REPORT NO: P09000/00/0101

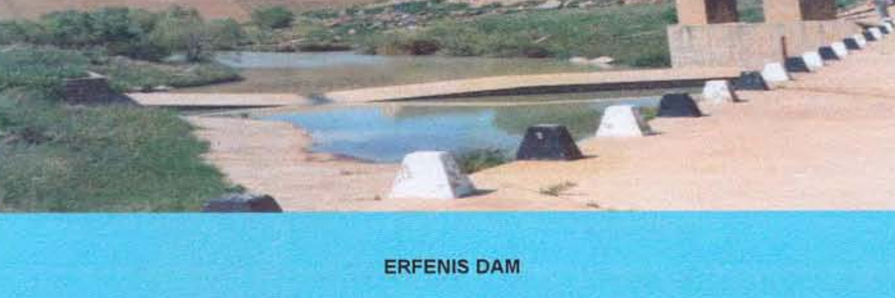
DEPARTMENT: WATER AFFAIRS AND FORESTRY

Directorate: Water Resources Planning

MIDDLE VAAL WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT: VOLUME 1 OF 3
FINAL : AUGUST 2002



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Title:	**Middle Vaal Water Management Area: Water Resources Situation Assessment – Main Report – Volume 1 of 3**
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Project Name:	Water Resources Situation Assessment
DWAF Report No:	P09000/00/0101
Status of Report:	FINAL
First Issue:	November 2001
Final Issue:	August 2002

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MIDDLE VAAL WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT

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 Middle Vaal Water Management Area, which occupies portions of the Free State and North-West 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, 1998 (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, 1998 (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 and existing infrastructure 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, 1998 (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.

DIAGRAM 1: LAYOUT OF ORANGE/VAAL RIVER BASIN

PREFACE

The Orange/Vaal River Basin extends over four countries, covering an area of 964 000 km². Almost 600 000 km² of the basin falls within South Africa, mainly covering the central part, and which represents nearly half of the surface area of the country. It incorporates the whole of Lesotho (where the main river is known as the Senqu), reaches to the southern part of Botswana, and drains most of the southern half of Namibia. From its origin in the highlands of Lesotho, the Orange River passes through different landscapes and highly varied climatic regions on its 2 300 km journey to the Atlantic Ocean. As a consequence, runoff from the different sub-catchments in the basin is disproportionate to the size of the catchment areas, as illustrated by the fact that approximately 40% of the MAR of the Orange River Basin is contributed by catchments in Lesotho which cover only 4% of the land area of the basin. This is in contrast to the downstream desert reaches of the Orange River where evaporation losses are in excess of the runoff from local tributaries.

The Vaal River forms the main tributary to the Orange River. It originates on the plateau west of the Drakensberg escarpment and drains much of the central highveld of South Africa.

Within South Africa, the Orange/Vaal River Basin includes 5 of the 19 Water Management Areas (WMA). These are the Upper Vaal, Middle Vaal, Lower Vaal, Upper Orange and Lower Orange WMAs. The small portion of the Crocodile West and Marico WMA that falls within the Orange/Vaal River Basin has no significant effect on the water resources situation of the basin. Great differences occur with respect to the hydro-meteorological characteristics as well as nature and level of development in these WMAs. The Vaal River is probably the most developed and regulated river in Southern Africa, while some of the largest dams in Africa have been built in Lesotho and on the main stem of the Orange River. Although linked together by the natural watercourses, a particular characteristic of the Orange/Vaal WMAs is the extensive intercatchment transfer of water within WMAs as well as interbasin transfers between these and other adjoining WMAs. The relative location of the Orange/Vaal WMAs together with a schematic representation of the main transfers of water, are given in **Diagram 1**.

An additional five WMAs are directly linked to the Orange River Basin (and the Orange/Vaal WMAs) through interbasin transfers, while the impacts of water resource management within the basin also indirectly extend to other WMAs and to the neighbouring countries of South Africa outside the basin (Zimbabwe, Swaziland and Mozambique). The main interdependencies among the Orange/Vaal (and other interlinked) WMAs relate to flow volume, flow regime and water quality.

A summarised description of the main features of each of the Orange/Vaal WMAs, effecting other WMAs and countries, follows:

Upper Vaal WMA

This is the most developed, industrialised and populous of the Orange/Vaal WMAs. From a water resource management perspective it is a pivotal WMA in the country. Large quantities of water are transferred into the WMA from the Usutu to Mhlatuze and the Thukela WMAs as well as from the Senqu (Orange) River in Lesotho. Similarly large quantities of water are released along the Vaal River to the Middle Vaal and Lower Vaal WMAs and are also transferred to the Crocodile West and Marico, and the Olifants WMAs.

Middle Vaal WMA

The Middle Vaal WMA is dependant on water releases from the Upper Vaal WMA for meeting the bulk of the water requirements by the urban, mining and industrial sectors within its area of jurisdiction, with local resources mainly used for irrigation and smaller towns. Water is also transferred via the Vaal River through this WMA, from the Upper Vaal WMA to the Lower Vaal WMA. Water quality in the Vaal River is strongly influenced by usage and management practices in the Upper Vaal WMA.

Lower Vaal WMA

Over 90% of the water used in the Lower Vaal WMA is sourced through releases from the Upper Vaal WMA and from Bloemhof Dam on the Vaal River, on the border with the Middle Vaal WMA. About 80% of the water use in this WMA is for irrigation (mainly at the Vaalharts irrigation scheme). Essentially only irrigation return flows, which are of high salinity, and unregulated flood flows from the Vaal River, reach the confluence with the Orange River.

Upper Orange WMA

Close to 60% of the water resources generally associated with the Upper Orange WMA, originate from the Senqu River in Lesotho. Developments in Lesotho can therefore have a significant impact on the Upper Orange WMA. The two largest storage reservoirs in South Africa, created by the Gariep and Vanderkloof Dams, are located in this WMA. Two thirds of the total yield realised by the dams in Lesotho and in the Upper Orange WMA together, is transferred to the Upper Vaal and Fish to Tsitsikamma WMAs, and released to the Lower Orange WMA as well as for use by Namibia.

Lower Orange WMA

Water requirements in the Lower Orange WMA are far in excess of the yield available from resources within the WMA, and about 95% are supplied by water released from the Upper Orange WMA. High evaporation losses from the Orange River, which are of the same order, as the water requirements in the WMA, are characteristic of the region. Namibia also abstracts water from the Orange River.

Summarising remarks

From a national point of view, the Orange/Vaal River system can be regarded as the most important river system in South Africa, not only because of its size and strategic central location, but because it sustains about half the economic production and a large proportion of the population of the country. It is evident that water resource management in the Orange/Vaal WMAs should be well co-ordinated and be viewed in an integrated systems context. Therefore none of the water resources situation assessment reports for the five WMAs in the Orange/Vaal River Basin should be interpreted in isolation, but rather as part of a suite of reports. Management of water resources in the basin should also be within the framework of the Orange-Senqu River Commission (ORASECOM) recently established by South Africa, Lesotho, Botswana and Namibia. Furthermore, impacts on water resources in other WMAs as well as in the neighbouring countries (other than the Orange co-basin countries), as a result of interbasin transfers, should also be of primary consideration in the management of the Orange/Vaal River Basin and river system.

The reader of this report is requested to take cognisance of the inter-relationships between the three Vaal WMA's, as set out in their respective WMA reports. The surplus yields passing from the Upper Vaal WMA has considerable bearing on the passage of water flowing through the Middle and Lower Vaal WMA's and further downstream to the Lower Orange WMA and influence the calculation of surplus yields that could be used for future development.

The report numbers for the four water management areas are as follows :

- Upper Vaal WMA : 08000/00/0101 (Stewart Scott).
- Middle Vaal WMA : 09000/00/0101 (Stewart Scott).
- Lower Vaal WMA : 10000/00/0101 (BKS).
- Lower Orange WMA : 14000/00/0101 (V3).

SYNOPSIS

1. Introduction

The National Water Act, 1998 (Act No. 36 of 1998) requires the Minister of the Department of Water Affairs and Forestry (DWAF) 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.

As a component of the National Water Resource Strategy, the Minister of DWAF 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 and the national database should, in addition to contributing to the establishment of the National Water Resources Strategy, provide a tool for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

The study was carried out as a desktop exercise using data from reports, electronic databases (WR90) and data supplied by associated studies, local authorities and DWAF. The study considers conditions as they were in 1995.

2. Physical Features

The Middle Vaal WMA is located downstream of the confluence of the Vaal and the Rietspruit Rivers and upstream of Bloemhof Dam: It extends to the headwaters of the Schoonspruit River in the north and the Vet River in the south. It covers a catchment area of 52 563 km^2. It includes parts of Free Stae and North-West provinces.

The following table describes the key areas.

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT NO.	
NO.	KEY AREA NAME AND POINT		
C	Rhenoster - C70K outlet	C70 A-K	C70 Tertiary catchment
	Vals – C60J outlet	C60A-J	C60 Tertiary catchment
	Johan Neser – C24G outlet	C24C-G	Johan Neser Dam
	Vaal – C25C outlet	C24A-B, C24H-J, C25A-C)	Confluence of Vaal, Sandspruit and Makwassiespruit Rivers
	Bloemhof – C25F outlet	C25D-F	Bloemhof Dam
	Allemanskraal – C42E outlet	C42A-E	Allemanskraal Dam
	Erfenis – C41 outlet	C41A-E	Erfenis Dam
	Vet C43D outlet	C41F-J, C42F-L, C43A-D	Confluence of Vaal and Vet Rivers

The Middle Vaal WMA is relatively flat with a maximum elevation of about 2 200 m in the hilly upper reaches of the Vals River and a minimum elevation of about 1 250 m in the vicinity of Bloemhof Dam. Pans and other enclosed drainage basins are a feature of the western parts

Climatic conditions can vary considerably from west to east across the Middle Vaal WMA The mean annual temperature ranges between 18 °C in the west to 14 °C in the east, with an average of about 16 °C for the catchment as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. 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 overall feature of mean annual rainfall over the Middle Vaal WMA is that it decreases fairly uniformly westwards from the eastern escarpment regions across the central plateau area. The MAP for the watershed ranges from a high of 700 mm in the east to a low of 500 mm in the west with an average of about 550 mm.

Humidity is generally highest in February (the daily mean over the Middle Vaal WMA ranges from 62 % in the west to 66 % in the east) and lowest in August (the daily mean ranges from of 52 % in the west to 58 % in the east).

Average gross potential mean annual evaporation (as measured by Class A-pan) ranges from 1 800 mm in the east to a high of 2 600 mm in the dry western parts. The highest A-pan evaporation is in January (range 200 mm to 300 mm) and the lowest evaporation is in June (100 mm to 120 mm).

The area south of the Vaal River is underlain by fine sedimentary rocks of the Karoo system. The total area of the Karoo system represents about 80% of the Vaal River Basin. To the north of the Vaal River igneous and metamorphic rocks predominate but there are extensive dolomitic exposures in the most northerly part of this WMA and also east of Klerksdorp.

Soil depths are generally moderate to deep with flat to undulating relief over the entire Middle Vaal WMA. There are three main soil types that predominate and these are distributed across the catchment as follows.

- Sandy Loam : Most of the WMA consists of this soil type from the central portion of the WMA upstream of Bloemhof Dam which generally has a flat relief to the north of the WMA which is more undulating.
- Clay Loam: This soil type extends from the sandy loan area further eastwards into the headwaters of the Sand, Vet, Elandspruit and Renoster Rivers.
- Clay Soil: A relatively small area at the confluence of the Sand and Vet Rivers.

In this WMA the predominant veld type is “pure grassveld”. In the northern areas there is a bit of “false grassveld” while upstream of Bloemhof Dam there is some “tropical bush and savanna”.

3. Development Status

The total urban and rural population in this WMA is just over 1,5 million (1995 figures) with the urban population being just over 1,1 million. The Vaal key area (C24 and C25) and the Vet key area (C41, C42 and C43) contribute most of the urban and rural population.

Of the total land use of about 530 km^2, irrigation accounts for about 39% and alien vegetation covers about 13%. This WMA is not as heavily urbanised as the Upper Vaal WMA , covering 47% of the total land use.

The following table shows land use per key area as well as population.

CATCHMENT				Irrigation (field area) (km²)	Alien vegetation (km²)	Urban (km²)	Other (km²)	Total (km²)	Population
SECONDARY		TERTIARY							
No	Description	No.	Key Area Description						
C7	Rhenoster	C70	Rhenoster (70A-K)	21,9	0	0	6 634,1	6 656	100 206
C6	Vals	C60	Vals (C60A-J)	2,4	1,6	43	7 824,0	7 871	189 202
C2	Johan Neser	C24	Johan Neser (C24C-G)	41,8	3,9	0	5 598,3	5 644	53 065
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	9,4	17,8	78	8 175,8	8 281	494 197
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0	45,8	0	4 913,2	4 959	73 161
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0	0	0	3 628,00	3 628	40 867
	Erfenis	C41	Erfenis (C41A-E)	0	0	0	4 724,00	4 724	44 908
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	132,4	1,5	131	10 535,1	10 800	513 495
Total in Free State				**161,5**	**31,6**	**174**	**38 573,7**	**38 940,8**	**1 019 213**
Total in North-West				**46,4**	**39,0**	**78**	**13 458,8**	**13 622,2**	**489 889**
TOTAL IN WMA				**207,9**	**70,6**	**252**	**52 032,5**	**52 563,0**	**1 509 102**

Note: Dryland sugar cane and afforestation all zero. . For Dryland crops, Nature Reserves and Rural Settlements, data was not readily available.

Field area (or green cover area) taken from the Vaal River Irrigation Study (Loxton Venn & Assoc., 1999b)

4. Existing Water Related Infrastructure

There are several major industries, a number of large mines and a growing urban population in this WMA. MidVaal Water Company and Sedibeng Water are the major suppliers of water and have two major offtakes from the Vaal River, one in the Klerksdorp – Orkney area and the other in quaternary catchment C25C, upstream of Bloemhof Dam. Sedibeng Water also abstracts a smaller quantity in the Sand River in the vicinity of Virginia.

There are some large dams in the catchment namely : Bloemhof Dam, Erfenis Dam, Allemanskraal Dam, Elandskuil Dam, Rietspruit Dam, Johan Neser Dam, Serfontein Dam and Koppies Dam. There is a large network of reservoirs, pipelines, pumpstations, water purification works and sewage treatment works serving towns.

Irrigation is also of importance with a number of dams such as Erfenis, Allemanskraal, Koppies and Johan Neser Dam supporting Government Water Schemes and irrigation Boards. Bloemhof Dam regulates supply of water to the Vaalharts and Taung Irrigation Schemes downstream in the Lower Vaal WMA.

The following table shows the combined capacities of individual town and regional potable water supply schemes by key area.

CATCHMENT				TOWN AND REGIONAL WATER SUPPLY SCHEMES			
SECONDARY		TERTIARY				CAPACITY	
No.	Description	No.	Key Area Description	Number of People Supplied	% of Key Area Population	($10^6 m^3/a$) (1)	(ℓ/capita/d)#
C7	Rhenoster	C70	Rhenoster (70A-K)	62 350	62,2		145
C6	Vals	C60	Vals (C60A-J)	148 050	78,3		294
C2	Johan Neser	C24	Johan Neser (C24C-G)	21 150	39,9		185
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C	404 700	81,9		179
	Bloemhof	C25	U/S Bloemhof (C25D-F)	51 200	70,0		113
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	24 150	59,1		156
	Erfenis	C41	Erfenis (C41A-E)	26 500	59,0		137
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	376 800	73,4		224
Total in Free State				**708 950**	**70,0**		(1)
Total in North-West				**405 950**	**82,9**		(1)
TOTAL IN WMA				**1 114 900**	**73,9**		**203**

Note: (1) This information is not readily available.
Daily urban consumption calculated from urban usage data.

