
Barkly West
Kimberley
Douglas
Delportshoop
Danielskuil
Postmasburg
Olifantshoek
Sishen
Kathu
Kuruman
Hotazel
Van Zylsrus
Morokweng
Piet Plessis
Molopo
Kuruman
D41E
D41F
D41D
D41C
D41B
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
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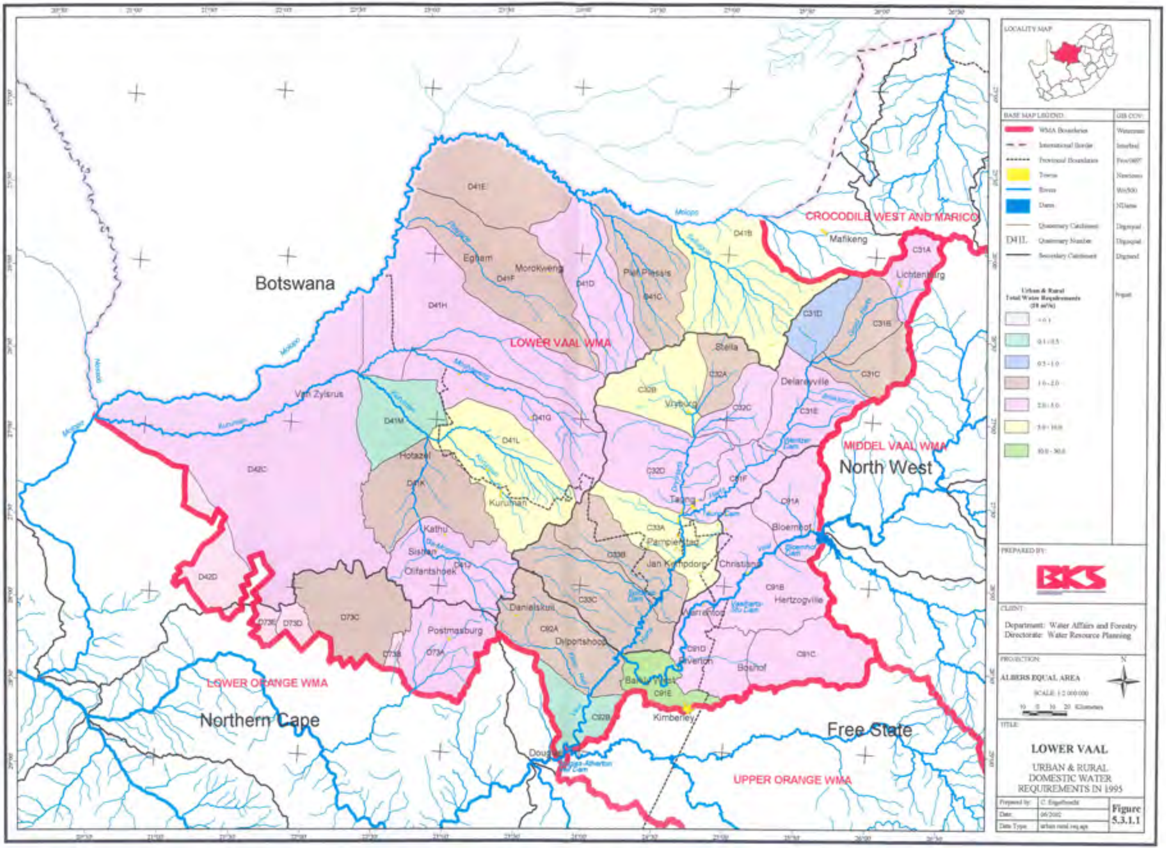
C91B
C91C
C91D
C91E
C92A
C92B



LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Urban & Rural Total Water Requirements
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
URBAN & RURAL DOMESTIC WATER REQUIREMENTS IN 1995
Figure 5.3.1.1
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Mafikeng
Lichtenburg
Delareyville
Stella
Vryburg
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Boshof
Barkly West
Kimberley
Danielskuil
Postmasburg
Olifantshoek
Sishen
Kathu
Kuruman
Hotazel
Van Zylsrus
Egham
Morokweng
Piet Plessis
D41E
D41F
D41D
D41C
D41B
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
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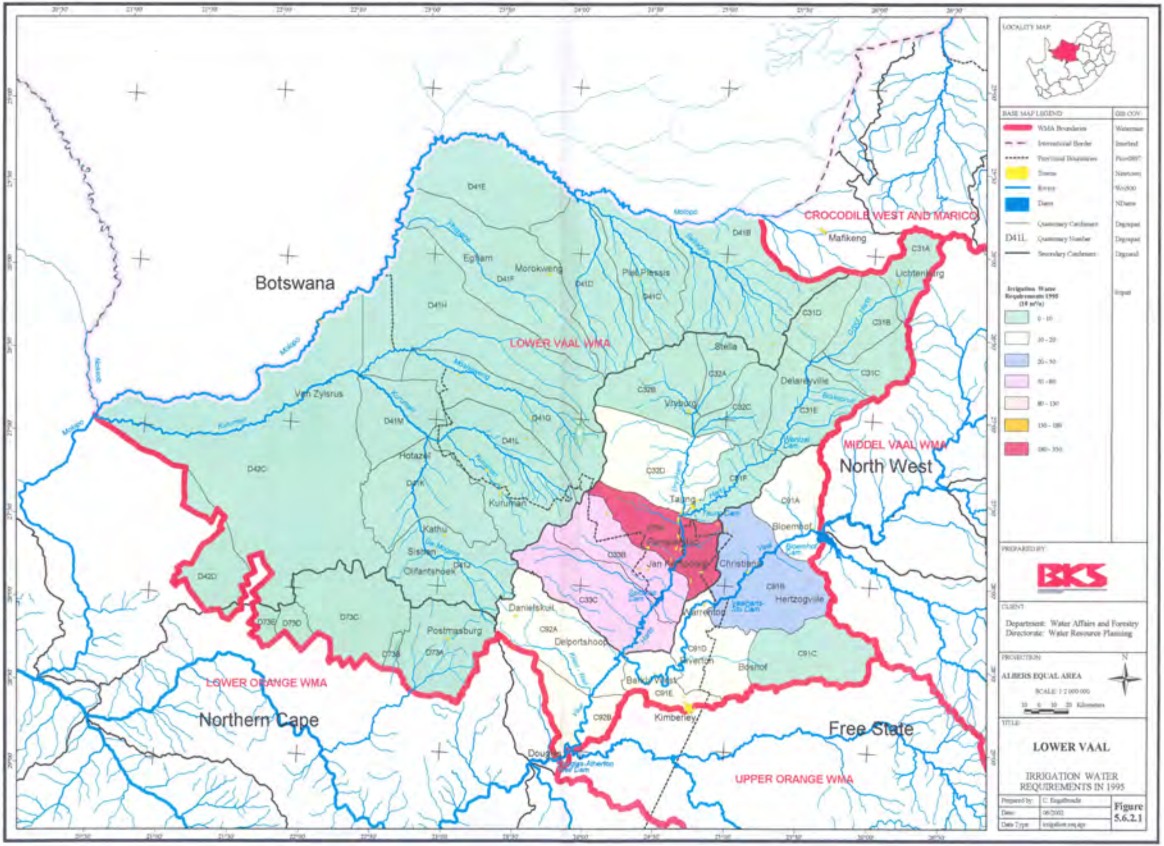
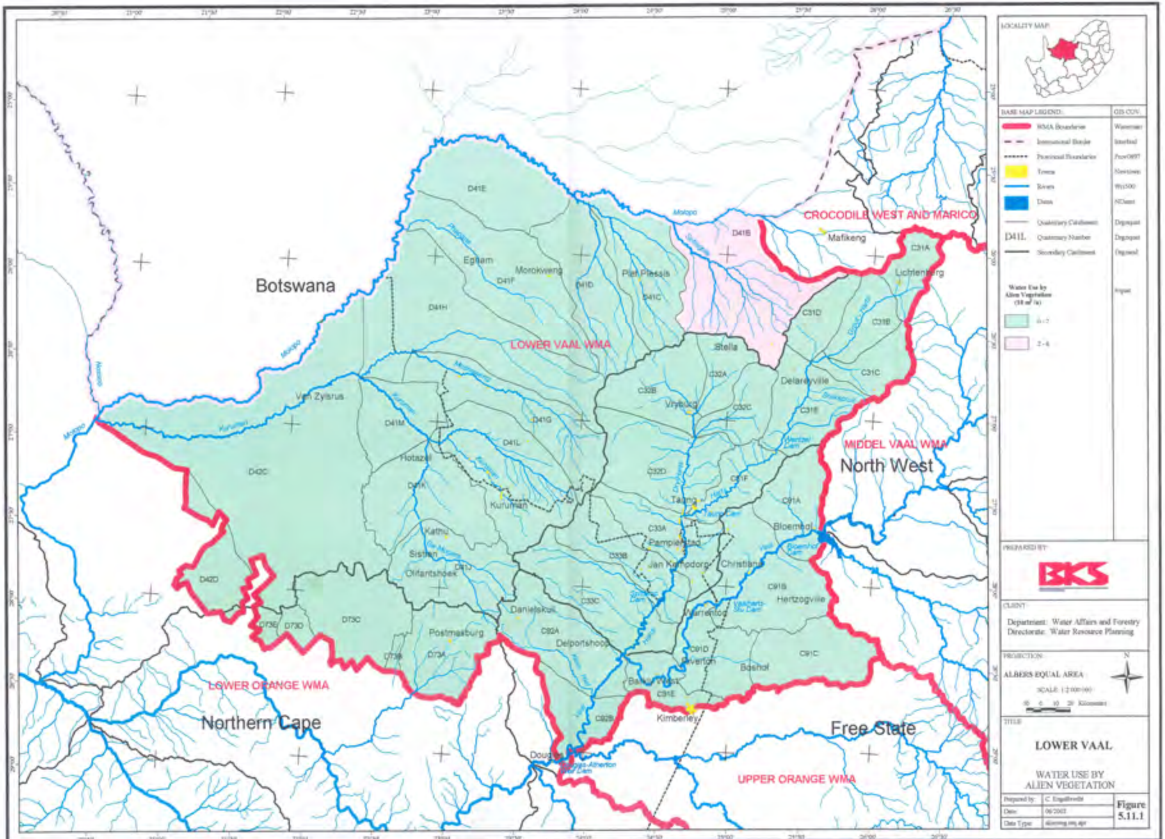
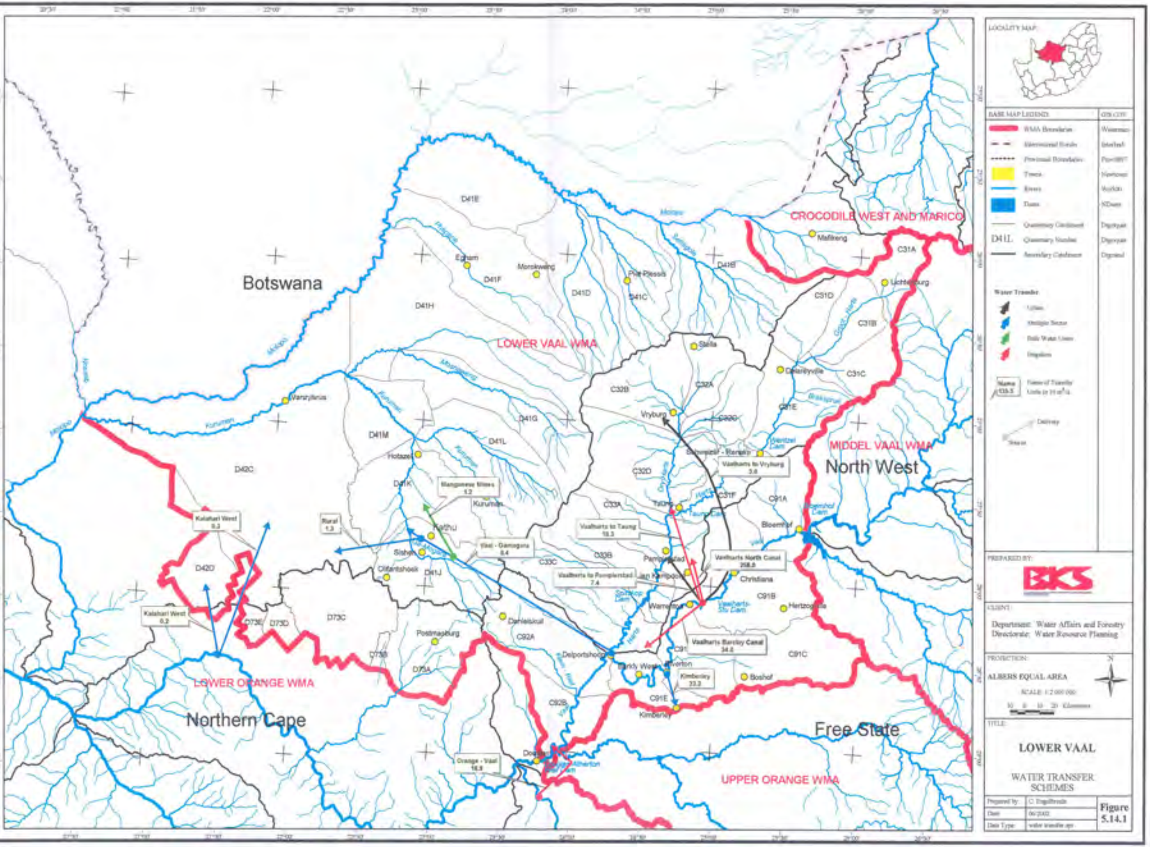
C91C
C91D
C91E
C92A
C92B

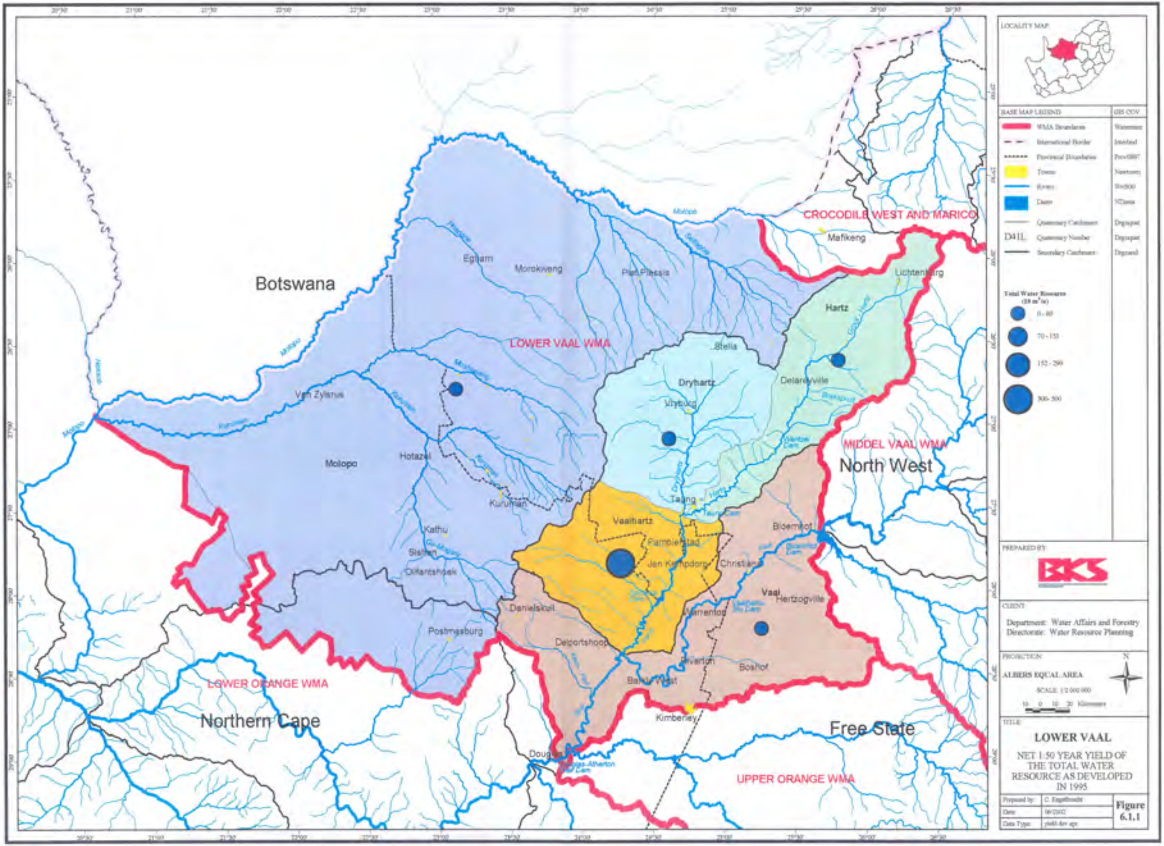


LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Irrigation Water Requirements 1995
0 - 10
10 - 20
20 - 50
50 - 80
80 - 130
130 - 180
180 - 350
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Harts
Vaal
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Taung
Bloemhof
Christiana
Hertzogville
Jan Kempdorp
Warrenton
Boshof
Barkly West
Kimberley
Douglas
D41E
D41B
D41F
D41D
D41C
D41H
C31A
C31D
C31B
C32A
C32B
C32C
C31C
C31E
D41G
D41M
D41L
D42C
D41K
D41J
D42D
D73E
D73D
D73C
D73B
D73A
C32D
C31F
C91A
C33B
C33C
C91B
C92A
C91D
C91C
C91E
C92B
PREPARED BY
BKS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:2 000 000
10 0 10 20 Kilometers
N
TITLE
LOWER VAAL
IRRIGATION WATER REQUIREMENTS IN 1995
Prepared by: C. Engelbrecht
Date: 06/2002
Figure 5.6.2.1



Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Vaal
Harts
Mafikeng
Lichtenburg
Stella
Delareyville
Vryburg
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Boshof
Kimberley
Barkly West
Riverton
Delportshoop
Danielskuil
Postmasburg
Olifantshoek
Sishen
Kathu
Kuruman
Hotazel
Van Zylsrus
Egham
Morokweng
Piet Plessis
Douglas
D41E
D41F
D41D
D41C
D41B
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND:
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Water Use by Alien Vegetation
2 - 6
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
Kilometers
TITLE:
LOWER VAAL
WATER USE BY ALIEN VEGETATION
Prepared by:
Date:
Data Type:
Figure 5.11.1


Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Kalahari West
0.2
Kalahari West
0.2
Rural
1.3
Manganese Mines
1.2
Vaal - Gamagara
8.4
Vaalharts to Taung
10.3
Vaalharts to Vryburg
3.6
Vaalharts North Canal
258.8
Vaalharts to Pampierstad
7.4
Vaalharts Barkly Canal
34.0
Kimberley
23.2
Orange - Vaal
18.8
Mafikeng
Lichtenburg
Vryburg
Taung
Bloemhof
Christiana
Warrenton
Hertzogville
Boshof
Kimberley
Barkly West
Delportshoop
Danielskuil
Postmasburg
Olifantshoek
Sishen
Kathu
Kuruman
Hotazel
Vanzylsrus
Eghan
Morokweng
Piet Plessis
Stella
Douglas
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
Water Transfer
Urban
Irrigation
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
WATER TRANSFER SCHEMES
Figure 5.14.1

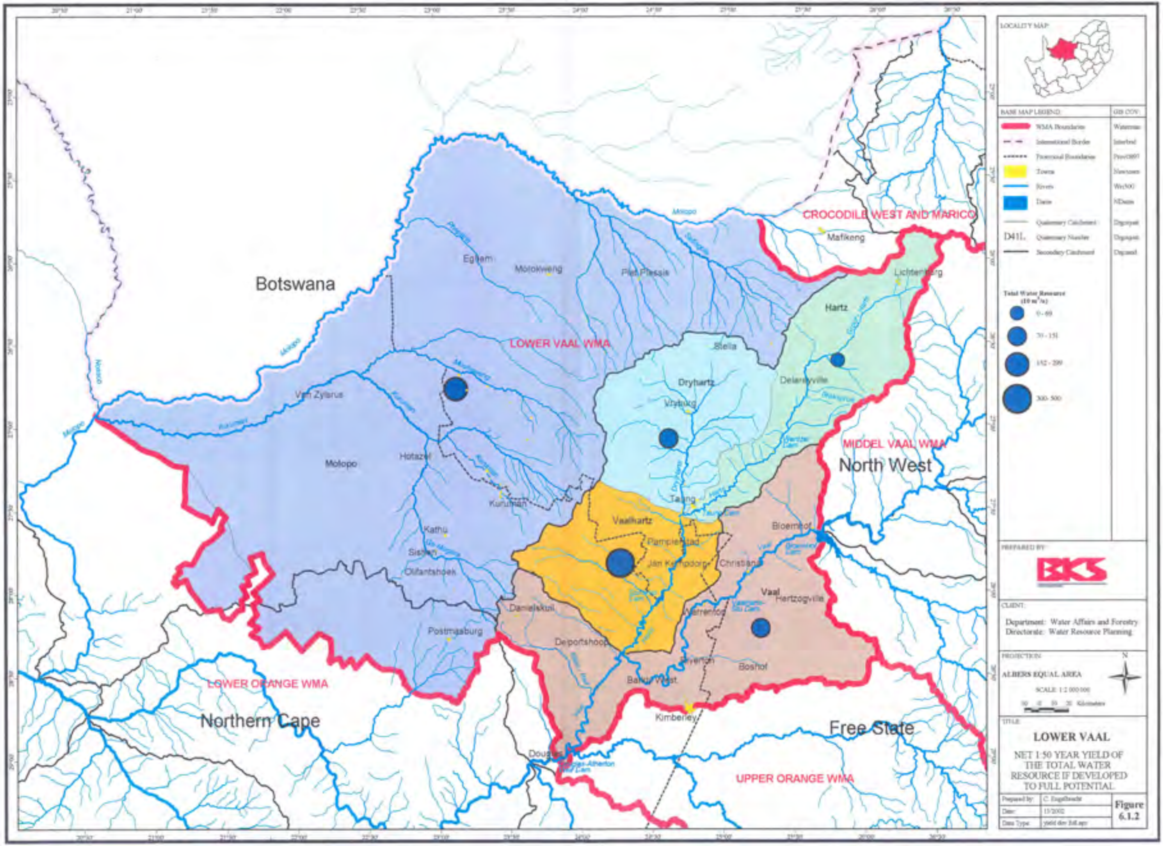


TITLE:

LOWER VAAL

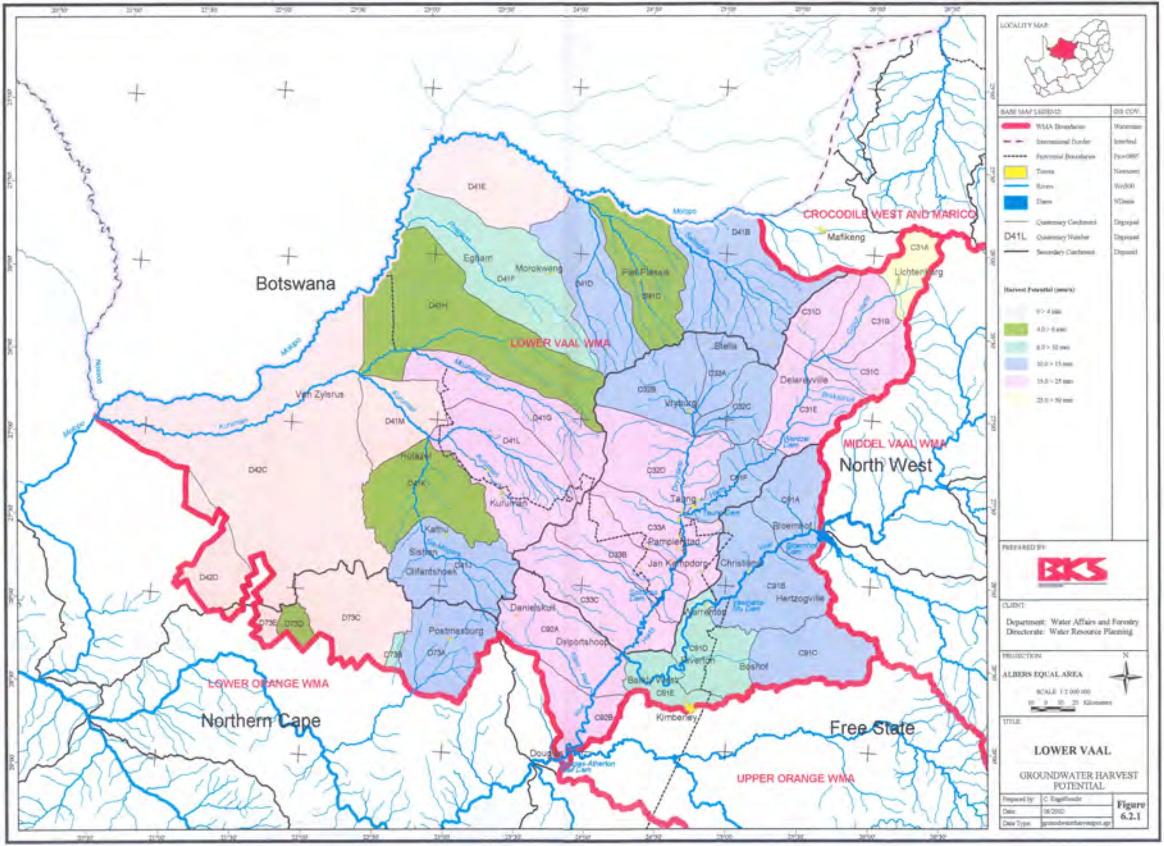
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE AS DEVELOPED IN 1995