5. Water Requirements

The various water user sectors in this WMA are as follows and are given in the following along with the total water requirements in the WMA in 1995 :

- Ecological Reserve (environmental - in-stream flow requirements). This water is not consumed.
- Domestic (urban and rural users).
- Bulk industrial (including thermal power stations) and mining.
- Water transfers.
- Agricultural (including livestock and game).
- Afforestation.
- Alien vegetation.

The vast majority of quaternary catchments analysed generated C management classes, i.e moderately modified aquatic ecosystems that will require 20-40% MAR. Bearing in mind that the assessments were only done at quaternary catchment outlets, there are no A class rivers and only about 10% of were designated as B class. This points to the relatively poor state of aquatic ecosystems.

This WMA is not heavily urbanised, the largest urban areas are in the Vet (C41 – C43) and Vaal (C24 - C25) key areas. The bulk of potable water is delivered by Sedibeng Water (parts of the Free State) and MidVaal Water Company.

Rural usage can be categorised into domestic rural use, livestock watering and subsistence irrigation (nil however in this WMA). There is no significant rural infrastructure in the Middle Vaal WMA.

There are no strategic users in this WMA.

This WMA is characterised by a large number of mines (Free State Gold fields area and North West Gold fields area). The economy of the Middle Vaal WMA is dominated by the mining sector, particularly gold mining.

During 1995, mining operations discharged some 38,5 x $10^6 m^3$ of water directly into the catchment river systems out of a total discharge of 94,5 x $10^6 m^3$ (BKS et al, 1998d). This represents 40 % of all discharges and impacts significantly on both the hydrology and water quality of the Middle Vaal system (the Sand / Vet catchment in particular). The impact in terms of quality is generally negative for downstream users.

Other non-strategic bulk waster users in this WMA are small users linked to Sedibeng Water and MidVaal Water Company. For further details, refer to **Appendix D2**.

Most of the irrigation in this WMA is concentrated along the Sand and Vet rivers i.e the Sand-Vet GWS. Other significant irrigation areas are the Rhenoster River GWS and the Klerksdorp Irrigation Board.

There is no hydro power and afforestation is negligible. There is a small amount of alien vegetation. Information on dryland agriculture is not readily available.

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.

There are no major inter-basin exports or imports. There are some minor transfers as follows :

- From the Vaal Dam in the Upper Vaal WMA to Heilbron.
- From Erfenis Dam to Brandfort in the Upper Orange WMA.

The following table shows the water requirements per user group in 1995.

USER GROUP	1995 WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m^3/ a)
Ecological reserve (5)	109,1	118,2
Domestic (1)	86,7	87,5
Bulk water use (4)	85,2	87,7
Neighbouring States	0,0	0,0
Agriculture	(2) 184,3	125,1
Afforestation	0,0	0,0
Alien vegetation	1,5	0,15
Water transfers (3)	2,3	2,3
Hydropower	0,0	0,0
TOTALS	**1961**	**452**

(1) Includes urban (82,0) and rural (4,6) domestic requirements and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation (153,8), dryland sugar cane (0), livestock and game (30,5).
(3) Only transfers out of the WMA are included (Brandfort transfer).
(4) Includes thermal powerstations (0), other bulk users (3,6) and mines (81,6).
(5) At outlet of WMA, refer to Table 5.2.4.1.

The following table shows the urban and rural domestic water requirements in 1995

CATCHMENT				URBAN (1)	RURAL (1)	TOTAL	1:50 YEAR ASSURANCE	HUMAN RESERVE (AT 1:50) (2)
SECONDARY		TERTIARY						
No.	Description	No.	Key Area Description	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)
C7	Rhenoster	C70	Rhenoster (C70A-K)	3,2	0,4	3,6	3,8	1,0
C6	Vals	C60	Vals (C60A-J)	15,8	0,5	16,3	16,4	1,8
C2	Johan Neser	C24	Johan Neser (C24C-G)	1,4	0,4	1,8	1,8	0,5
	Vaal	C24,25	Vaal (C24A,B, H,J, C25A-C)	26,2	1,0	27,2	27,5	4,5
	Bloemhof	C25	U/s Bloemhof (C25D-F)	2,1	0,3	2,4	2,4	0,7
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	1,4	0,2	1,5	1,6	0,3
	Erfenis	C41	Erfenis (C41A-E)	1,3	0,2	1,6	1,6	0,4
	Vet	C41-43	Vet (C41F-J, C42F-L, C43A-D)	30,6	1,6	32,3	32,5	4,7
Total in Free State				**57,8**	**3,5**	**61,2**	**61,5**	**9,4**
Total in North-West				**24,2**	**1,1**	**25,5**	**26,0**	**4,5**
TOTAL IN WMA				**2000**	**4,6**	**86,7**	**87,5**	**71**

Note:
(1) The values include conveyance and distribution losses.
(2) The Human Reserve is the minimum water requirement of the population, estimated at 25 ℓ / capita / day (DWAF criterion).

Regarding losses, the distribution losses include losses due to leaking pipes and reservoirs as well as unaccounted for or unmetered water. The distribution losses can range from 5% of urban water supplied too as high as 35% of urban water supplied in urban centres where proper maintenance is not done and where there is unmetered water supplied. Generally losses due to the distribution system are of the order of 10%.

In semi-arid areas wastewater is regarded as a supplementary source of water. The return flows generated from this WMA supplement the base flow of the Vaal River, thus benefiting all downstream users.

Return flows from urban areas can be divided into three categories:

- The return flows from urban water systems can manifest in two distinct ways:

As wastewater (effluent) concentrated by means of waterborne sewage that is treated and released into the surface river network.

As wastewater diffused locally by means of pit toilets (eg. Loflos, aquaprivies, etc), septic tanks / french drains, or more complex methods such as soil bucket systems or disposal via evaporation from oxidation ponds.

- Return flow due to leakage of clean water.

  There are no known clean returns.

- Stormwater returns.

Return flow due to impervious urban areas (into storm water system). The urban areas in this WMA total 252 km^2 and the return flow generated from these areas is 13,8 $x10^6m^3/a$.

Total urban effluent returns for 1995 are estimated at about 25,3 x 10^6m^3 and the total urban return flow is 39,1 x 10^6m^3.

The return flow generated by rural consumers is negligible and in most cases can be taken as zero.

Return flows generated by bulk users are directly proportional to the type of industry. Some mines in this WMA pump out large amounts of groundwater. Total return flow to the river system is 17,6 $x10^6m^3/a$.

Irrigation return flow is negligible.

The following table summarises water requirements per key area at 1:50 year assurance .

CATCHMENT				STREAMFLOW REDUCTION ACTIVITIES ($10^6m^3/a$)		WATER USE ($10^6m^3/a$)		WATER REQUIREMENT ($10^6m^3/a$)						ECOLOG-ICAL RESERVE ($10^6m^3/a$)	TOTAL ($10^6m^3/a$)
SECONDARY		TERTIARY													
No.	Description	No.	Key Area Description	AFFOREST-ATION	DRYLAND SUGAR CANE	ALIEN VEG.	RIVER LOSSES[2]	BULK	IRRI-GATION	RURAL	URBAN	WATER TRANSFERS OUT[1]	NEIG-HOURING STATES		
C7	Rhenoster	C70	Rhenoster (70A-K)	0,0	0,0	0,00	0,0	0,0	15,3	6,0	3,3	0,0	0,0	0,0	30
C6	Vals	C60	Vals (C60A-J)	0,0	0,0	0,04	0,0	0,0	1,6	4,5	15,9	0,0	0,0	0,0	44
C2	Johan Neser	C24	Johan Neser (C24C-G)	0,0	0,0	0,07	0,0	0,0	21,7	3,2	1,4	0,0	0,0	1,7	531
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	0,0	0,0	0,01	40,0	49,1	6,0	4,8	26,4	64,9	0,0	0,0*	2122
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,0	0,0	0,03	40,0	0,0	0,0	3,1	2,1	0,0	0,0	103,8	161
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	0,0	0,00	0,0	0,0	0,0	2,4	1,4	0,0	0,0	5,5	21
	Erfenis	C41	Erfenis (C41A-E)	0,0	0,0	0,00	0,0	0,0	0,0	3,0	1,3	2,3	0,0	7,2	21
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	0,0	0,0	0,00	0,0	38,6	50,0	8,3	30,8	0,0	0,0	0,0*	143
Total (Free State)				**0,0**	**0,0**	**0,05**	**47,8**	**41,8**	**72,4**	**27,6**	**58,2**	**66,0**	**0,0**	**50,2**	**3961**
Total (North-West)				**0,0**	**0,0**	**0,10**	**32,2**	**45,9**	**22,2**	**7,7**	**24,4**	**1,2**	**0,0**	**68,0**	**2357**
TOTALIN WMA				**0,0**	**0,0**	**0,15**	**80,0**	**87,7**	**94,6**	**35,3**	**82,6**	**67,2[3]**	**0,0**	**118,2**	**1208[4]**

Notes: * Negative values for ecological reserve taken as zero.

(1) Only potable water transfers.

(2) Evaporation losses from dams, rivers and wetlands are not included because they are part of the available yield.

(3) Total transfers in 1995 = 67,2 x 10^6m^3, transfers out of WMA was 2,3 x 10^6m^3 to Brandfort TLC in the Upper Orange WMA. The remainder is within WMA transfers = 64,9 x 10^6m^3.

(4) Total requirement in 1995 at 1:50 assurance: 565,8 x 10^6m^3 – 64,9 x 10^6m^3 = 500,9 x 10^6m^3 because the within WMA transfers are accounted for in the water requirements of key areas.

6. Surface Water Resources

Mean annual runoff (MAR) from the total Vaal River catchment is approximately 4 000 x $10^6 m^3$. When expressed as an equivalent unit runoff from the 196 000 km^2 catchment, the MAR averages out at about 15 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 associated with an increase in evaporation rates. For the Middle Vaal WMA, the MAR totals 887,5 x $10^6 m^3$. Unit runoff varies from over 23 mm in the upper reaches of the Renoster and Vals Rivers to as little as 4 mm in the vicinity of the Bloemhof Dam. Equivalent figures for mean annual rainfall (MAP) are 570 mm (east) and 500 mm (west) and, for mean annual evaporation (MAE) – 1 800 mm (east) and 2 600 mm (west).

The developed yield from surface water in 1995 totals 245,4 x $10^6 m^3$ and the total potential surface water yield is the same due to the fact that the Middle Vaal is fully developed. The developed yield from groundwater is 56,7 x $10^6 m^3$ and the potential yield is 370,0 x $10^6 m^3$. If the relationship between surface water and groundwater is taken into account, the total developed yield is 302,1 x $10^6 m^3$ and the total potential yield is 615,4 x $10^6 m^3$. Surface water yields have not had the ecological Reserve deducted from them i.e the yield is calculated as if the ecological Reserve is zero.

The following table shows the water resources per key area.

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CATCHMENT				SURFACE WATER RESOURCES ($10^6m^3/a$)			SUSTAINABLE GROUNDWATER RESOURCE		TOTAL WATER RESOURCE ($10^6m^3/a$)	
SECONDARY		TERTIARY								
No.	Description	No.	Key Area Description	NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED IN 1995	1:50 YEAR TOTAL POTENTIAL
C7	Rhenoster	C70	Rhenoster (70A-K)	138,3	27,0	27,0	9,1	41,7	36,1	68,7
C6	Vals	C60	Vals (C60A-J)	156,6	12,7	12,7	3,3	59,1	16,0	71,8
C2	Johan Neser	C24	Johan Neser (C24C-G)	87,7	25,2	25,2	16,4(1)	60,8	41,6	86,0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	65,8	26,5	26,5	10,1	54,1	36,6	80,6
	Bloemhof	C25	U/S Bloemhof (C25D-F)	16,5	39,7	39,7	1,2	28,3	40,9	68,0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	96,1	41,2	41,2	1,7	27,3	42,9	68,5
	Erfenis	C41	Erfenis (C41A-E)	167,4	55,0	55,0	2,9	42,5	57,9	97,5
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	159,1	18,1	18,1	12,0	56,2	30,1	74,3
Total in Free State				**743,6**	*****	*****	**30,6**	**261,6**	*****	*****
Total in North-West				**143,9**	*****	*****	**26,1**	**109,4**	*****	*****
TOTAL IN WMA				**887,5**	**245,4**	**245,4**	**56,7**	**370,0**	**302,1**	**615,4**

Note : (1) Groundwater use for irrigation from Ventersdorp Eye Subterranean GWCA (DWAF, 1999).
(*) Provincial split not readily available.

7. Water Balance

The following is a summary of the water balance for each key area.

- **RHENOSTER KEY AREA**

In 1995 this key area had a small surplus of about 12,8 x $10^6 m^3$. This key area is rural in nature and has significant controlled irrigation and rural requirements (87 % of total requirements). Heilbron and Viljoenskroon TLC's are the most significant urban centers in the area. Water is imported from the Upper Vaal WMA (Vaal Dam) to supply the needs of Heilbron TLC. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources.

- **VALS KEY AREA**

In 1995 this key area had a small surplus of about 4,9 x $10^6 m^3$. While the key area is rural in nature, it has significant urban requirements (73 % of total requirements). The urban requirements are dominated by the requirement of Kroonstad TLC (13,2 x $10^6 m^3$). Water is imported from the Vaal key area (Vaal River) by Sedibeng Water to supply the needs of the Bothaville TLC. Treated sewage and stormwater returns from Kroonstad in particular contribute significantly (33 % of total resource) to the water resources of the Vals key area. All irrigation in the Vals catchment is regarded as diffuse (DWAF, 1999) and is not significant. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is limited to the exploitation of the groundwater resources.

- **JOHAN NESER KEY AREA**

In 1995 this key area had a small surplus of about 13,5 x $10^6 m^3$. The area is rural in nature and has significant controlled irrigation and rural requirements (90 % of total requirements). Ventersdorp and Coligny TLC's are the most significant urban centres in the area. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources.

- **VAAL KEY AREA**

In 1995 this key area had a surplus of about 556,5 x $10^6 m^3$, which includes the surplus yield from the Upper Vaal WMA of about 678 x $10^6 m^3$ which was 'transferred' downstream to this key area.

Located within this key area is the North West Goldfields, therefore urban and bulk water requirements account for 40% of total requirements. The main urban centres are Klerksdorp, Orkney and Stilfontein in the NW Goldfields and Odendaalsrus in the Free State. The requirements of Stilfontein, Buffelsfontein, Vaal Reefs and Hartebeesfontein Gold Mines make up over 90 % of bulk requirements in the area. Effluent returns from these towns and mines increase the water resources of the area significantly.

This area also exports water (33%) from the Vaal River to a number of adjacent key areas, the most significant being Sedibeng Water export of water at Balkfontein to the Free State Goldfields in the Vet key area. River losses account for 20 % of total requirements.

The potential for water resources development within this area is dependent on the availability of water from the Upper Vaal WMA and on the exploitation of groundwater resources.

- **BLOEMHOF KEY AREA**

In 1995 this key area had a surplus of 450,8 x $10^6 m^3$ (including the surplus from the Upper VaalWMA) which was transferred downstream to the Lower Vaal WMA.

The requirements of this key area are dominated by non-consumptive requirements. These are the ecological reserve requirement of the Vaal River (70% of total requirement) and river losses (29%). Consumptive requirements by urban and rural users are small in comparison (3%). Wolmaransstad and Wesselsbron are the most important urban centres in the area. There is no significant irrigation in this area.

The potential for water resources development in this area is controlled by requirements in the Upper Vaal WMA and upstream Vaal key area and by the scheduled irrigation requirements of the downstream Lower Vaal WMA and is probably limited to the exploitation of groundwater resources.

- **ALLEMANSKRAAL KEY AREA**

In 1995 this key area had a surplus of about 34 x $10^6 m^3$. The key area is rural in nature and water requirements are dominated the ecological reserve requirement of the upstream Sand River (59%). Consumptive requirements by urban and rural users make up the rest of the requirements. Irrigation water requirements are not significant. Senekal is the most important urban center in the area.

This key area does contribute to the downstream yield of the Sand River. Due to scheduled irrigation requirements in the downstream Vet key area the potential for water resources development within this area is probably limited to the exploitation of groundwater resources.

- **ERFENIS KEY AREA**

In 1995 this key area had a surplus of about 44,2 x $10^6 m^3$. The key area is rural in nature and water requirements are dominated by the ecological reserve requirement of the upstream Vet River (52%). Consumptive requirements by urban and rural users make up 31% of total requirements. There is an export (17%) of water from Erfenis Dam to Brandfort TLC in the Upper Orange WMA. Irrigation water requirements are not significant. Winburg and Marquard are the most important urban centers in the area.

This key area does contribute to the downstream yield of the Vet River. Due to scheduled irrigation requirements in the downstream Vet key area the potential for water resources development within this area is probably limited to the exploitation of groundwater resources.

- **VET KEY AREA**

In 1995 this key area had a surplus of about 56 x $10^6 m^3$. This is because the water resources of this key area are augmented by transfers from Vaal River (Vaal Key area) by Sedibeng Water for urban and bulk use in the Free State Goldfields and by the upstream yields of Erfenis and Allemanskraal key areas.

The mining (30%) and urban water requirements (24%) of the Free State Goldfields dominate the water requirements of this key area. The main urban centres are Welkom and Virginia and the main mines are Harmony, President Steyn, African Rainbow Minerals and Bambanani Gold Mines. Returns from these users contribute about 10 % to the water resources of the key area.

Irrigation water requirements (40%) for controlled irrigation are significant and are the most important in the WMA as a whole. Approximately 122 km^2 is scheduled for irrigation in three areas, namely Sand-Vet GWS (Sand), Sand-Vet GWS (Vet) and Vet River GWS.

Actual irrigation requirement are significant therefore this key area does not contribute to the yield of the Lower Vaal WMA. The potential for water resources development within the key area is limited to the exploitation of groundwater resources.

The following table shows the water balance per key area.

CATCHMENT				AVAILABLE 1:50 YEAR YIELD IN 1995 ($10^6 m^3/a$)			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQ. AT 1:50 YEAR ASSURANCE[2] ($10^6 m^3/a$)	WATER BALANCE AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)
SECONDARY		TERTIARY		SURFACE WATER	GROUNDWATER USE IN 1995	TOTAL	IMPORTS[1]	EXPORTS[1]	RE-USABLE	TO SEA		
No.	Description	No.	Key Area Description									
C7	Rhenoster	C70	Rhenoster (70A-K)	(+) 27,0	(+) 9,1	(+) 35,9	(+) 0,9	0,0	(+) 0,6	n/a	(-) 24,6	(+) 12,8[7]
C6	Vals	C60	Vals (C60A-J)	(+) 12,7	(+) 3,3	(+) 16,2	(+) 1,9	0,0	(+) 8,8	n/a	(-) 22,0	(+) 4,9[7]
C2	Johan Neser	C24	Johan Neser (C24C-G)	(+) 25,2	(+) 16,4	(+) 41,6	0,0	0,0	0,0	n/a	(-) 28,1	(+) 13,5[7]
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	(+) 26,5	(+) 10,1	(+) 36,6	(+) 678,5[3]	(-) 64,9	(+) 32,6	n/a	(-) 126,3	(+) 556,5[4]
	Bloemhof	C25	U/S Bloemhof (C25D-F)	(+) 39,7	(+) 1,2	(+) 40,9	(+) 558,6[4]	0,0	(+) 0,3	n/a	(-) 149,0	(+) 450,8[6]
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	(+) 41,2	(+) 1,7	(+) 42,9	0,0	0,0	(+) 0,4	n/a	(-) 9,3	(+)34,0[5]
	Erfenis	C41	Erfenis (C41A-E)	(+) 55,0	(+) 2,9	(+) 57,9	0,0	(-) 2,3	(+) 0,1	n/a	(-) 11,5	(+) 44,2[5]
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	(+) 18,1	(+) 12,0	(+) 30,1	(+) 139,1[5]	0,0	(+) 14,1	n/a	(-) 127,7	(+) 55,6[6]
Total (Free State)				**&**	**&**	**&**	**&**	**&**	**&**	**n/a**	**&**	**&**
Total (North-West)				**&**	**&**	**&**	**&**	**&**	**&**	**n/a**	**&**	**&**
TOTAL in WMA				**(+) 245,4**	**(+) 56,7**	**(+) 302,1**	**(+) 1 379,0**	**(-) 67,2**	**(+) 56,9**	**n/a**	**(-) 498,5**	
Surplus yield from Middle Vaal WMA for Lower Vaal WMA												**(+) 506,4[6]**

Note:
(1) Potable water transfers only.
(2) Requirements include ecological reserve, river losses, urban, rural, irrigation, bulk , alien vegetation and afforestation.
(3) Transfer surplus yield from the upstream Upper Vaal WMA (Stewart Scott, 2002).
(4) Transfer surplus yield from upstream Vaal key area to downstream key area.
(5) Surplus yields from Allemanskraal and Erfenis key areas are transferred to the downstream Vet key area.
(6) Surplus yields from u/s Bloemhof and Vet key areas are available for downstream Lower Vaal WMA.
(7) Yields not available to downstream key areas (Pitman, 1999).
(&) Provincial split not readily available.

8. Costs of Water Resource Development

Although not as highly developed as the Upper Vaal WMA, there is also not much potential for further development in the Middle Vaal WMA.

There is a subterranean area at Ventersdorp which provides water for irrigation. It is, however, not known whether there is any further potential for developing this resource. There are no other known potential well fields that could be developed on a major scale.

9. Conclusions and Recommendations

The Middle Vaal WMA is not as highly developed as the Upper Vaal WMA but there is still a significant amount of development. There are no transfer schemes directly into this WMA but certain urban, rural, industrial, mining, ecological and irrigation requirements benefit from transfers upstream into the Upper Vaal WMA. At the 1:50 level of assurance as at 1995, the Middle Vaal WMA passed about 506 x 10^6m^3 to the Lower Vaal WMA. This surplus should, however, not be viewed in isolation but be considered along with the Lower Vaal.

Although surface water in the total Vaal River system has been fully developed, exploitation of groundwater in the key areas is low and ranges from about 5% to 20%. Pollution of groundwater by mines may hinder potential development.

Return flows are extremely significant in some of the key areas but also carry pollution effects.

The following table summarises available yield and water requirements.

CATCHMENT				AVAILABLE 1:50 YEAR YIELD IN 1995 $(10^6 m^3/a)$	WATER TRANSFERS AT 1:50 YEAR ASSURANCE $(10^6 m^3/a)$		RETURN FLOWS AT 1:50 YEAR ASSURANCE $(10^6 m^3/a)$	WATER REQ. AT 1:50 YEAR ASSUR-ANCE[2] $(10^6 m^3/a)$	WATER BALANCE AT 1:50 YEAR ASSUR-ANCE $(10^6 m^3/a)$
SECONDARY		TERTIARY							
No.	Description	No.	Key Area Description	TOTAL	IMPORTS[1]	EXPORTS[1]	RE-USABLE		
C7	Rhenoster	C70	Rhenoster (70A-K)	(+) 35,9	(+) 0,9	0,0	(+) 0,6	(-) 24,6	(+) 12,8[7]
C6	Vals	C60	Vals (C60A-J)	(+) 16,2	(+) 1,9	0,0	(+) 8,8	(-) 22,0	(+) 4,9[7]
C2	Johan Neser	C24	Johan Neser (C24C-G)	(+) 41,6	0,0	0,0	0,0	(-) 28,1	(+) 13,5[7]
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	(+) 36,6	(+) 678,5[3]	(-) 64,9	(+) 32,6	(-) 126,3	(+) 556,5[4]
	Bloemhof	C25	U/S Bloemhof (C25D-F)	(+) 40,9	(+) 558,6[4]	0,0	(+) 0,3	(-) 149,0	(+) 450,8[6]
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	(+) 42,9	0,0	0,0	(+) 0,4	(-) 9,3	(+)34,0[5]
	Erfenis	C41	Erfenis (C41A-E)	(+) 57,9	0,0	(-) 2,3	(+) 0,1	(-) 11,5	(+) 44,2[5]
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	(+) 30,1	(+) 139,1[5]	0,0	(+) 14,1	(-) 127,7	(+) 55,6[6]
TOTAL in WMA				**(+) 302,1**	**(+) 1 379,0**	**(-) 67,2**	**(+) 56,9**	**(-) 498,5**	
Surplus yield from Middle Vaal WMA for Lower Vaal WMA									**(+) 506,4[6]**

Note: (1) Potable water transfers only.
(2) Requirements include ecological reserve, river losses, urban, rural, irrigation, bulk , alien vegetation and afforestation.
(3) Transfer surplus yield from the upstream Upper Vaal WMA (Stewart Scott, 2002).
(4) Transfer surplus yield from upstream Vaal key area to downstream key area.
(5) Surplus yields from Allemanskraal and Erfenis key areas are transferred to the downstream Vet key area.
(6) Surplus yields from u/s Bloemhof and Vet key areas are available for downstream Lower Vaal WMA.
(7) Yields not available to downstream key areas (Pitman, 1999).

Although every effort has been spent in obtaining accurate data, manipulation of this data and checking and verification thereof, the information presented in this report is dependent on the accuracy and quality of the numerous reports and documentation previously compiled by other organisations. It is therefore likely that some information may have to be revised in the future. A great deal of effort was spent on the metadata for the project database in order to make future enhancements as efficient a process as possible.

The following recommendations were made :.

- While overall irrigation data can be considered reliable, this data is not available on a quaternary catchments basis and therefore quaternary catchment irrigation data represents an estimate only and must be considered to be of poor quality. In order to improve on quaternary catchments based information it is therefore recommended that a study is undertaken to determine the areal distribution and crop types at quaternary catchment scale.

- Information on rural water requirements was not readily available. There is a need to determine this requirement for the various categories of rural users.

- The available information on livestock and game was for 1988 and 1990. In addition this data was only available at Magisterial district level and like irrigation the data at quaternary catchment level must be considered unreliable.

- A survey of a number of TLC's was undertaken to try and determine urban water requirements. This exercise was fairly successful and should be extended to the remaining TLC's. Most small TLC's were not surveyed and their water requirements were estimated using default usages. In the opinion of the Situation Assessment Consultant the default usages are too high for most small towns and as a consequences usages have been inflated.

- The situation assessment consultant did review river losses, however this data appears to have been ignored. This is possibly a result of problems with the river losses sub-model of WSAM.

- Information on allocations, authorisations and permits needs to be centralised and reviewed by an organisation (persons) skilled in the interpretation of these allocations. Thus allowing the assessment of the available resources and the volumes allocated.

- Information concerning conveyance losses (most kinds) were generally not readily available. While defaults were provided and these were used extensively, a study of this crucial 'requirement' is recommended. Irrigation conveyance losses are significant in this WMA and there is a need to quantify them. In addition no information on rural losses was known and the WSAM default of 20 % was applied. There is no information indicating whether this sort of loss is acceptable.

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TABLES*:*

FIGURES:

DIAGRAMS

ABBREVIATIONS AND ACRONYMS

CCWR	Computing Centre for Water Research
CMA	Catchment Management Agency
DWAF	Department of Water Affairs and Forestry
ELSU	Equivalent Large Stock Units
GIS	Geographic Information System
GJTMC	Greater Johannesburg Transitional Metropolitan Council
GWS	Government Water Scheme
IRP	Integrated Resource Planning
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MD	Magisterial District
MLC	Metropolitan Local Council
NWA	National Water Act
NWSR	National Water Supply Regulation
SABS	South African Bureau of Standards
TLC	Transitional Local Council
TRC	Transitional Regional Council
WMA	Water Management Area WSA
WR90	Water Resources 1990
WSA	Water Service Act
WSAM	Water Situation Assessment Model

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.

CAUCASION

Of the White race.

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) 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.

(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, 1998 (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 which 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, in addition to contributing to the establishment of the National Water Resource Strategy, 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 Middle Vaal Water Management Area (Middle Vaal WMA), which occupies portions of the Free State and North-West 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.

It should be noted that, although the Modder/Riet catchment has C designated secondary catchments i.e C51 and C52, it is part of the Upper Orange WMA and is not included in either the Upper, Middle or Lower Vaal which comprise the remaining C designated secondary catchments.

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

The basic hydrological data used was that contained in the report, "The Surface Water Resources of South Africa, 1990," which was published by the Water Research Commission (Stewart Scott, 1990). The data was modified to take account of the Vaal River System Analysis Update Study (BKS et al, 1997). Land-use data was obtained from reports on the Vaal River System Analysis Update Study, from the report on the Surface Water Resources of South Africa, 1990, from the Vaal River Irrigation Study (Loxton et al, 1999b) and a number of other reports as indicated in the **References section**.

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 Middle Vaal WMA 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 Middle Vaal Water Management Area, is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect of the Middle Vaal WMA are presented in the nine chapters that make up the main body of this report, and a number of appendices containing mainly 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 Middle Vaal WMA covers 52 563 km^2 and is part of the Orange River watercourse as shown in **Figure 2.1.1** .

The study area is shown in **Figure 2.1.2** .

The Middle Vaal WMA is located downstream of the confluence of the Vaal and the Rietspruit Rivers and upstream of Bloemhof Dam. It extends to the headwaters of the Schoonspruit River in the north and the Vet River in the south.

There is relatively little urbanisation in this WMA with Welkom being the largest urban area. Other urban areas are Klerksdorp, Stilfontein, Kroonstad, Winburg, Marquard, Senekal, Lindley, Bothaville, Viljoenskroon, Heilbron, Virginia, Makwassie, Wolmaranstad, Leeudoringstad, Ventersdorp and Orkney.

The topography and secondary river catchments are shown in **Figure 2.1.3** .

The hydrological sub-catchments showing numbered quaternary sub-catchments, key area boundaries, rivers, dams and main towns are shown in **Figure 2.1.4** .

The Vaal River is fed by a number of tributaries in the Middle Vaal WMA, of which the most significant are the (in downstream order) Rhenoster, Schoonspruit, Vals and Vet Rivers. From a water resources point of view the most important is the Vet River.

The Middle Vaal WMA consists of the tertiary catchments C24, C25, C41, C42, C43, C60 and C70 as shown in **Figure 2.1.4** . The figure also shows the main rivers and towns, the WMA boundary, secondary catchments, provincial boundaries where applicable, and names of adjacent Water Management areas.

The Middle Vaal WMA is relatively flat with a maximum elevation of about 2 200 m in the hilly upper reaches of the Vals River and a minimum elevation of about 1 250 m in the vicinity of Bloemhof Dam. Pans and other enclosed drainage basins are a feature of the western parts. **Figure 2.1.3** shows the topography and river catchments and **Figure 2.1.4** shows the 58 quaternary catchments and other main features.

2.2 CLIMATE

Climatic conditions can vary considerably from west to east across the Middle Vaal WMA.

Temperature

The mean annual temperature ranges between 18 °C in the west to 14 °C in the east, with an average of about 16 °C for the catchment as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. The following table summarises temperature data for the Middle Vaal WM for these two months (Schulze et al, 1997).

TABLE 2.2.1: TEMPERATURE DATA

Month	Temperature (°C)	Average	Range
January	Mean temperature	22	20 – 24
	Maximum temperature	29	26 – 32
	Minimum temperature	16	14 – 18
	Diurnal range	14	13 – 16
July	Mean temperature	10	7 – 11
	Maximum temperature	18	16 – 20
	Minimum temperature	1	-2 – 2
	Diurnal range	17	16 - >18

Frost occurs throughout the Middle Vaal WMA in winter, typically over the period mid-May to late August. The average number of frost days per year for the Middle Vaal as a whole ranges from 30 in the northern and eastern parts up to 40 in the central plateau areas of the Free State.