Figure 6.1.1



Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Molopo
Hartz
Dryhartz
Vaalhartz
Vaal
Mafikeng
Lichtenburg
Eglem
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Taung
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Boshof
Barkly West
Kimberley
Douglas
LOCALITY MAP
BASE MAP LEGEND:
WMA Boundaries
International Border
Towns
Rivers
Dams
D41L
Total Water Resource
0 - 69
300 - 500
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE IF DEVELOPED TO FULL POTENTIAL
Prepared by:
Date:
Data Type:

Figure 6.1.2



LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Harvest Potential (mm/a)
Botswana
Northern Cape
North West
Free State
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Vryburg
Delareyville
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Barkly West
Boshof
Kimberley
Douglas
D41E
D41F
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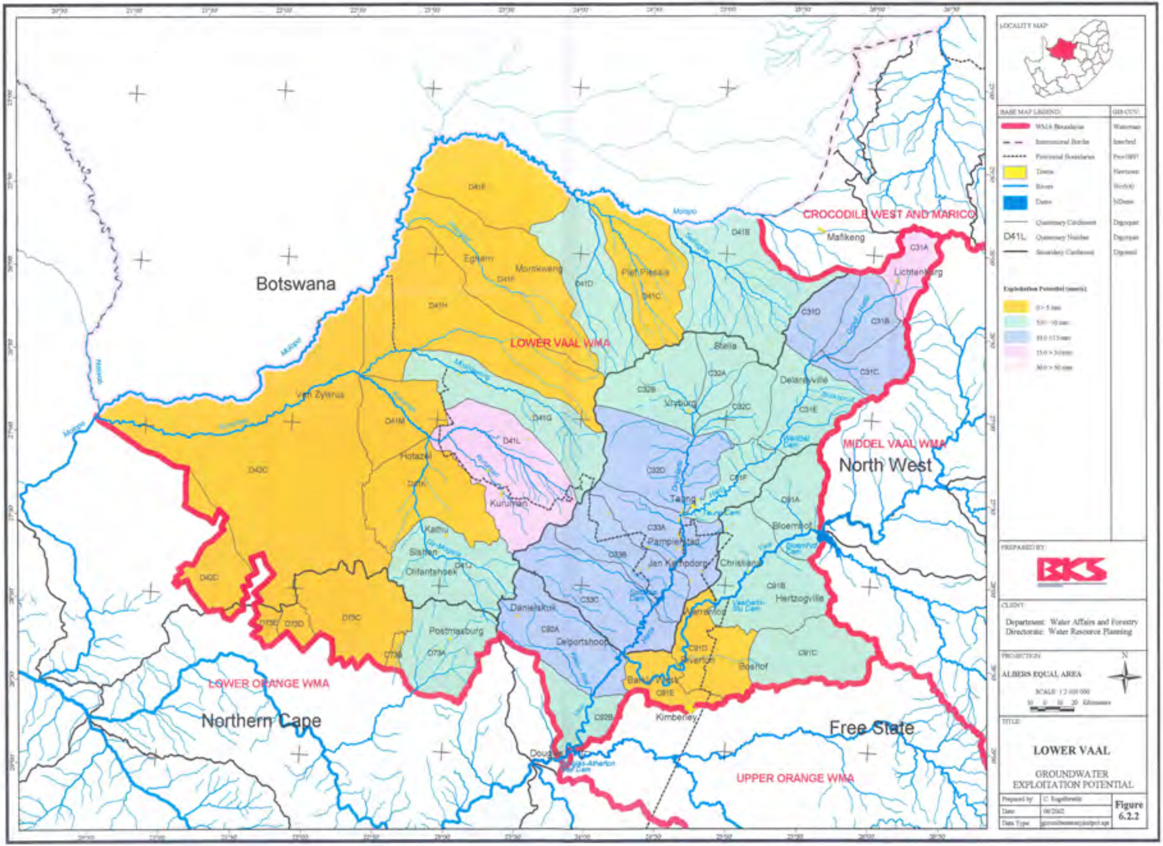
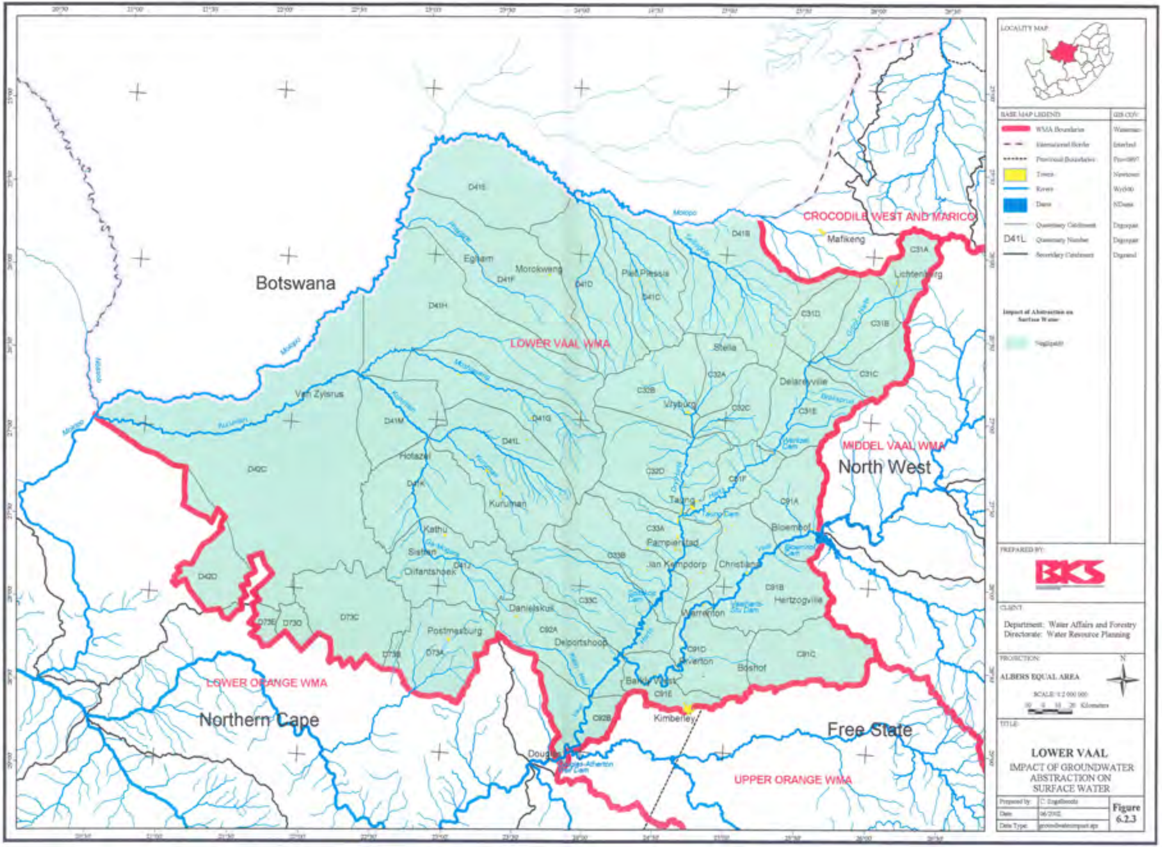
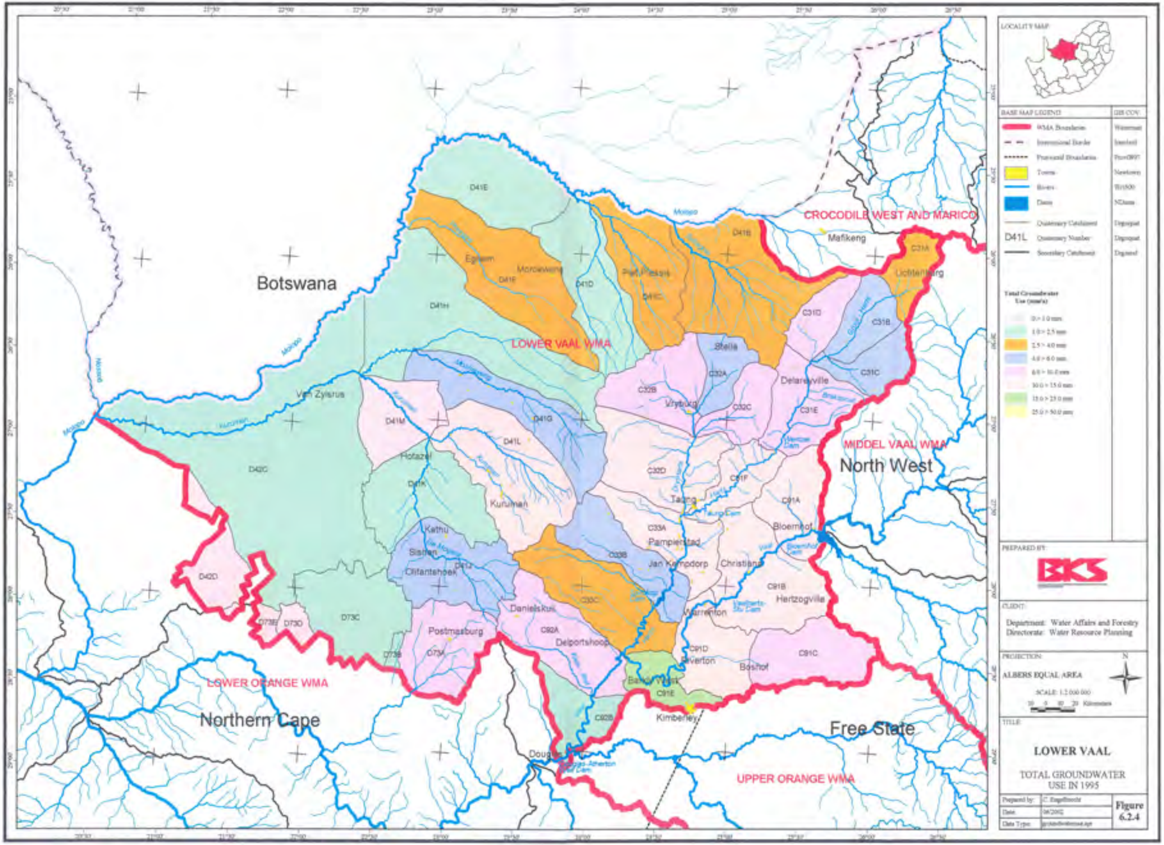
D41H
D41G
D41M
D41L
D41K
D41J
D42C
D42D
D73C
D73D
D73E
D73A
D73B
C31A
C31D
C31B
C31C
C31E
C31F
C32B
C32A
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
Kilometers
TITLE:
LOWER VAAL
GROUNDWATER HARVEST POTENTIAL
Prepared by:
Date:
Data Type:
Figure 6.2.1