Rainfall

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 Middle Vaal WMA is four per annum (at any single location) and the mean lightning flash density is 5-6 per km^2 per annum. The overall feature of mean annual rainfall over the Middle Vaal WMA is that it decreases fairly uniformly westwards across the central plateau area. The MAP ranges from about 700 mm in the east to about 500 mm in the west with an average of about 550 mm. The average coefficient of variation (CV) ranges from 25% to 35%.

For the driest year in five (80% exceedance probability) the annual rainfall for the eastern half of the Middle Vaal WMA is about 550 mm and for the western half the annual rainfall is about 300 mm. It can be as low as about 250 mm in some places. For the wettest year in five (20% exceedance probability) the annual rainfall in the eastern half is about 700 mm and can be as high as 1 000 mm. For the western half the annual rainfall is about 500 mm and can be as high as 800 mm in places.

Figure 2.2.1 shows the study area and distribution of MAP with an inset of a histogram showing the monthly distribution of rainfall.

Humidity and evaporation

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 Middle Vaal WMA ranges from 62 % in the west to 66 % in the east) and lowest in August (the daily mean ranges from of 52 % in the west to 58 % in the east).

Average gross potential mean annual evaporation (as measured by Class A-Pan) ranges from 1 800 mm in the east to a high of 2 600 mm in the dry western parts. The highest A-pan evaporation is in January (range 200 mm to 300 mm) and the lowest evaporation is in June (100 to 120 mm).

The gross irrigation requirements (based on rainfall and A-pan evaporation) assume 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%). The median gross irrigation requirement ranges from 1 800 mm/a in the dry western parts to 1 000 mm/a in the eastern escarpment areas. The minimum monthly requirement is in June (ranges from 70 mm to 120 mm) and the maximum monthly requirement is in September (ranges from 150 mm to 240 mm).

Figure 2.2.2 shows the study area and distribution of mean annual gross evaporation with an inset showing the monthly distribution.

2.3 GEOLOGY

As for the Upper Vaal WMA, the area south of the Vaal River is underlain by fine sedimentary rocks of the Karoo system (compact arenaceous and argillaceous strata – refer to **Figure 2.3.1**). The total area of the Karoo system represents about 60% of the Middle Vaal WMA. To the north of Bloemhof Dam, igneous and metamorphic rocks predominate (compact sedimentary strata and compact sedimentary extrusive and intrusive rocks – refer to **Figure 2.3.1**) but there are extensive dolomitic exposures in the most northerly part of this WMA and also east of Klerksdorp. The geology of the WMA showing the main rock types is given in **Figure 2.3.1** .

Dolomitic exposures can alter the normal flow of water in a catchment in that apparent losses occur in the areas where there are dolomites but this water invariably reappears in another area via springs.

The predominant minerals are gold and uranium. Gold mining, in particular is of particular economic importance.

2.4 SOILS

Figure 2.4.1 shows a generalised soils map of the WMA using some 16 broad soil groupings (obtained from 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 82 soil types. These soil types were then analysed according to features most likely to influence hydrological response, viz. depth, texture and slope.

Soil depths are generally moderate to deep with flat to undulating relief over the entire Middle Vaal WMA. There are three main soil types that predominate and these are distributed across the catchment as follows.

- Sandy Loam : Most of the WMA consists of this soil type from the central portion of the WMA upstream of Bloemhof Dam which generally has a flat relief to the north of the WMA which is more undulating.
- Clay Loam: This soil type extends from the sandy loan area further eastwards into the headwaters of the Sand, Vet, Elandspruit and Renoster Rivers.
- Clay Soil: A relatively small area at the confluence of the Sand and Vet Rivers.

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

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 heterogeneous 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 2.5.1.1**),including 75 variations. These 70 veld types fall into 11 broad categories, ranging from various forest types to sclerophyllous (Fynbos) types (**Table 2.5.1.1**).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 WMA is rather broad.

TABLE 2.5.1.1: 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	
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	
Succulent Karoo	31	
Orange River Broken Veld	32	
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 Karoo	42	
Mountain Renosterveld	43	
Highveld Sourveld and Dohne Sourveld	44	**Temperate and Transitional Forest and Scrub**

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
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

In this WMA the predominant veld type is "pure grassveld". In the northern areas there is a bit of "false grassveld" while upstream of Bloemhof Dam there is some "tropical bush and savanna". The Acock's veld types are shown in **Figure 2.5.2.1** .

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, 1989 (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 which 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, 1998 (Act No. 36 of 1998). 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 of South Africa are to be protected in terms of the National Water Act, 1998 (Act No. 36 of 1998). This will be accomplished by classifying each water resource, setting the resource quality objectives and determining the Reserve. This process had not yet been completed and therefore it was necessary to determine the present condition or present ecological status class (PESC) of the water resources so as to estimate the quantities of water required to maintain them in this condition for the purpose of the 1995 water resources situation assessment

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** .

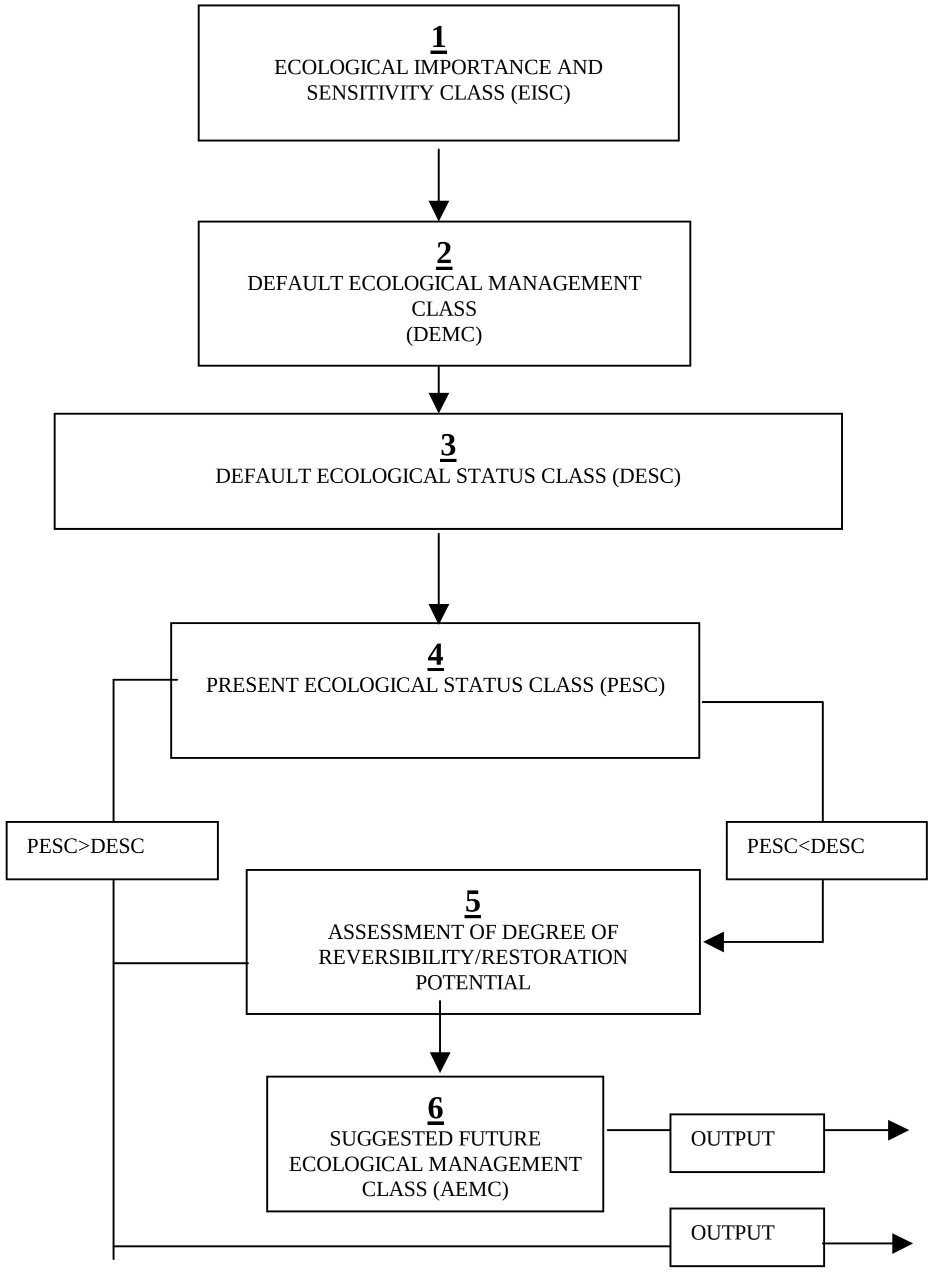


Diagram 2.6.2.1: Procedure followed to determine the river classifications

<u>EISC</u> | <u>DEMC</u> and <u>DESC</u>

Very high → No human induced hazards →Class A: Unmodified natural

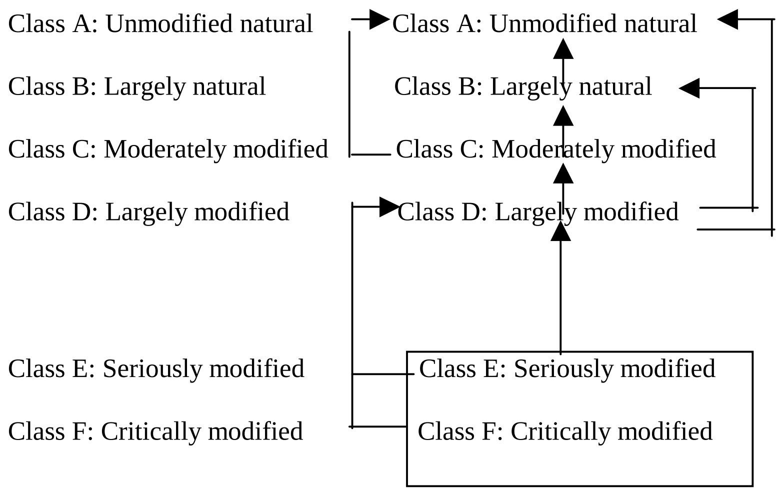
High → Small risk allowed →Class B: Largely natural

Moderate → Moderate risk allowed →Class C: Moderately modified

Low/marginal→ Large risk allowed →Class D: Largely modified

<u>PESC</u> <u>PESC: SUGGESTED ATTAINABLE IMPROVEMENT</u>

<u>Acceptable range of AEMC:</u>



→: indicates relationship.
——▶: indicates possible direction of desirable change.

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

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 main stem 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.

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 main stem 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 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 main stem 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 main stem 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 change 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 quantity and quality. Other sensitive ecosystems, specifically protected areas, are discussed in **Section 2.6.4**.

The ecological significance/conservation importance of the river systems falling within the Middle Vaal WMA, as exemplified by their Ecological Importance and Sensitivity Classes (EISC), are summarised in **Figures 2.6.3.1 to 2.6.3.3**. These show, respectively for each quaternary catchment, the default ecological management class, the present ecological status class, and the suggested future ecological management class. Definitions of these EISC are given in the glossary of terms at the front of this report. The EISC of a river is an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred.

The default ecological management class (**Figure 2.6.3.1**) showed that the majority of the catchment could be tolerated as class C (moderately modified) with only one quaternary catchment even being of class D (largely modified). In the northerly regions of the WMA there were quaternary catchments where a class B could be tolerated. The present ecological status class (**Figure 2.6.3.2**) showed no class A (unmodified, natural) in quaternary catchments and a scattering of class B (largely natural). The largest portion of the WMA showed class C with the remainder being Class D and three quaternary catchments of class E-F (seriously/critically modified) upstream of Bloemhof Dam and Erfenis Dam. The suggested future management class (**Figure 2.6.3.3)** showed the worst class as being class D. Portions of classes D and C from **Figure 2.6.3.2** showed improvement to class B, mainly in the eastern, south-eastern and northern parts part of the WMA.

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

As previously alluded to, the sensitive ecosystems outlined above only include those relevant to aquatic ecosystems. However, in addition to these ecosystems the Middle Vaal WMA contains other protected areas which may be impacted directly or indirectly upon by development activities associated with water resources. These protected areas include Natural Heritage Sites as well as Scientific and Wilderness Areas, National Parks and Reserves, Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas, Protected Land/Seascapes.

Table 2.6.4.1 contains a list of the protected areas within the Middle Vaal WMA. All water resource development should take cognisance of these sites and it is the developer's responsibility to identify the exact proximity of activities to any of these sites, and to ensure that activities do not threaten the integrity of these sites. This consideration is particularly pertinent where water resource development activities impact on the supply of water resources to these areas and hence their long-term ecological sustainability.

TABLE: 2.6.4.1: PROTECTED NATURAL AREAS AND NATURAL HERITAGE SITES WITHIN THE MIDDLE VAAL WMA.

AREA NAME	CATEGORY	QUATERNARY AND PROVINCE
Faan Meintjies Nature Reserve	Habitat and Wildlife Management Area	C24A (North West)
Bloemhof Dam Nature Reserve	Habitat and Wildlife Management Area	C25D/E/F (North West)
Sandveld Nature Reserve	Habitat and Wildlife Management Area	C25F/C43D (Free State)
Wolwespruit Nature Reserve	Habitat and Wildlife Management Area	C25G (North West)
Barberspan Nature Reserve	Habitat and Wildlife Management Area	C31D (North West)
Erfenis Dam Nature Reserve	Habitat and Wildlife Management Area	C41E (Free State)
Willem Pretorius Game Reserve	Habitat and Wildlife Management Area	C42D/E (Free State)
Koppies Dam Nature Reserve	Habitat and Wildlife Management Area	C70C (Free State)

Notes :

(1) Information from (Readers Digest, 1990)

(2) This list should only be viewed as a guide to the protected areas, since as the status of protected areas is constantly changing and new areas are receiving protection, the list cannot be comprehensive. It is the developer's responsibility to ascertain the location of any protected areas adjacent to the development and to ensure that activities do not impact on these areas

Details of known Nature Reserves are as follows:

Faan Meintjies Nature Reserve is located 14 km to the north of Klerksdorp. The 1 300 ha reserve comprises grassy plains and sandy ridges. Mammal species include eland, black wildebeest, red hartebeest, zebra, blesbok, gemsbok, springbok, impala and white rhino.

Bloemhof Dam Nature Reserve is situated along the northern shore of Bloemhof Dam. The 14 000 ha reserve is covered by sandy grassveld. Main species include eland, red hartebeest, blesbok, springbok, black wildebeest, zebra and ostrich. Carp, yellowfish, mud-fish and barbel are amongst the fish species in the dam.

Sandveld Nature Reserve is situated mainly on a peninsula between the Vaal and Vet Rivers, created by the inundation of Bloemhof Dam. The 14 700 ha reserve is characterised by flat terrain and thorny vegetation, similar to the Kalahari sandveld to the north west. Main mammal species are giraffe, eland, gemsbok, red hartebeest, springbok, duiker and steenbok. Bird life includes whitebacked vulture, kori bustard, yellowbilled hornbill, long tailed shrike and various ducks and geese.

Wolwespruit Nature Reserve is situated on the north bank of the Vaal River upstream of Bloemhof Dam. The 2 500 ha reserve has impala, duiker, steenbok, zebra, blesbok, red hartebeest and black wildebeest.

Barberspan Nature Reserve is located 16 km to the north east of Delareyville in flat, grassy terrain. The main feature is the 1 800 ha pan situated within the 3 100 ha reserve. The reserve has abundant bird life, with more than 350 species being observed. The perennial pan is an important sanctuary for birds when other pans in the region are dry.

Erfenis Dam Nature Reserve is situated along the northern shore of Erfenis Dam. The 343 ha reserve has black Wildebeest, red hartebeest, mountain reedbuck and zebra, as well as white springbok and yellow blesbok, which are local variants of these two species. The dam is home to waterfowl with large numbers of African Shellduck and Egyptian Geese.

Willem Pretorius Game Reserve surrounds Allemanskraal Dam. Grassy flats dominate the area to the south of the dam and the northern side is characterised by hills with a mixture of grasslands and thick bush. Mammal species include springbok, black wildebeest, white rhino, giraffe, buffalo and impala. There is also a variety of waterfowl on the dam.

Koppies Dam Nature Reserve surrounds Koppies Dam, 12 km to the east of Koppies. The 2 965 ha reserve is home to black wildebeest but the intention is to introduce other species.

Table 2.6.4.1 shows ecologically sensitive sites, nature reserves, etc.

2.7 CULTURAL AND HISTORICAL SITES

Development of water supplies and services can have a negative impact on the archaeological and cultural heritage by way of development of dams, pipelines, canals, water services infrastructure and enterprises following on the provisions of water.

The National Monuments Act, 1969 (Act No. 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the Environment Conservation Act, 1989 (Act No. 73 of 1989) provides for the integration of cultural resources into environmental management processes.

Any given development may have an impact on archaeological or cultural heritage sites. It is essential therefore that potential impacts of any water supply and services related development should be assessed at the earliest possible phase of project planning.

Permission for the development to proceed is granted by the National Monuments Council once it is satisfied that steps have been taken to safeguard archaeological or cultural heritage sites, or that they have been adequately recorded and/or sampled.

No general listing of the sites of palaeontological, archaeological and historical significance within the Middle Vaal WMA is available. Some information was, however, obtained (Morris and National Monuments Council brochure). The National Monuments Council does possess a database of National Monuments within each province, but this is only of limited use since it only lists National Monuments (as declared within the Government Gazette), and the vast majority of these occur within urban areas which are unlikely to be impacted upon by water resources projects. Accordingly, it is the responsibility of the developer to liaise with the National Monuments Council and South African Museum to establish whether they are aware of any sites of cultural/historical/archaeological interest within any area earmarked for development. Moreover, it is the developer's responsibility to ensure that the development area is surveyed for archaeological sites or artefacts, and that necessary steps are taken to conserve them if they are present. To this end, the developer should be familiar with the relevant sections of the National Monuments Act and any other relevant legislation (e.g. National Parks Act, 1975 (No. 57 of 1975)), and should consult with the National Monuments Council on discovering sites or artefacts of palaeontological, archaeological or historical significance. Also, developers should take cognisance of the fact that the National Heritage Act is likely to supersede the National Monuments Act in April 2000, and should undertake to familiarise themselves with the contents of the new Act.

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The Vaal River is the principal source of water supply for the Free State and North West Goldfields areas and is the most important river in the WMA.

The Vaal River basin boasts South Africa's earliest major multi-purpose scheme, which is also the first major inter-basin transfer scheme, viz. the Vaal River Development scheme, of which the main storage unit is Vaal Dam which is in the Upper Vaal WMA. Constructed during the mid-nineteen thirties, Vaal Dam was designed to serve both the Reef Complex and the Vaal-Harts Irrigation Scheme in the Lower Vaal WMA (involving diversion of water from the Vaal River into the Harts River valley). Although for many years most of the water from the Vaal River went to Vaal-Harts, the major share now goes to Rand Water (in the Upper Vaal WMA) for distribution throughout its 17 000 km^2 supply area.

Bloemhof Dam (in the Middle Vaal WMA), built in 1970, helped to relieve Vaal Dam of part of the downstream load. Upstream of Bloemhof Dam, Goldfields Water and MidVaal Water Company (previously the Western Transvaal Regional Water Supply Company) withdraw significant amounts of water from the Vaal River. The Vaal River also provides water to the Lower Vaal WMA, to Kimberley and other riparian towns and to the Gamagara pipeline (serving the Kalahari (Hotazel-Postmasburg) mineral complex.

To meet spiralling water demands within the basin, various importation schemes have been implemented, the most important of which are the Tugela-Vaal, Usutu-Vaal and the recently completed Phase 1A of the Lesotho Highlands Water Scheme (all entering the Upper Vaal WMA). Other waters brought into the Vaal River basin are those from the Caledon River to augment the supply to Bloemfontein (covered in the Upper Orange WMA report).

Most of the major tributaries of the Middle Vaal WMA support irrigation schemes. The Sand-Vet Irrigation Scheme within the Sand-Vet Government Water Scheme (GWS) is the most important in the Middle Vaal WMA. Other significant irrigation schemes in this WMA are the Schoonspruit and Rhenoster GWS.

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 inquiries 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

Information on historical growth trends is not readily available. However migration to urban areas is a significant trend in this WMA because of the perception that job opportunities are greater and services are better and because significant numbers of farm workers have been displaced by farmers because of land claim concerns. Refugees and migrants (including illegal migrants) from neighbouring states are not a significant portion of the population.

3.2.4 Population Size and Distribution in 1995

Quaternary catchment urban and rural population data was obtained from the National Demographic Study (Markdata and Schlemmer, 2000*)*. This data has been reproduced in **Figure 3.2.4.1** (shown as pie diagrams) and **in Appendices A.1** (urban data) and **A.2** (rural data). The quaternary catchment data has been summarised in **Table 3.2.4.1** into key area and provincial, urban and rural population data.

In 1995, about 1 509 000 people were estimated to be living in this WMA. A significant proportion (74 %) of the population is urbanised. As expected the Vaal (North West Goldfields) and Vet (Free State Gold Fields) key areas are the most urbanised (36 % and 34 % respectively) and they also have the largest rural populations (35 % and 23 % respectively).

Approximately 70 % of the population in the Free State portion of the WMA are urbanised and 83 % are urbanised in the North West portion of the WMA.

TABLE 3.2.4.1: POPULATION IN 1995.

CATCHMENT						POPULATION IN 1995		
PRIMARY		SECONDARY		TERTIARY		URBAN	RURAL	TOTAL
No	Description	No	Description	No.	Key Area Description			
C	Vaal	C7	Rhenoster	C70	Rhenoster (70A-K)	62 350	37 856	100 206
		C6	Vals	C60	Vals (C60A-J)	148 050	41 152	189 202
		C2	Johan Neser	C24	Johan Neser (C24C-G)	21 150	31 915	53 065
			Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	404 700	89 497	494 197
			Bloemhof	C25	U/S Bloemhof (C25D-F)	51 200	21 961	73 161
		C4	Allemanskraal	C42	Allemanskraal (C42A-E)	24 150	16 717	40 867
			Erfenis	C41	Erfenis (C41A-E)	26 500	18 408	44 908
			Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	376 800	136 695	513 495
Total in Free State						**708 950**	**310 263**	**1 019 213**
Total in North-West						**405 950**	**83 939**	**489 889**
TOTAL IN WMA						**1 114 900**	**394 202**	**1 509 102**

3.3 MACRO-ECONOMIC INFLUENCES

3.3.1 Introduction

The purpose of this section is to provide an economic overview of the salient features of the Middle Vaal Water Management Area (WMA) in terms of the following aspects:

- The present economic development of the Middle Vaal WMA on a sectoral basis, taking into account the context of economic development in South Africa.
- The comparative advantages of the Middle 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 B.2** 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 B4.**

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

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 Middle Vaal WMA was R20,7bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

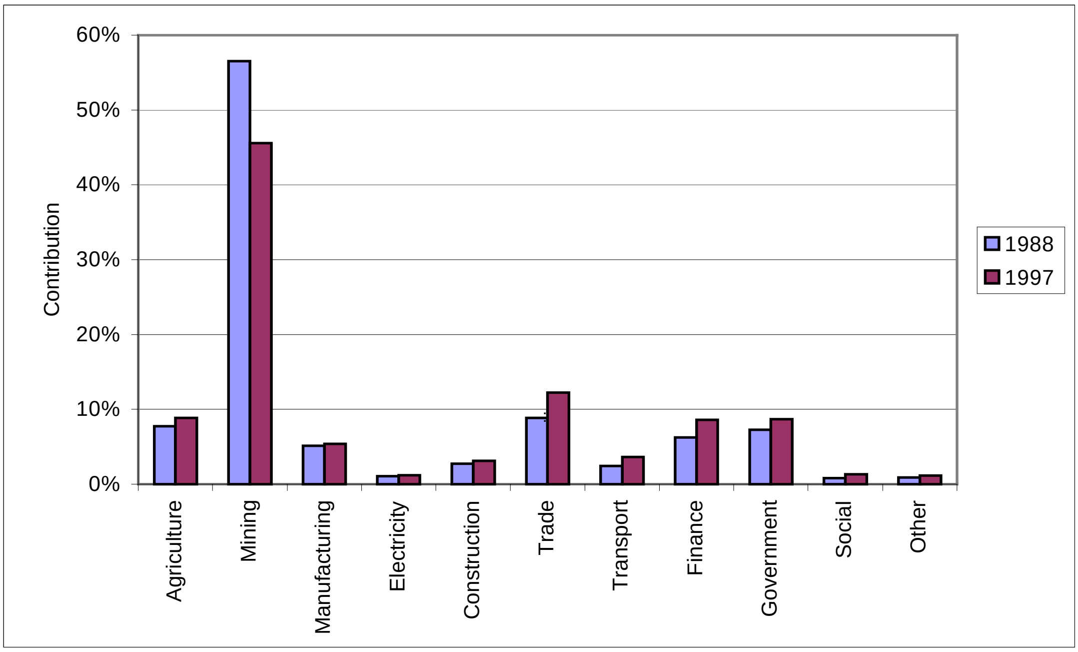
- Klerksdorp 33,5%.
- Welkom 26,6%.
- Virginia 10,0%.
- Kroonstad 7,2%.
- Other 22,7%.

Economic Profile

The composition of the Middle Vaal WMA economy is shown in **Diagram 3.3.4.1**. The most important sectors in terms of contribution to GGP are shown below:

- Mining 45,6%.
- Trade 12,3%.
- Agriculture 8,9%.
- Other 33,2%.

Diagram 3.3.4.1: Contribution by Sector to Economy of Middle Vaal Water Management Area, 1988 and 1997 (%).



Some of the main agricultural products being cultivated are maize, groundnuts and sorghum. There has recently been an increase in sunflower production, because of an unstable maize market and higher profit margins on sunflower production. However, it is expected that sunflower production will top-off over the next two to three years, since the market is being oversupplied. Livestock farming consists mainly of dairy, beef and sheep farming enterprises.

The main economic sector in the Middle Vaal WMA is mining, with a contribution of 45,6% to GGP. The main mining activity in this area is gold mining. Very few gold mines have a life span beyond the year 2010, although the reserve base could support mining in the Goldfields District up to the year 2030. The future of gold mining will furthermore be determined by the performance of the gold price, the rand exchange rate, the industry's ability to reduce operating costs, a constructive tax regime and realistic environmental and safety standards.

The trade sector is the second largest contributor to GGP. Trade activities is a derived demand. The levels of personal consumption expenditure and international trade largely drive the trade sector's performance.

Economic Growth

The average annual economic growth by sector is shown in **Diagram 3.3.4.2**. Between 1987 and 1997 the highest growth rates were recorded in the following sectors:

- Social services : 3,7%.
- Trade : 2,8%.
- Construction : 2,0%.

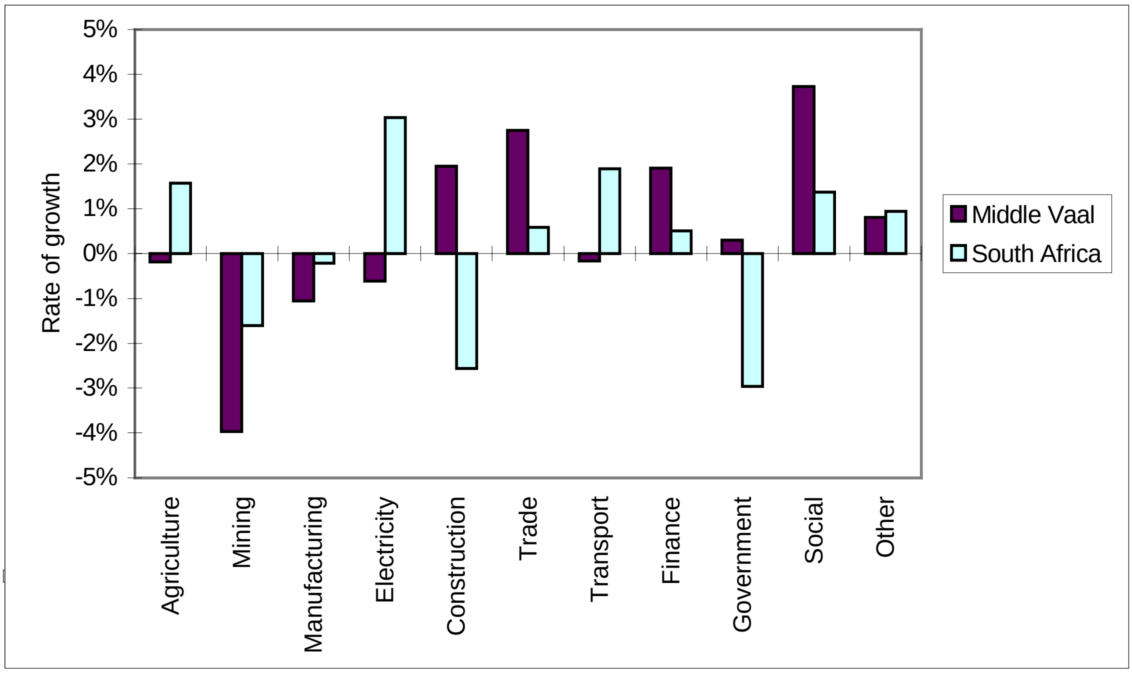
Growth in the social services sector could be attributed to the importance of areas such as Klerksdorp and Kroonstad in catering in the health and educational needs of the communities.

A number of important commercial centres are situated in the Middle Vaal WMA. These centres such as Klerksdorp and Welkom recorded expansion, e.g. a new shopping centre was built in Klerksdorp, which contributed to growth in the trade sector.

Although the mining sector is the main economic activity in this region, negative growth was recorded. This negative growth rate could be attributed to the low gold price and higher operating costs experienced by the mining sector.

Growth in the construction sector could be attributed to large development projects such as the new shopping centre in Klerksdorp and RDP housing.

Diagram 3.3.4.2: Average Annual Economic Growth by Sector of Middle Vaal Water Management Area and South Africa, 1988-1997.



Labour

Of the total labour force of 659 000 persons, 23,1% are unemployed, which is lower than the national average of 29,3%. Sixty seven percent (67,0%) are active in the formal economy. Thirty six percent (35,8%) of the formally employed labour force work for the mining sector, while 24,1% are employed in the government sector and 16,9% in the agricultural sector.

During the period 1980 – 1994 employment growth was recorded in the financial services sector (3,9% per annum) and the trade sector (0,3% per annum).