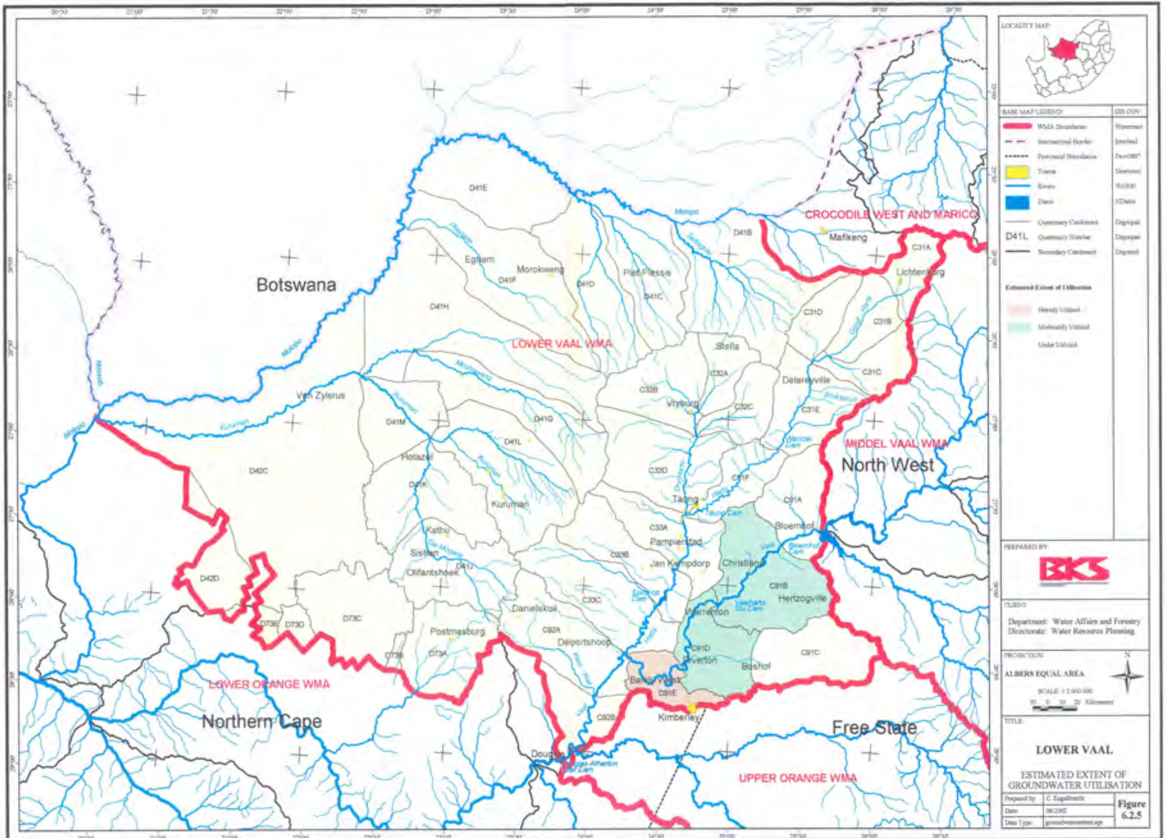
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Exploitation Potential (mm/a)
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Mafikeng
Lichtenburg
Egnam
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Kathu
Sishen
Olifantshoek
Hertzogville
Warrenton
Danielskuil
Delportshoop
Postmasburg
Riverton
Boshof
Barkly West
Kimberley
Douglas
C31A
C31B
C31C
C31D
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
D41B
D41C
D41D
D41E
D41F
D41G
D41H
D41J
D41K
D41L
D41M
D42C
D42D
D73A
D73B
D73C
D73D
D73E
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
GROUNDWATER
EXPLOITATION POTENTIAL
Prepared by:
Date:
06/2002
Data Type
Figure
6.2.2