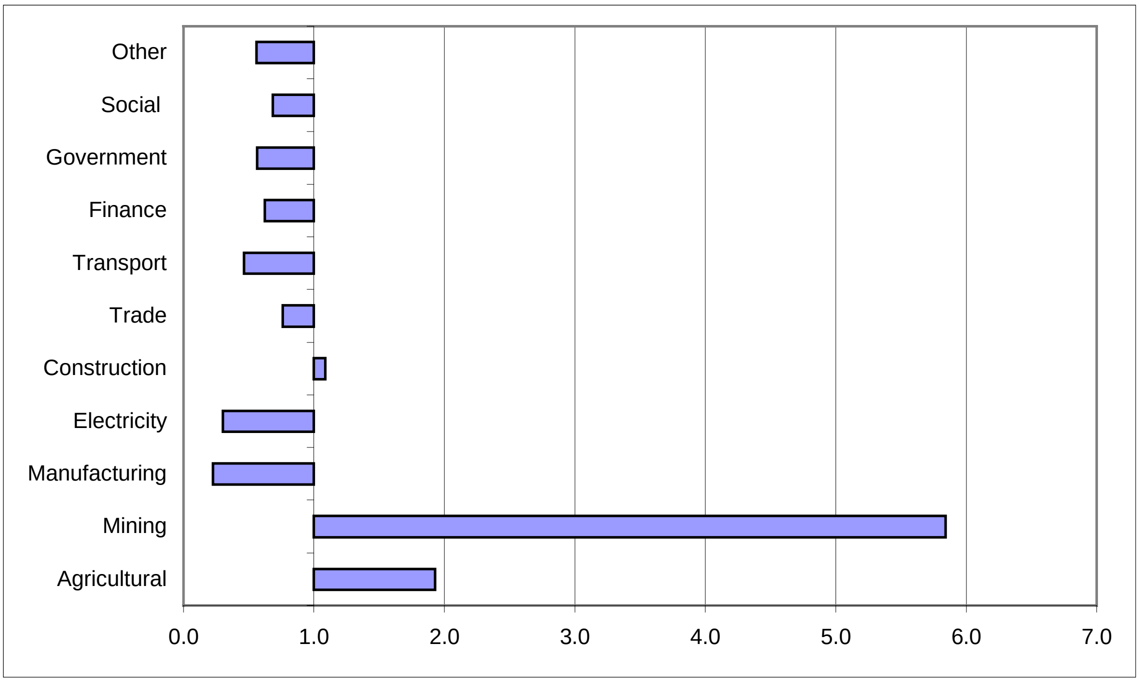
3.3.5 Comparative advantages

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

- Agriculture : 1,9.
- Mining : 5,8.
- Construction : 1,1.

Diagram 3.3.5.1: Middle Vaal Gross Geographic Product Location Quotient by Sector, 1997.



The mining sector has a large comparative advantage seen within a national context. This could largely be attributed to the importance of gold mining in the Middle Vaal WMA. The majority of mines still have a life-span of 10-30 years and it can be expected that this sector will continue to have a comparative advantage during that period.

The comparative advantage of the agricultural sector can be attributed to the diversity of products both in terms of crop and in livestock production. This WMA is important in the production of maize, beef cattle, sheep, dairy and wheat.

The fact that the agricultural sector has become increasingly diversified and that more farmers are putting land under irrigation further contributed to the comparative advantage of the agricultural sector .

Growth in sectors such as trade and financial services has lead to new development, hence new construction. Growth in construction activities has strengthened this sector's location quotient to a value of 1,1, which indicates that in a national context, this WMA has attracted a larger than average proportion of construction investment.

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, 1956 (Act No 54 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, 1998 (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

Chapter 3 of the NWA deals with protection of the water resources.

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, 1997 (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.
- Existing lawful use recognised under the NWA until such time as the person is required to apply for a licence.

The statutory difference between water resources within an area proclaimed as a government water control area in terms of the Water Act, 1956 (Act No 54 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, 1956 (Act No 54 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 licence 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 licence 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 licence can be increased at each review period but not for more than the review period. This is known as the “revolving licence”.

If a person who has an existing lawful use applies for a licence 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 licence 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, 1997 (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 licence;
- If a licence is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a licence 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, 1997 (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, 1991 (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, 1995 (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, 1994 (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, 1989 (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, 1998 (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, 1983 (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.

3.4.8 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, 1956 (Act No 54 of 1956) had until 29 February 2000 to transform into a WUA. All WMA'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.

3.4.9 Institutions

MidVaal Water Company and Sedibeng Water are major suppliers of potable bulk water in this WMA. **Appendix A.1** lists all Local Councils as at 1995. **Figure 3.4.8.1** shows magisterial district and district council boundaries in 1995 and **Figure 3.4.8.2** shows the water board boundaries and TLC/TRC boundaries.

The following district councils exist in this WMA:

- Eastern Free State (part of).
- Northern Free State (part of).
- Southern.
- Goldfields.
- Rustenberg.
- Central.
- Bloem area.

The following irrigation schemes, boards and controlled areas occur in this WMA:

In the Sand-Vet Area:
Sand-Vet GWS (Sand), Sand-Vet GWS (Vet)and Vet GWS.

In the Rhenoster-Vals Area:
Renoster GWS, Weltevrede Management (MB).

In the Vaal Area:
Vaal River GWCA, Klerksdorp Irrigation Board

3.5 LAND USE

3.5.1 Introduction

Agriculture is one of the main activities in this WMA. The irrigation of crops such as wheat, maize and fodder crops occurs throughout the WMA. The Sand-Vet GWS is the most important irrigation area in the WMA. Livestock farming and some game farming occurs. A summary of known nature reserves is provided in **Section 2.6.3**. There is no sugarcane or significant afforestation in this WMA.

Urban development is significant in the area of the North West Goldfields (Klerksdorp, Orkney and Stilfontein) and the Free State Goldfields (Welkom, Virginia, etc). The MidVaal Water Company is the main supplier of bulk water to urban areas in the North West Goldfields and Sedibeng Water is the main supplier of bulk water in the Free State Goldfields.

There are no significant strategic bulk users or large industries in the WMA. The WMA is characterised by a large number of gold mines (Free State Goldfields area and North West Goldfields area). The economy of the Middle Vaal WMA is dominated by the mining sector, particularly gold mining.

Figure 3.5.1.1 shows secondary catchment boundaries, rivers and dams, urban complexes and towns, mines, large industries, power stations and irrigated and afforested areas. **Table 3.5.1.1** shows areas of irrigation, alien vegetation infestation and urbanisation for key areas and provinces.

TABLE 3.5.1.1: LAND USE BY KEY AREAS

CATCHMENT				Irrigation (field area) (km²)	Alien vegetation (km²)	Urban (km²)	Other (km²)	Total (km²)
SECONDARY		TERTIARY						
No	Description	No.	Key Area Description					
C7	Rhenoster	C70	Rhenoster (70A-K)	21,9	0	0	6 634,1	6 656
C6	Vals	C60	Vals (C60A-J)	2,4	1,6	43	7 824,0	7 871
C2	Johan Neser	C24	Johan Neser (C24C-G)	41,8	3,9	0	5 598,3	5 644
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	9,4	17,8	78	8 175,8	8 281
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,0	45,8	0	4 913,2	4 959
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	0	0	3 628,0	3 628
	Erfenis	C41	Erfenis (C41A-E)	0,0	0	0	4 724,0	4 724
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	132,4	1,5	131	10 535,1	10 800
Total in Free State				**161,5**	**31,6**	**174**	**38 573,7**	**38 940,8**
Total in North-West				**46,4**	**39,0**	**78**	**13 458,8**	**13 622,2**
TOTAL IN WMA				**207,9**	**70,6**	**252**	**52 032,5**	**52 563,0**

Note : (1) No dryland sugar cane and afforestation is negligible.
(2) Other landuse includes dryland crops, Nature Reserves and Rural Settlements for which data was not readily available.

3.5.2 Irrigation

Irrigated Areas

The total irrigated area and various crop category areas for each key area are shown in **Table 3.5.2.1**. Both harvested area (which includes re-use of irrigable areas for different seasons) and field area (physical maximum crop area under irrigation at any one time) have been shown. A map depicting the extent of the existing irrigation is shown in **Figure 3.5.1.1** and **Appendix D.1** lists harvested crop area data.

The harvested irrigated area is defined as the maximum area under irrigation during any stage of the year. Due to the regionalised distribution of the prescribed crop factors given in the report (Loxton et al, 1999a), it was found unrealistic to simply determine the maximum irrigated area on the basis of the month with maximum crop area. To solve this problem in a realistic fashion the irrigated area was accepted as the maximum of the mid-summer crop area and the mid-winter crop area. Considering the given full range of crop factors available, mid-summer was defined as January/February while mid-winter was defined as July/August. Using this approach it was ensured that maximum but realistic allowance was made for double cropping, where appropriate.

Harvested irrigation area data for this WMA was extrapolated from the Vaal River Irrigation Study (Loxton et al, 1999b). This study represents the irrigation situation in the Vaal River catchment in 1995.

The report (Loxton et al, 1999b) presents harvested irrigated crop area and defined river reaches. This data had to be disaggregated into quaternary catchment data. The disaggregation represents an estimate and was undertaken as follows:

- Each river reach area was reviewed and the irrigated harvested crop area was noted from Table 7.2 of the report (Loxton et al, 1999b).
- The main river channel quaternary catchments in each river reach area were noted (the assumption being that most irrigation is from the main river channel) and where applicable, maps of the irrigation areas were reviewed. Refer to Figure 11.11 of the report (Loxton et al, 1999b).

For example the irrigation area known as Sand Vet GWS (Vet area) has an irrigation field area of 52,45 km^2 (harvested crop area of 100,57 km^2), and the main river channel quaternary catchments from which irrigation is most likely to occur are C41G, C41H and C41J. No information on the physical location of the irrigation in this irrigation area was known. As a result the field area per quaternary catchment was estimated equally for each quaternary catchment to be 17,48 km^2. This means that overall irrigation data can be considered reliable but quaternary catchment irrigation data represents an estimate only and must be considered to be of poor quality.

TABLE 3.5.2.1: 1995 IRRIGATION LAND USE.

CATCHMENT				IRRIGATED AREA BY CROP CATEGORY (km2)				
SECONDARY		TERTIARY		Perennial	Summer	Winter	Total harvested area[2]	Total field area[3]
No	Description	No.	Key Area Description					
C7	Rhenoster	C70	Rhenoster (70A-K)	7,8	14,1	6,7	28,6	21,9[S,F]
C6	Vals	C60	Vals (C60A-J)	0,4	2,0	1,0	3,4	2,4[S]
C2	Johan Neser	C24	Johan Neser (C24C-G)	10,3	31,5	6,5	48,3	41,8[M,S]
C2	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	4,3	5,1	1,5	10,9	9,4[M,S]
C2	Bloemhof	C25	U/S Bloemhof (C25D-F)	0	0	0	0	0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0	0	0	0	0
C4	Erfenis	C41	Erfenis (C41A-E)	0	0	0	0	0
C4	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	10,8	121,6	85,4	217,8	132,4[M,S]
Total in Free State				**21,2**	**140,3**	**93,9**	**255,4**	**161,5**
Total in North-West				**12,4**	**34,0**	**7,2**	**53,6**	**46,4**
TOTAL IN WMA				**33,6**	**174,3**	**101,1**	**309,0**	**207,9**

Note: (1) There are no undifferentiated crops in this area. Crop area data from Tables 7.2 and 8.2 of the Vaal River Irrigation Study (Loxton et al., 1999b).
(2) Total crop area irrigated in 1995.
(3) Physical area (summer and perennial crop area) under irrigation in 1995.
(M/S/F) Mechanical, sprinkler and flood irrigation systems.

Irrigation Methods

The most common irrigation methods used in this WMA are sprinkler and mechanical (centre pivot) systems. In general the irrigation methods used for a specific crop type do not vary significantly between different catchments.
The information on the irrigation methods used in the study area was obtained from the report (Loxton et al., 1999b) and is shown for each key area in **Table 3.5.2.1** .

Enterprise Returns

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 demands of domestic and urban water use. In order to do this it will be necessary to base such decisions on sound economic principles such as economic return per unit of water. Although acknowledged to be fairly generalised, only three economic categories of irrigated crops have been used for the purpose of this study. The following table shows the suggested net incomes from the various income categories as well as typical crops within each category.

TABLE 3.5.2.2: ASSURANCE CATEGORIES FOR IRRIGATED CROPS

Category	Crop Examples
Low	Maize, wheat, soya bean, dry beans, groundnuts and pastures for small stock
Medium	Vegetables, potatoes, seed production and pastures for dairying.
High	Citrus, deciduous fruit and nuts, sub-tropical fruit and nuts, grapes, sugar cane, tea and specialty vegetables

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

The economic value of crops is shown for each quaternary catchment in **Appendix D.1.**

The economic value of crop does not appear to be a consideration when determining quotas for so called scheduled irrigation areas and does not appear to be the driving motivation for why irrigation water is supplied.

In the Middle Vaal WMA, significant double cropping occurs in the Sand-Vet GWS. The harvested area in 1995 was 217,8 km^2, whereas the scheduled or field area is 120 km^2 (Table 8.2, of the report Loxton et al., 1999b). This represents a double cropping factor of 1,8. However irrigation water requirements are determined for field area and do not consider double cropping. This degree of double cropping does not occur anywhere else within the WMA.

3.5.3 Dryland Farming

The main dryland crops that are cultivated are maize, wheat and fodder pastures (kikuyu and rye). Due to climatic conditions, no dry land sugar cane is being produced in the study area and the extent of dryland cultivation is not known.

3.5.4 Livestock and game farming

Introduction

The livestock species reviewed, included cattle (beef and milk), sheep, goats, pigs, horses, donkeys and mules. While game species reviewed, ranged from black wildebeest to zebra. This data was available from several sources at magisterial district scale. All livestock and game species had to be converted to “equivalent large stock units” (ELSUs), before disaggregation to quaternary catchment scale.

Sources of information

Livestock and game data was obtained from 2 main sources, namely:

- Department of Agriculture (DOA), 1990 Food Survey, digital data provided by Glen Agricultural Station. This data is available on a primary catchment basis per magisterial district.
- Central Statistical Services (CSS), produced a “Census of Agriculture, 1988” on a magisterial district basis and is similar to that provided by the DOA. Data on pigs, horses, mules and donkeys is available from this survey. The main disadvantages of this data is that unlike the “Glen” data it is not presented per primary catchment and game is not broken down into species.

It was assumed that livestock and game data for 1988 and 1990 can be used to represent 1995 figures as the general consensus is that agriculture has reached a threshold and livestock numbers are unlikely to change significantly. Furthermore the 1988 and 1990 data represents both mature and immature livestock and game numbers, therefore these numbers can be extrapolated to represent the mature livestock and game numbers for 1995. The CSS livestock data was used if the Food Survey data looked suspect or if data was missing. For example the Food Survey database did not provide any data on pig numbers while the CSS survey did.

Conversion of data

The first step involved converting the different livestock and game species into Equivalent Large Stock Units (ELSUs). The ELSU conversion factors for various species of livestock and game is provided in **Appendix F.3**. This conversion table was provided by the DWAF. Unconverted magisterial district data for livestock and game species is also provided in **Appendix F.3**.

The disaggregation of ELSUs from Magisterial District (MD) to quaternary catchment resolution was based on a uniform spatial distribution of ELSUs within a MD. The actual disaggregation was carried out pro-rata to the areas of the quaternary catchments within the MD. Judgement was, however, exercised where there was additional information.

Appendix F.3 lists equivalent large stock numbers at quaternary catchment scale. The average water use by ELSUs is taken at 45 ℓ/ELSU/day. The overall ELSUs for key areas and provinces for 1995 are given in **Table 3.5.4.1** and **Figure 3.5.4.1**. **Section 5.3.3** provides information on the water requirements of livestock in the WMA.

Cattle and sheep farming is the main type of stock farming in this WMA.

TABLE 3.5.4.1: 1995 LIVESTOCK AND GAME POPULATIONS.

CATCHMENT				Number of ELSU
SECONDARY		TERTIARY		
No	Description	No.	Key Area Description	
C7	Rhenoster	C70	Rhenoster (70A-K)	270 426
C6	Vals	C60	Vals (C60A-J)	192 785
C2	Johan Neser	C24	Johan Neser (C24C-G)	137 409
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	180 967
	Bloemhof	C25	U/S Bloemhof (C25D-F)	136 858
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	107 327
	Erfenis	C41	Erfenis (C41A-E)	136 772
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	322 772
Total in Free State				**1 164 885**
Total in North-West				**320 431**
TOTAL IN WMA				**1 485 316**

3.5.5 Afforestation and Indigenous Forests

The climate is unsuitable for commercial afforestation.

There is no appreciable indigenous afforestation.

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 m³/a by Le Matre (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 estimated 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.

Data on alien vegetation eradication schemes in this WMA was not readily available from the Working for Water Programme Co-ordinator.

Table 3.5.6.1 gives the condensed area of alien vegetation per key area.

TABLE 3.5.6.1: INFESTATION BY ALIEN VEGETATION.

CATCHMENT				CONDENSED AREA OF ALIEN VEGETATION (km^2)
SECONDARY		TERTIARY		
No	Description	No.	Key Area Description	
C7	Rhenoster	C70	Rhenoster (70A-K)	0
C6	Vals	C60	Vals (C60A-J)	1,6
C2	Johan Neser	C24	Johan Neser (C24C-G)	3,9
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	17,8
	Bloemhof	C25	U/S Bloemhof (C25D-F)	45,8
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0
	Erfenis	C41	Erfenis (C41A-E	0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	1,5
Total in Free State				**31,6**
Total in North-West				**39,1**
TOTAL IN WMA				**70,7**

3.5.7 Urban Areas

Assurance of water supply for urban users ranges from 95% to 99%. The human Reserve for this WMA is set at 25 ℓ/capita/day and has an assurance of supply of 99,9%.

Urbanisation in this WMA is concentrated around the Free State and North West Province gold mining areas. Welkom is the largest urban area in the Free State. Other significant towns in the Free State are Virginia, Kroonstad, Bothaville, Senekal and Viljoenskroon.

Klerksdorp is the most significant urban area in the North West Province. Other important towns are Orkney, Stilfontein, Wolmaranstad, and Ventersdorp.

All urban areas are listed in **Appendix A.1** and are shown in **Figure 3.5.1.1**. A total urban area of 252 km^2 was estimated from WR90 data. The data from WR90 represents the 1990 situation and it is expected that the urban areas are underestimated for all areas within the WMA.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

3.6.1 Introduction

Due to different levels of assurance of water supply, so-called Bulk Users have been divided into three categories:

- Strategic users (power stations).
- Mining.
- Other Bulk users (includes major industries).

These bulk users are those not supplied by municipalities.

Mining is treated as a separate category (**Section 3.7**) because return flows from mines can be significant (quantitatively and qualitatively) and have been divided into treated effluent returns and groundwater pumped into the system for operational reasons.

3.6.2 Strategic Bulk Users

For the purpose of this study, strategic bulk users apply only to power stations, which require a high assurance of water supply. There are, however, no operational power stations in this WMA.

3.6.3 Major Industries

There are no major industries in this WMA. There are some other bulk users which are small users (e.g. farmers, rural institutions) that receive water from Sedibeng Water and from MidVaal Water Company. **Appendix F.5** lists these small bulk users and their assurance of water supply ranges from 95% to 99% with the majority being at 98% (refer to **Appendix F.9**).

3.7 MINES

Mining operations in South Africa encompass a wide range of activities, which include the extraction, dressing and beneficiation of naturally occurring minerals to render the material marketable or to enhance the market value of the material. Mining operations include underground and surface mines and quarries. Assurance of water supply for mines ranges from 98% to 99% (**Appendix F.9**).

Figure 3.7.1 shows the location of operating mines.

Products of the mining industry in the WMA include precious metals (gold, uranium, etc.), base metals, semi-precious stones, industrial minerals and dimension stone. This WMA is characterised by a large number of gold mines (Free State Goldfields area and North West Goldfields area). **Appendix F.6** lists all known operating mines in the WMA with special reference to mines that impact on the hydrology and or water quality of the WMA.

Data about mines was obtained from a number of sources including:

- Council of Geoscience, SAMINDABA database (SA Mining Database).
- Reports on the "Vaal River Systems Analysis Update" Study (BKS et al, 1998d,e,f).

It should be noted that the names of many mines have changed in the past 5 years and the names provided in the **Appendix F.6** may be out of date.

Discharges from mines impact significantly on both the hydrology and water quality of the Middle Vaal system. This is true of the tributary catchments of the Vaal River catchment. The decline in water quality of the Middle Vaal WMA has a significant component from mine pollution upstream in the Upper Vaal WMA, with gold mines in the Sand River catchment being of particular concern. For example in 1995 the Buffelsfontein and Stilfontein Gold Mines decanted 16,4 x $10^6 m^3$ of groundwater into the Koekemoerspruit. The impact in terms of quality is generally negative for these smaller systems and for downstream users.

The economy of the Middle Vaal WMA is dominated by the mining sector (45,6% of GGP) particularly gold mining. Refer to **Section 3.3.4**.

3.8 WATER RELATED INFRASTRUCTURE

Due to the fact that this WMA's water resources were fully utilised many years ago, a number of dams have been constructed and water transfer schemes have been developed which transfer water from the Vaal River to adjacent areas of significant gold mining.

There are two important water transfer schemes within the WMA. MidVaal Water Company has a significant network of reservoirs, pump stations and pipelines from the Vaal River to Klerksdorp, Orkney and Stilfontein and to Buffelsfontein, Stilfontein and Vaal Reefs Goldmines. Sedibeng Water also has a significant network of reservoirs, pump stations and pipelines from the Vaal River to Welkom, Virginia, etc and to Harmony, Avgold, Beatrix, Joel, etc, Gold Mines.

Bloemhof Dam, Allemanskraal Dam and Erfenis Dam are the largest dams in this WMA but there are several other important dams as listed in **Table 4.3.1**.

There are numerous sewage treatment works, some of which return purified effluent to various rivers within this WMA. Most of the smaller towns return sewage water to oxidation ponds. As with the Upper Vaal WMA some re-use of treated sewage water occurs but this information is not readily available.

Major infrastructure in the WMA is shown on **Figure 4.1.1** and a schematic diagram, **Figure 4.1.2**, also shows major infrastructure. More detailed information is provided in **Chapter 4**.

CHAPTER 4: WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

There are a number of large gold mines in the area. These mines together with a growing urban population have very high requirements for an assured water supply. The MidVaal Water Company and Sedibeng Water are the major suppliers of bulk water.

The MidVaal Water Company has a major offtake from the Vaal River, in the Klerksdorp – Orkney area. MidVaal Water Company has an authorisation to abstract 86,87 x $10^6 m^3/a$ from the Vaal River (DWAF Permit 97/16/2/77). In 1995 it abstracted 56,8 x $10^6 m^3$ mainly for mining and urban water requirements (MidVaal, 1999).

Sedibeng Water has a major offtake from the Vaal River at Balkfontein, upstream of Bloemhof Dam. Sedibeng Water also abstracts a smaller quantity from the Sand River in the vicinity of Virginia. Sedibeng Water has authorisation to abstract 125 x $10^6 m^3/a$ from the Vaal River and 12,8 x $10^6 m^3/a$ from the Sand River (DWAF Permits 131/11/81 and 12/23/80). In 1995 it abstracted 74,1 x $10^6 m^3$ from the Vaal River and 2,8 x $10^6 m^3$ from the Sand River (Sedibeng Water, 1999). The water was mainly for mining and urban requirements.

Figures 4.1.1 and 4.1.2 show water related infrastructure such as dams, water treatment works, reservoirs, sewage treatment works, pipelines, irrigation schemes, etc.

Provides a summary of potable water supply schemes per key area and for the provinces. Per capita urban consumption ranges from 113 ℓ/capita/day in the relatively sparsely populated and undeveloped u/s Bloemhof key area to 294 ℓ/capita/day in the more developed Vals key area. Per capita rural consumption is estimated at 25 ℓ/capita/day.

There are some large dams in the catchment and their details have been recorded in **Table 4.3.1**. Details of known weirs have been included in **Appendix E.1.** There is a network of reservoirs, pump stations and sewage treatment works, details of which have been provided in **Appendix E.2, E.3 and E.4.** Details of groundwater abstractions have been included in **Appendix E.5**. Details of pipelines and canals have been provided in **Appendices E.6 and E.7**. There are no known hazardous waste sites in this WMA.

TABLE 4.1.1: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES BY KEY AREA.

CATCHMENT				TOWN AND REGIONAL WATER SUPPLY SCHEMES			
SECONDARY		TERTIARY		Number of People Supplied	% of Drainage Area Population	CAPACITY	
No.	Description	No.	Key Area Description			($10^6 m^3$) (1)	(ℓ/ capita/d)#
C7	Rhenoster	C70	Rhenoster (70A-K)	62 350	62,2		145
C6	Vals	C60	Vals (C60A-J)	148 050	78,3		294
C2	Johan Neser	C24	Johan Neser (C24C-G)	21 150	39,9		185
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C	404 700	81,9		179
	Bloemhof	C25	U/S Bloemhof (C25D-F)	51 200	70,0		113
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	24 150	59,1		156
	Erfenis	C41	Erfenis (C41A-E)	26 500	59,0		137
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	376 800	73,4		224
Total in Free State				**708 950**	**70,0**		**-**
Total in North-West				**405 950**	**82,9**		**-**
TOTAL IN WMA				**1 114 900**	**73,9**		**203**

Note: (1) This information is not readily available.
\# Daily urban consumption calculated from urban usage data.

4.2 MAJOR WATER SUPPLY SCHEMES AND WATER SUPPLIERS

4.2.1 Sedibeng Water

A significant amount of potable water for urban use is provided by Sedibeng Water. Water from the Vaal River is purified at the Balkfontein Water Purification Works and from the Sand River at the Virginia Water Purification Works. While Sedibeng Water operates mainly in the Middle Vaal WMA, it also operates the Qwa Qwa network in the Upper Vaal WMA and is responsible for water supply in the Taung area of the Lower Vaal WMA. During 1995, Sedibeng Water supplied about 34 x 10^6 m^3 to about 514 000 people in the Middle Vaal WMA. Refer to **Table 4.3.3** for capacity details and to **Appendices E.3 and E.6** for pump station and pipeline details.

4.2.2 MidVaal Water Company

Formerly known as the Western Transvaal Regional Water Company, the MidVaal Water Company purifies water from the Vaal River to supply three TLC's, Klerksdorp, Stilfontein and Orkney and three Gold Mines, Vaal Reefs, Hartbeesfontein and Buffelsfontein. During 1995, MidVaal Water Company supplied about 19,4 x 10^6 m^3 to about 300 000 people in the Middle Vaal WMA, all within the

North West Province. Refer to **Table 4.3.3** for capacity details and to **Appendices E.3 and E.6** for pump station and pipeline details.

4.2.3 Heilbron and Brandfort Transfers

The only transfers that occur out of or into this WMA are small but are significant for the users concerned.

There is an import from Vaal Dam in the Upper Vaal WMA to Heilbron TLC (Rhenoster key area). The bulk water supply of Heilbron TLC was taken over by Rand Water in 1998 and the transfer is by pipeline via Sasolburg TLC.

There is an export from Erfenis Dam in the Middle Vaal WMA to Brandfort TLC (Modder River catchment in the Upper Orange WMA).

4.2.4 Boreholes

Groundwater from the Ventersdorp Eye Subterranean GWCA is used for irrigation in the Johan Neser key area. The estimated allocation for 2 723 ha of irrigation in the GWCA is 25,2 x 10^6 m^3/a (DWAF, 1995). It was assumed that additional abstractions occur for other rural water use (this information is not known).

Since 1996, Sedibeng Water has abstracted groundwater from boreholes in the Wolmaranstad for supply to Wolmaranstad or Makwassie TLCs.

The water requirements of a number of small urban centres in the Free State are supplemented by groundwater. **Appendix E.5** lists the known centres, the number of boreholes and where available the 1995 abstractions.

4.3 MAIN RESOURCE INFRASTRUCTURE

The most important dam in this area is Bloemhof Dam which is fed by the Vaal River and Allemanskraal Dam and Erfenis Dam (fed by the Sand and Vet rivers respectively).

Table 4.3.1 gives details of all major dams in the Middle Vaal WMA. Using WR90 data, storages in this WMA have been shown graphically for selected areas in **Diagram 4.3.1**. Details of urban water supply schemes and bulk potable water supply schemes are given in **Tables 4.3.2 and 4.3.3.**

Table 4.3.1 provides details of all major dams in the Upper Vaal WMA. Details of Water supply schemes are given in **Table 4.3.2**.

TABLE 4.3.1: MAIN DAMS IN THE MIDDLE VAAL WMA.

NAME	LIVE STORAGE CAPACITY (10^6 m^3/a)	DOMESTIC SUPPLY (10^6 m^3/a)	IRRIGATION SUPPLY (10^6 m^3/a)	OTHER SUPPLY (10^6 m^3/a)	OWNER	1:50 YR YIELD (10^6 m^3/a)
Erfenis	212,3	0	16.4	0	DWAF	#
Allemanskraal	174,2	0	15,2	0	DWAF	#
Koppies	42,3	0	3,2	0	DWAF	9,,8
Rietspruit	7,3	0	6,6	0	DWAF	11,4
Johan Neser	5,8				DWAF	10,4
Bloemhof	1 263,3	0	0	8 088,8 @	DWAF	142,0

Note : 1. Domestic, irrigation and other supply taken from reservoir records for the 1995 hydrological year. Live storage also taken from reservoir records (where available) otherwise
" List of Hydrological Gauging Stations (Volume 2) July 1990.
2. @ Bloemhof given as total abstractions from reservoir records
3. # Erfenis and Allemanskraal combined yield = 100 x 10^6 m^3/a

Using WR90 data, storages in this WMA have been shown graphically for selected areas in **Diagram 4.3.1**. Dams on the Vaal River and major tributaries have been designated as major dams and others as minor dams.

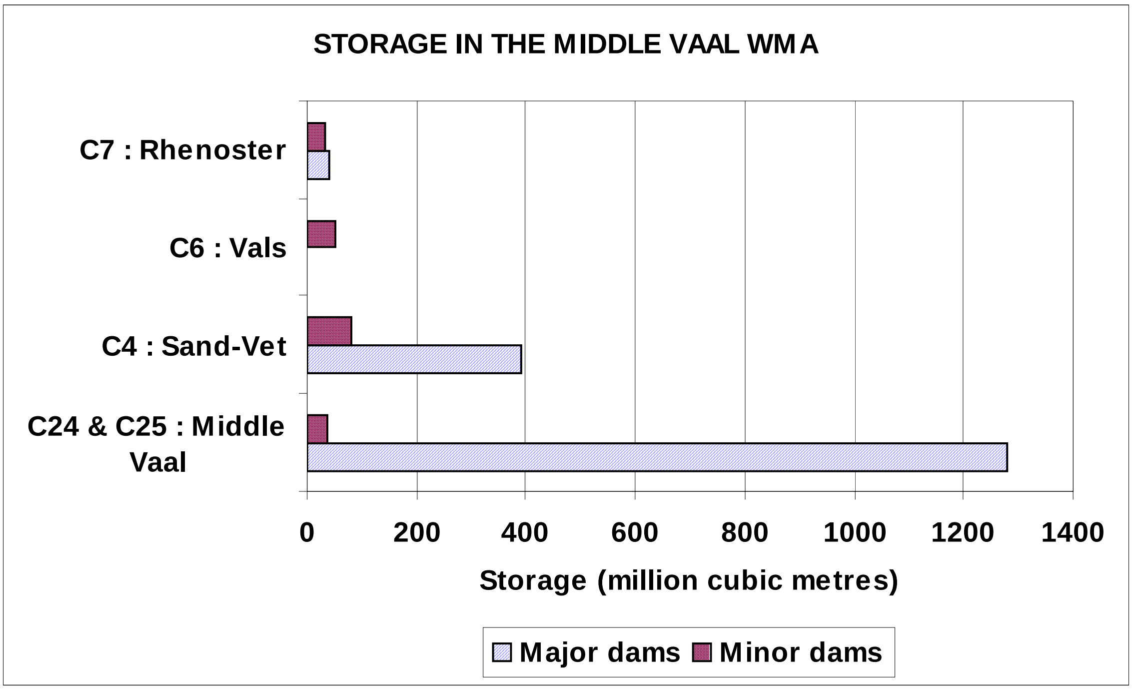


Diagram 4.3.1: Storage in the Middle Vaal WMA

TABLE 4.3.2: REGIONAL WATER SUPPLY SCHEMES : BULK WATER SUPPLY INFRASTRUCTURE.