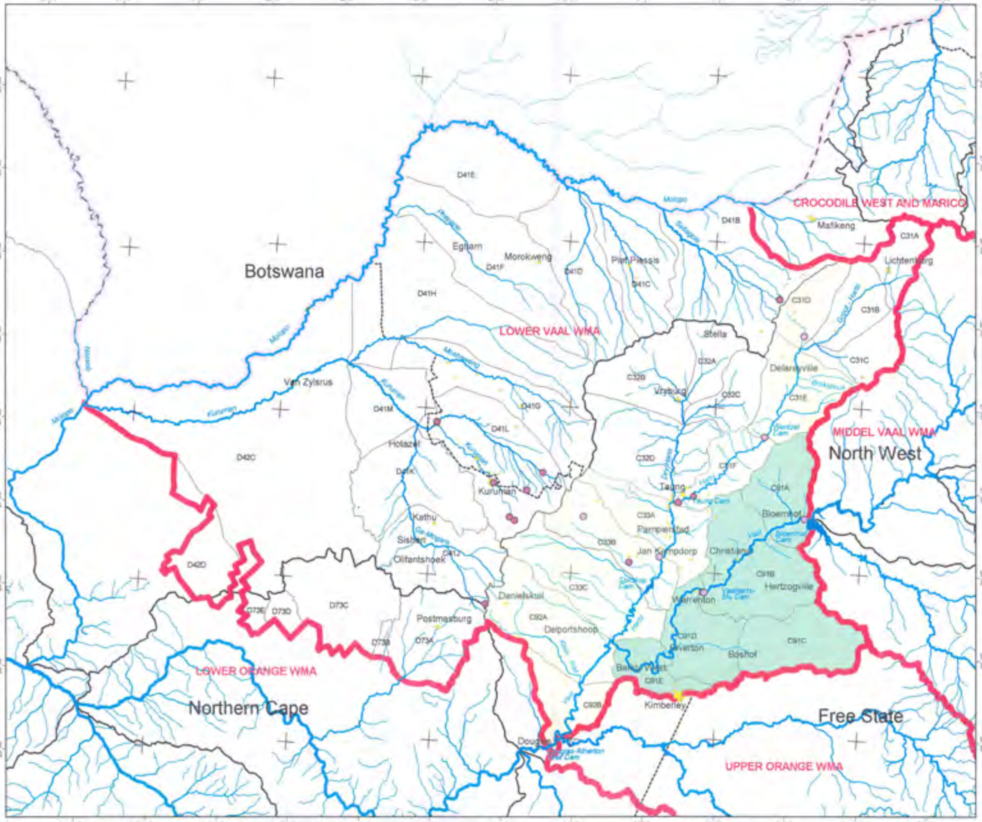
LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Impact of Abstraction on Surface Water
Negligible
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Ganyesa
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Taung
Kathu
Sishen
Olifantshoek
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Windsorton
Barkly West
Boshof
Kimberley
Douglas
Molopo
Kuruman
Harts
Vaal
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
Kilometers
N
TITLE:
LOWER VAAL
IMPACT OF GROUNDWATER ABSTRACTION ON SURFACE WATER
Prepared by: C. Engelbrecht
Date: 06/2002
Figure 6.2.3



Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Delareyville
Stella
Vryburg
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Warrenton
Hertzogville
Boshof
Barkly West
Kimberley
Delportshoop
Danielskuil
Postmasburg
Olifantshoek
Sishen
Kathu
Kuruman
Hotazel
Van Zylsrus
Douglas
Piet Plessis
Morokweng
Molopo
Kuruman
Vaal
LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Total Groundwater Use (mm/a)
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
TOTAL GROUNDWATER USE IN 1995
Prepared by:
Date:
Data Type:
Figure 6.2.4



LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
Towns
Rivers
Dams
D41L
Estimated Extent of Utilisation
Heavily Utilised
Moderately Utilised
Under Utilised
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Vaal
Harts
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Taung
Bloemhof
Pampierstad
Jan Kempdorp
Christiana
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Riverton
Boshof
Barkly West
Kimberley
Douglas
D41E
D41B
C31A
D41F
D41D
D41C
D41H
C31D
C31B
C32A
C32B
C32C
C31C
C31E
D41M
D41G
D41L
D42C
C32D
C31F
D41K
C91A
C33A
C33B
D42D
D41J
C91B
C33C
D73E
D73D
D73C
C92A
C91D
C91C
D73B
D73A
C91E
C92B
PREPARED BY:
BKS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
LOWER VAAL
ESTIMATED EXTENT OF GROUNDWATER UTILISATION
Prepared by: C. Engelbrecht
Date: 06/2002
Figure 6.2.5



LOCALITY MAP

BASE MAP LEGEND

WMA Boundaries

International Border

Provincial Boundaries

Towns

Rivers

Dams

Quaternary Catchment

D41L Quaternary Number

Secondary Catchment

Surface Water Quality Class

Good

Marginal

No Data

Water Quality Monitoring Stations

Adequate Data

Inadequate Data

PREPARED BY:

BKS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resource Planning

PROJECTION:

ALBERS EQUAL AREA

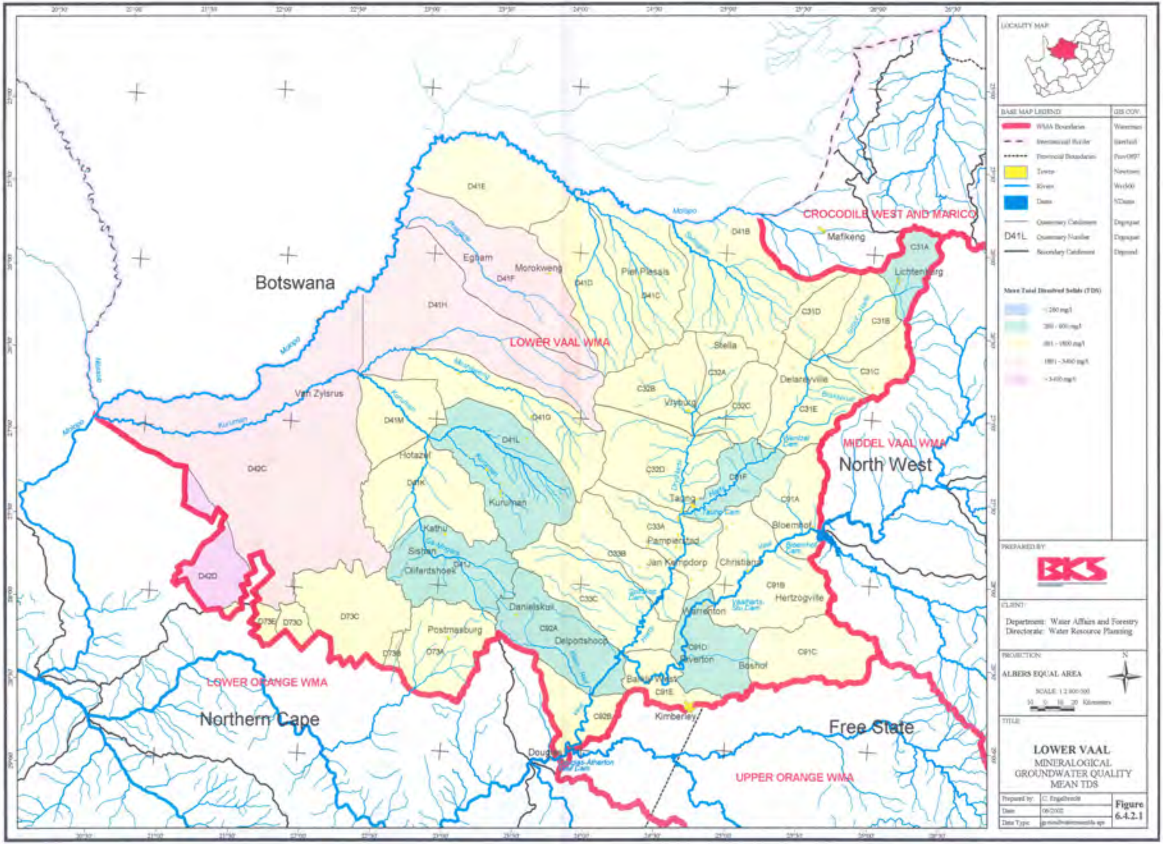
SCALE: 1:2 000 000

TITLE:

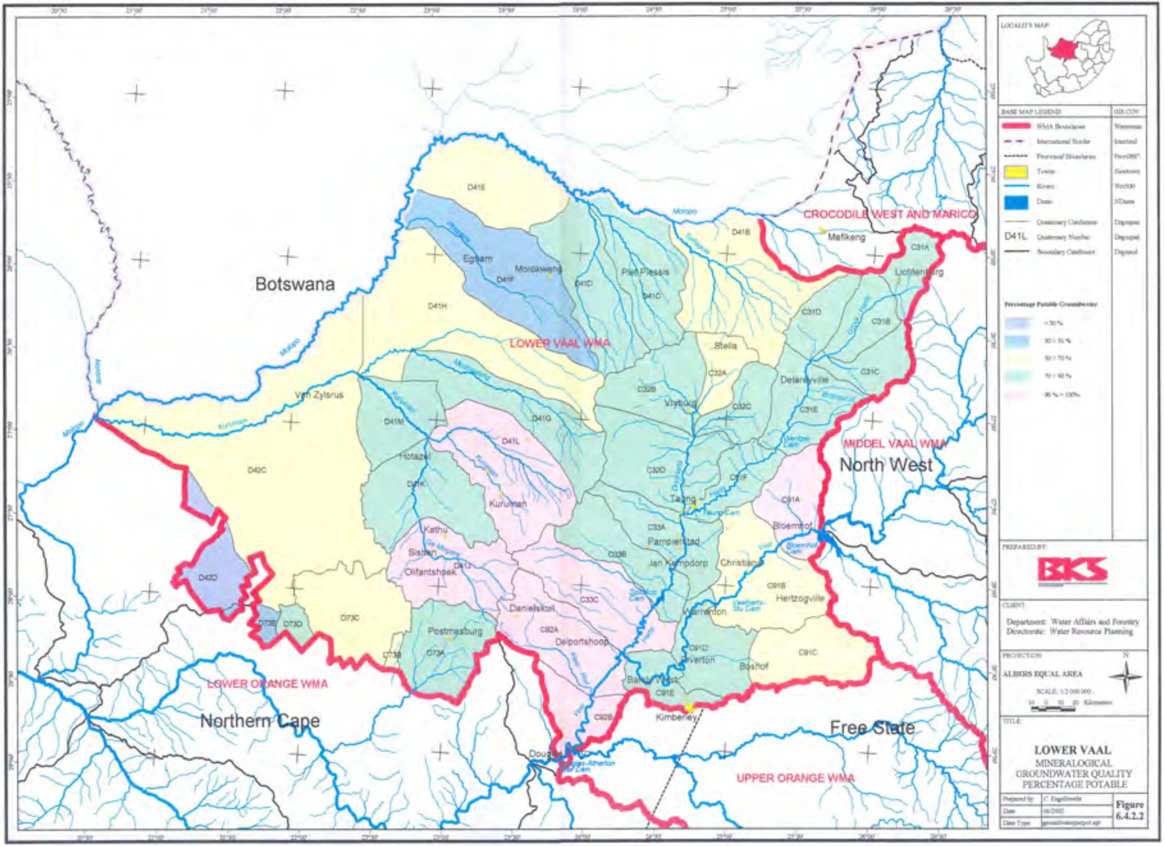
LOWER VAAL

MINERALOGICAL SURFACE WATER QUALITY

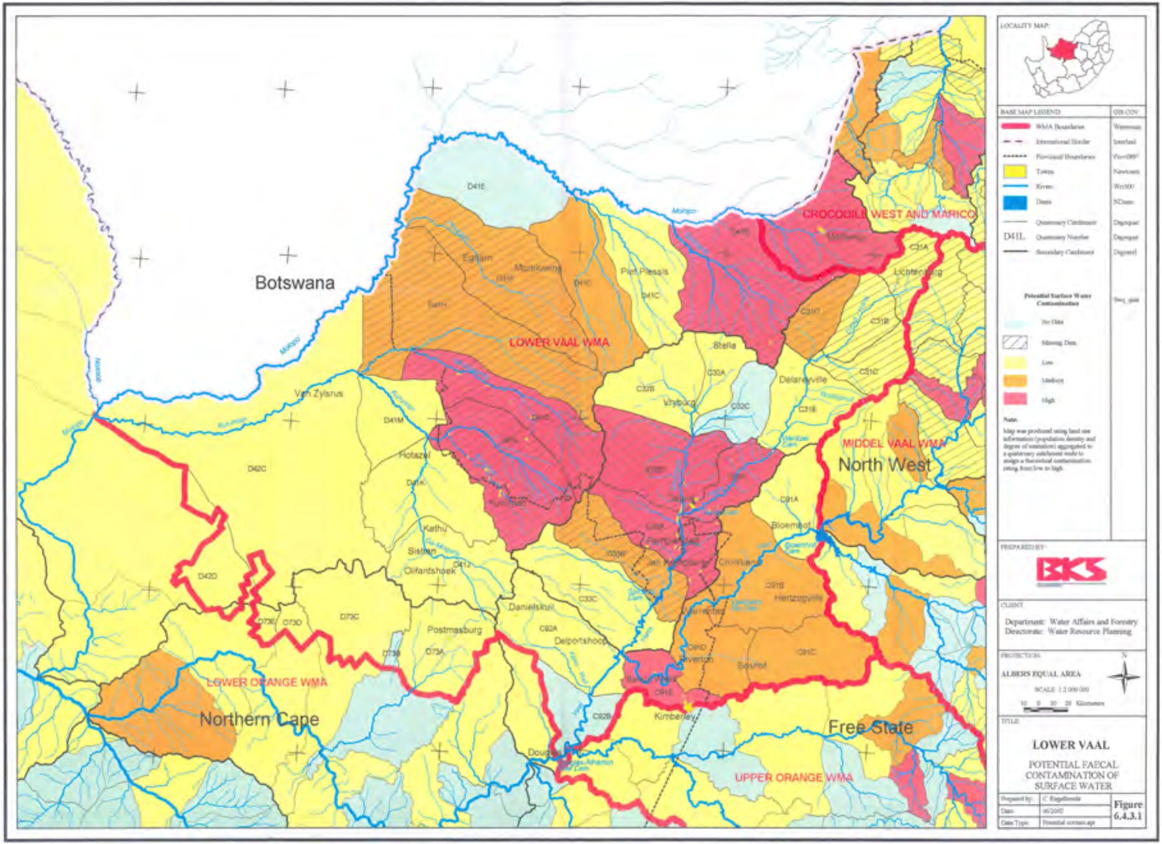
Prepared by:	C. Engelbrecht	Figure 6.4.1.1
Date:	06/2002	



LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
Towns
Rivers
Dams
D41L
Mean Total Dissolved Solids (TDS)
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
Lichtenburg
Egham
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Kathu
Sishen
Olifantshoek
Danielskuil
Postmasburg
Delportshoop
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Boshof
Barkly West
Kimberley
Douglas
Molopo
Kuruman
D41E
D41F
D41H
D41D
D41C
D41B
C31A
C31D
C31B
C31C
C31E
C32A
C32B
C32C
C32D
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73B
D73A
C33A
C33B
C33C
C92A
C92B
C91A
C91B
C91C
C91D
C91E
C31F
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
Kilometers
TITLE:
LOWER VAAL
MINERALOGICAL
GROUNDWATER QUALITY
MEAN TDS
Prepared by:
C. Engelbrecht
Date:
Data Type:
Figure
6.4.2.1



LOCALITY MAP
BASE MAP LEGEND
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
Percentage Potable Groundwater
Botswana
CROCODILE WEST AND MARICO
LOWER VAAL WMA
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Molopo
Kuruman
Vaal
Harts
Mafikeng
Lichtenburg
Morokweng
Piet Plessis
Stella
Delareyville
Vryburg
Van Zylsrus
Hotazel
Kuruman
Taung
Kathu
Sishen
Olifantshoek
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Danielskuil
Postmasburg
Delportshoop
Riverton
Boshof
Barkly West
Kimberley
Douglas
D41E
D41F
D41D
D41C
D41B
C31A
D41H
C31D
C31B
C32A
C32B
C31C
C32C
C31E
D41M
D41G
D41L
D42C
D41K
C32D
C31F
C91A
C33A
C33B
D41J
C91B
D42D
C33C
C92A
D73E
D73D
D73C
D73B
D73A
C91C
C92B
C91E
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION
ALBERS EQUAL AREA
TITLE:
LOWER VAAL
MINERALOGICAL
GROUNDWATER QUALITY
PERCENTAGE POTABLE
Figure 6.4.2.2



Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Van Zylsrus
Hotazel
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Douglas
Kimberley
Vryburg
Stella
Delareyville
Lichtenburg
Bloemhof
Christiana
Hertzogville
Warrenton
Jan Kempdorp
Kuruman
Piet Plessis
Mareetsane
Eghann
Ganyesa
Morokweng
Bosho
Molopo
Kuruman
Kimberley
Vaal
Harts
D41E
D41H
D41C
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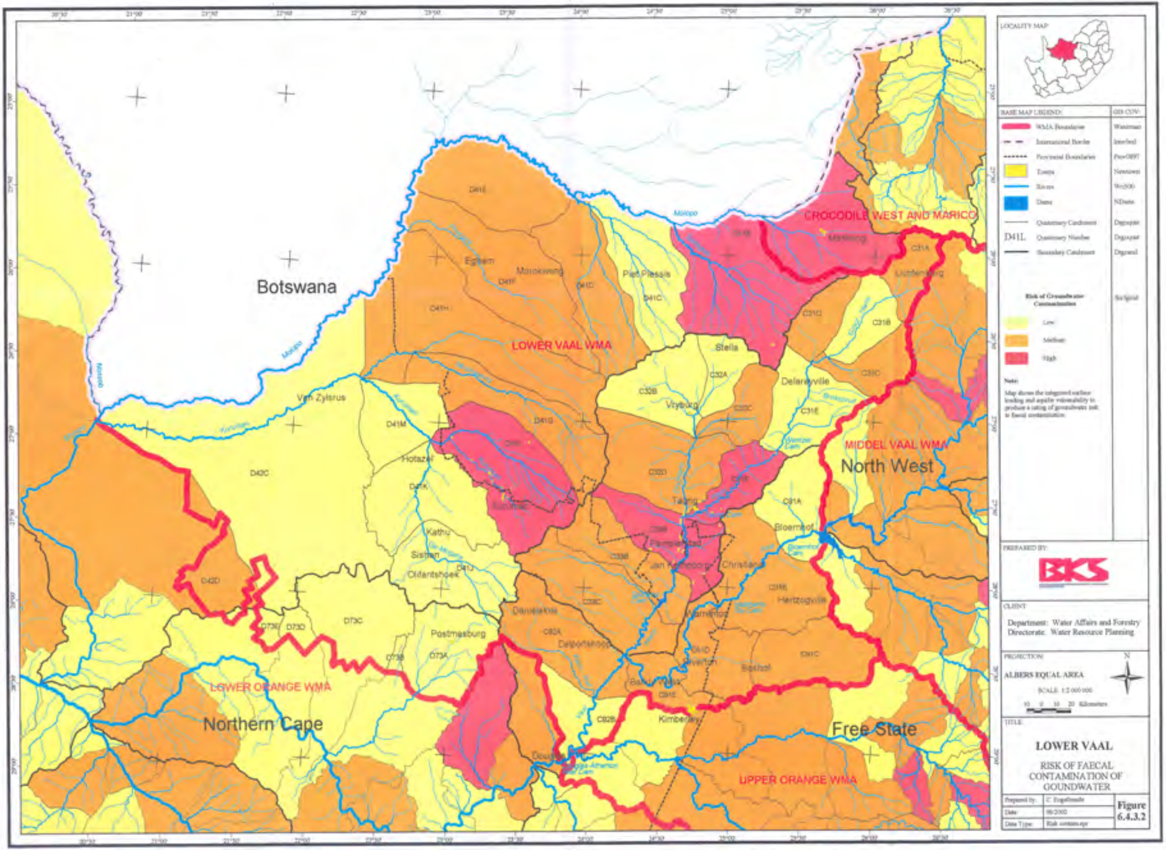
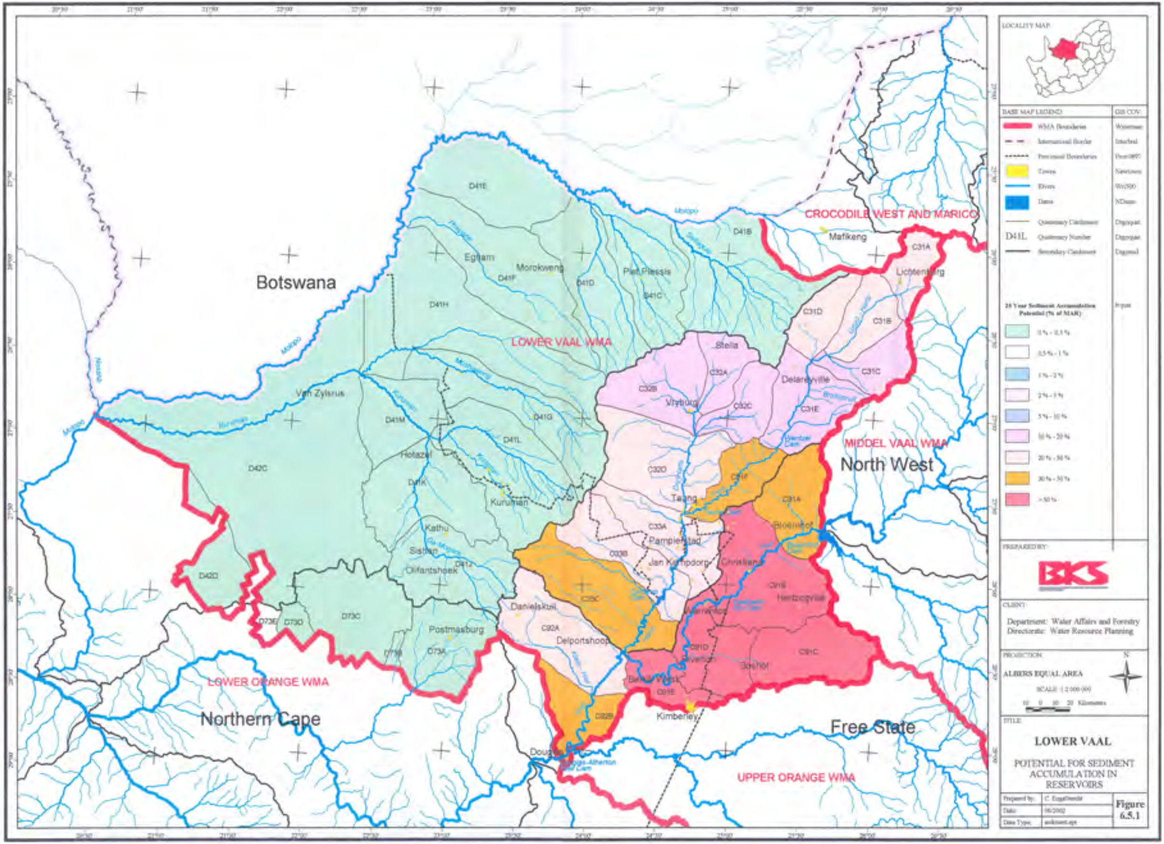
D42C
D42D
D73C
D73D
D73B
D73A
C31A
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L
Quaternary Number
Secondary Catchment
Potential Surface Water Contamination
No Data
Missing Data
Low
Medium
High
Note:
Map was produced using land use information (population density and degree of sanitation) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
10 0 10 20 Kilometers
N
TITLE:
LOWER VAAL
POTENTIAL FAECAL CONTAMINATION OF SURFACE WATER
Prepared by:
Date:
06/2000
Data Type:
Figure 6.4.3.1


Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
LOWER ORANGE WMA
UPPER ORANGE WMA
North West
Northern Cape
Free State
Molopo
Van Zylsrus
Hotazel
Kathu
Sishen
Olifantshoek
Postmasburg
Danielskuil
Delportshoop
Kuruman
Vryburg
Stella
Delareyville
Lichtenburg
Mafikeng
Piet Plessis
Morokweng
Taung
Pampierstad
Jan Kempdorp
Christiana
Bloemhof
Hertzogville
Warrenton
Barkly West
Kimberley
Douglas
Boshof
D41L
D42C
D42D
D73C
D73D
D73A
C32A
C32B
C31A
C31B
C31E
C91A
C91C
C92A
C92B
LOCALITY MAP
BASE MAP LEGEND:
GIS COV:
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Risk of Groundwater Contamination
Low
Medium
High
Note:
Map shows the categorised surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
SCALE 1:2 000 000
10 0 10 20 Kilometers
TITLE:
LOWER VAAL
RISK OF FAECAL CONTAMINATION OF GOUNDWATER
Prepared by:
Date:
Data Type:
Figure 6.4.3.2



LOCALITY MAP
BASE MAP LEGEND
GIS COV.
WMA Boundaries
International Border
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
D41L Quaternary Number
Secondary Catchment
25 Year Sediment Accumulation Potential (% of MAR)
0 % - 0,5 %
0,5 % - 1 %
1 % - 2 %
2 % - 5 %
5 % - 10 %
10 % - 20 %
20 % - 30 %
30 % - 50 %
> 50 %
PREPARED BY:
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resource Planning
PROJECTION:
ALBERS EQUAL AREA
N
10 0 10 20 Kilometers
TITLE:
LOWER VAAL
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Prepared by:
Date:
06/2002
Data Type:
Figure 6.5.1
Botswana
LOWER VAAL WMA
CROCODILE WEST AND MARICO
MIDDEL VAAL WMA
North West
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE WMA
Mafikeng
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Egham
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Molopo
Kuruman
D41E
D41F
D41D
D41C
D41B
D41H
D41G
D41L
D41M
D41K
D41J
D42C
D42D
D73E
D73D
D73C
D73A
C31A
C31D
C31B
C31C
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92A
C92B