PURIFICATION TREATMENT WORKS			RAW WATER SOURCE				
NAME	CAPACITY (Mℓ/d)	OWNER/ OPERATOR	NAME	YIELD * (10^6 m^3/a)	YIELD * (Mℓ/d)	ADDITIONAL YIELD ALLOCATED TO OTHER USERS (m^3 x 10^6/a)	OWNER AND OPERATOR
Arlington	D 0,29 O 0,43	Municipality	Dam Boreholes	Unknown	Unknown O 2,0	No	Municipality
Bultfontein		Municipality	Luipaardvlei Dam Boreholes	O 4,9 Y 0,57	O 13,4 Y 1,56	0	Municipality
Edenville		Municipality	Boreholes	O 0,4	O 1,1		Municipality
Excelsior	D 1,0 O 1,0	Municipality	Gryp Dam Boreholes	O 0,5 Y 0,01	O 1,37 Y 0,03		Municipality
Heilbron	D 2,0 O 2,0	Rand Water	Lang dam	Unknown	Unknown	0	Rand Water
Hoopstad	D 4,25 O 3,24	Municipality	Vet River	Y 0,80	Y 2,19		Municipality
Klerksdorp		MidVaal WC	Vaal River	Y 11,2	Y 30,6		MidVaal WC
Koppies	D 2,8 O 2,8	Municipality	Koppies Dam	Y 0,30	Y 0,82		Municipality
Kroonstad	D 60,0 O 35,0	Municipality	Vals River Dams	Y 8,76	Y 24,0		Municipality
Lindley	D 3,0 O 1,0	Municipality	Piekniekdraai Dam Vals River	Unknown	Unknown		Municipality
Leeudoringstad		MidVaal WC	Boreholes	Y 0,4	Y 1,0		MidVaal WC
Marquard	D 168,0 O 136,0	Municipality	Marquard Dam Laaispruit Dam	Unknown	Unknown		Municipality
Petrus Steyn	D 1,0 O 1,0	Municipality	Middelpunt Dam Boreholes	O 0,42 O 0,01 Y 0,14	O 1,15 O 0,36 Y 0,38	0	Municipality
Orkney		MidVaal WC	Vaal River	Y 2,0	Y 5,4		MidVaal WC
Senekal	D 9,0 O 9,0	Municipality	Cyferfontein Dam De Put Dam	O ,50 Y 0,81	O 1,37 Y 2,21	0	Municipality

PURIFICATION TREATMENT WORKS			RAW WATER SOURCE				
NAME	CAPACITY (Mℓ/d)	OWNER/ OPERATOR	NAME	YIELD * (10^6 m^3/a)	YIELD * (Mℓ/d)	ADDITIONAL YIELD ALLOCATED TO OTHER USERS (m^3 x 10^6/a)	OWNER AND OPERATOR
Steynsrus	D 3,0 O 1,0	Municipality	Steynrus Dam Catch Dam Boreholes	Unknown O 0,38 Y 30,03	Unknown O 1,03 Y 82,23	0	Municipality
Stilfontein		MidVaal WC	Vaal River	Y 2,5	Y 6,9		MidVaal WC
Theunissen	D 8,88 O 5,33	Municipality	Erfenis Dam	Y 0,62	Y 1,7		Municipality
Verkeerdevlei	D 0,6	Municipality	Unknown	Unknown	Unknown		Municipality
Vijoenskroon	D 5,0 O 4,5	Municipality	Rhenoster River	Y 1,1	Y 3,0		Municipality
Virginia		Municipality	Allemanskraal Dam	Y 3,5	Y 9,6		Municipality
Vredefort	D 2,4 O 2,4	Municipality	Unknown	Unknown	Unknown		Municipality
Welkom		Sedibeng Water	Vaal River	Y 13,0	Y 35,6		Sedibeng Water
Wesselsbron	D 3,4	Sedibeng Water	Unknown	Unknown	Unknown		Sedibeng Water
Winburg	D 2,46 O 2,40	Municipality	Rietfontein Dam Wolwas Dam 1&2 Laaispruit	Y 0,45	Y 1,24		Municipality
Wolmaranstad		Sedibeng Water	Makwassiespruit Boreholes	Y 0,01	Y 0,02		Sedibeng Water

Note : D denotes design
O denotes Operating yield
Y denotes Municipal Yearbook 1995 and is the average daily consumption
Where source of water is unknown, the source is generally local rivers.

TABLE 4.3.3: POTABLE WATER SUPPLY SCHEMES IN THE MIDDLE VAAL WMA.

Scheme Name	Raw water source	Population Supplied	Scheme Capacity		
			10^6 m^3/a	(Ml/day)	Limiting factor
Sedibeng – Northern sector	Vaal River	100 000	43,8	120	Unknown
Sedibeng – Southern sector	Vaal River Sand River	414 000 # #	90,2 12,8 (permit)	247 35 (?)	Unknown During dry periods, irrigation requirements restrict availability.
MidVaal	Vaal River	300 000	109,5	300	Unknown

Note : # Combined

TABLE 4.3.4: CONTROLLED IRRIGATION SCHEMES IN THE MIDDLE VAAL WMA.

SCHEME/ BOARD OR CONTROL AREA NAME	SCHEDULED AREA and OTHER CONTROLLED (ha)	CURRENT IRRIGATED AREA (ha)	PRODUCE	SUPPLY SOURCE	QUOTA (m^3/ha/a)	AVAILABLE YIELD (10^6 m^3 /a)	PRESENT AVE ANNUAL USE (10^6 m^3 /a)	THEORETICAL REQUIREMENT OF CURRENT IRRIGATED AREA [(2)] (10^6 m^3 /a)
Rhenoster River GWS	2 576	2 570	Annual low value	Rhenoster River/Koppies Dam	6 100		15,2	15,7
Weltevrede MB	288	288	Annual low value	Weltevreden Dam	6 100		1,7	1,8

SCHEME/ BOARD OR CONTROL AREA NAME	**SCHEDULED AREA and OTHER CONTROLLED (ha)**	**CURRENT IRRIGATED AREA (ha)**	**PRODUCE**	**SUPPLY SOURCE**	**QUOTA (m^3/ha/a)**	**AVAILABLE YIELD (10^6 m^3 /a)**	**PRESENT AVE ANNUAL USE (10^6 m^3 /a)**	**THEORETICAL REQUIREMENT OF CURRENT IRRIGATED AREA [(2)] (10^6 m^3 /a)**
Vaal River GWCA	577	356	Annual low value	Vaal River	6 100		2,3	3,5
Schoonspruit GWS	1 703	1 703	Annual low value	Schoonspruit/Rietspruit Dam	7 700		9,4	13,1
Klerksdorp IB	1 239	730	Annual low value	Schoonspruit/Johan Neser Dam	6 100		4,8	7,6
Ventersdorp Eye Subterranean GWCA	2 723	2 723	Annual low value	Groundwater	8 225		16,4	22,4
Taaibosspruit	63	63	Annual low value	Taaibospruit	5 309		0,3	0,33
Sand-Vet GWS (Vet)	5245	5245	Annual low value	Vet River/Erfenis Dam	7 200		46,4	37,8
Sand-Vet GWS (Sand)	5172	5172	Annual low value	Sand River/Allemanskraal Dam	7 200		39,7	37,2
Vet GWS	1779	1779	Annual low value	Vet River and canals	7 200		15,7	12,8
TOTALS	**21 365**	**20 629**			**5 309 to 8 225**		**149,6**	**148,73**

Note: Irrigation information from the report (Loxton et al., 1999b)

4.4 HYDRO-POWER

There are no hydropower stations in the Middle Vaal WMA.

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

The various water user sectors in this WMA are as follows:

- Ecological Reserve (environmental - in-stream flow requirements). This water is not consumed.
- Domestic (urban and rural users).
- Bulk water use (including thermal power stations and mine users).
- Agriculture (including livestock and game).
- Afforestation.
- Alien vegetation.
- Water transfers.

Table 5.1.1 summarises the 1995 water requirements and the equivalent requirement at 1:50 year assurance. The estimated total water requirement in 1995 is 469 x $10^6 m^3$.

Distribution losses and conveyance losses are included in the values given for water requirements, including water transfers, but return flows have not been subtracted. Water requirements for aquatic ecosystems are given as the requirement at the outlet to the WMA.

Not all water is required at the same assurance, for example, water for urban requirements must be provided at a much higher assurance than water for irrigation requirements. Refer to **Appendix F.9** for the assurance of supply for various users. Assurance is, however, taken into account in determining the equivalent 1:50 year requirement.

Figure 5.1.2 shows water requirements at 1:50 year assurance for the user groups at selected key points. Pie diagrams showing all the water requirements in the key areas have been included. The most significant water requirements are irrigation water requirements (33 %) and ecological reserve requirements (23 %). **Table 5.1.2** summarises water requirements of the user groups for key areas and for provinces.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP.

USER GROUP	1995 WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m^3/a)
Ecological reserve (5)	109,1	118,2
Domestic (1)	86,7	87,5
Bulk water use (4)	85,2	87,7
Neighbouring States	0,0	0,0
Agriculture	(2) 184,3	125,1
Afforestation	0,0	0,0
Alien vegetation	1,5	0,15
Water transfers (3)	2,3	2,3
Hydropower	0,0	0,0
TOTALS	**469,1**	**421,0**

(1) Includes urban (82,0) and rural (4,6) domestic requirements and commercial, institutional and municipal requirements
(2) Includes requirements for irrigation (153,8), dryland sugar cane (0), livestock and game (30,5),
(3) Only transfers out of the WMA are included (Brandfort transfer),
(4) Includes thermal powerstations (0), other bulk users (3,6) and mines (81,6).
(5) At outlet of WMA, refer to Table 5.2.4.1.

TABLE 5.1.2: WATER REQUIREMENTS PER USER GROUP FOR KEY AREAS AND PROVINCES AT 1:50 YEAR ASSURANCE.

CATCHMENT				USERS								
SECONDARY		TERTIARY		DOMESTIC USERS(1) (10^6m^3)		BULK USERS(2) (10^6m^3)	AGRICULTURAL USERS(3) (10^6m^3)		AFFOREST-ATION (10^6m^3)	ALIEN VEGETATION (10^6m^3)	WATER TRANSFERS(4) (10^6m^3)	HYDRO-POWER (10^6m^3)
No	Description	No.	Key area	Urban	Rural		Irrigation	Livestock and game				
C7	Rhenoster	C70	Rhenoster (C70A-K)	3,3	0,4	0,0	15,3	5,6	0,0	0,00	0,0	0,0
C6	Vals	C60	Vals (C60A-J)	15,9	0,5	0,0	1,6	4,0	0,0	0,04	0,0	0,0
C2	Johan Neser	C24	Johan Neser (C24C-G)	1,4	0,4	0,0	21,7	2,8	0,0	0,07	0,0	0,0
	Vaal	C24-C25	Vaal (C24A,B, C24H-J, C25A-C)	26,4	1,1	49,1	6,0	3,7	0,0	0,01	65,8	0,0
	Bloemhof	C25	U/s Bloemhof (C25D-F)	2,1	0,3	0,0	0,0	2,8	0,0	0,03	0,0	0,0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	1,4	0,2	0,0	0,0	2,2	0,0	0,00	0,0	0,0
	Erfenis	C41	Erfenis (C41A-E)	1,3	0,2	0,0	0,0	2,8	0,0	0,00	2,3	0,0
	Vet	C41-43	Vet (C41F-J, C42F-L, C43A-D)	30,8	1,7	38,6	50,0	6,6	0,0	0,00	0,0	0,0
Total in Free State				**58,2**	**3,7**	**41,8**	**72,4**	**23,9**	**0,0**	**0,05**	**66,9**	**0,0**
Total in North-West				**24,4**	**1,1**	**45,9**	**22,2**	**6,6**	**0,0**	**0,10**	**1,2**	**0,0**
TOTAL IN WMA				**82,6**	**4,8**	**87,7**	**94,6**	**30,5**	**0,0**	**0,15**	**68,1**	**0,0**

Notes:

(1) Includes urban and rural domestic requirements and indirect urban requirements.

(2) Includes thermal power stations, major industries, other bulk users and mines.

(3) Includes requirements for irrigation, dryland sugar cane, livestock and game. Assurance data from spreadsheet data from DWAF.

(4) Only potable water transfers out of key areas or provinces given. Where rivers forms boundary between provinces 50 % of known transfer assigned to each province.

(5) Provincial totals and WMA total are not the same because the transfers out of Grootdraai key area remain with in the Mpumalanga Province even if transfer is to another WMA.

5.2 ECOLOGICAL COMPONENT OF 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 quantity of 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 has been used is described in **Section 6.3**. 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. Furthermore, 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 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 tertiary catchments in the Middle Vaal WMA fall within the desktop Reserve parameter regions shown below:

Quaternary catchment	**Desktop Reserve Parameter Region**
C24	Southern Cape (wet). Number 7
C25, C31, C32, C33, C43 and C60	Lowveld. Number 18
C24, CC25, C43, C60 and C70	Vaal. Number 20

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, that is described in **Section 6.3**. 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 lowest 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 described in **Section 6.3** 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 Comments on the results

Indications are that the management classes produced, given the limitations of this procedure, represent a relatively accurate picture of the ecological state of the analysed rivers.

The vast majority of quaternary catchments analysed generated C management classes, i.e moderately modified aquatic ecosystems that will require 20-40% MAR. Bearing in mind that assessments were only done at quaternary catchment outlets, there are no A class rivers and only about 10% were designated as B class. This points to the relatively poor state of aquatic ecosystems.

5.2.4 Presentation of results

Table 5.2.4.1 shows the water requirements for the key points. Note that the key points considered coincide with catchment or sub-catchment outlets, or with the other specific criteria adopted for the WMA and that the key points (outlets of key areas) shown are those given in **Table 7.2.1**. Note also that there can be intra-quaternary catchment variation in class and state, so there may be intra-tertiary or intra-key point variation. The quaternary information for present ecological status class is contained in **Appendix F.1**.

The water requirements for the Ecological Component of the Reserve are summarised for the quaternary catchments in **Figure 5.2.4.1**.

TABLE: 5.2.4.1: WATER REQUIREMENT FOR ECOLOGICAL COMPONENT OF THE RESERVE.

KEY POINT	PRESENT ECOLOGICAL STATUS CLASS (PESC)	ECOLOGICAL WATER REQUIREMENTS FOR PESC		
		% VIRGIN MAR	VOLUME ($10^6 m^3/a$)	IMPACT ON EXISTING YIELD AS 1:50 YEAR YIELD ($10^6 m^3/a$)
Rhenoster (C70K)	C	11.8	16,3	0,0
Vals (C60J)	C	11,9	18,6	0,0
Johan Neser (C24G)	B	24,6	21,6	1,7
Vaal (C25C)	D	9,5	6,3	0,0 (-4,9)
U/S Bloemhof (C25 F)	E-F (use default D)	9,3	1,5	103,8
Allemanskraal (C42E)	C	13,0	12,5	5,5
Erfenis (C41E)	E-F (use default D)	7,9	13,2	7,2
Vet (C43D)	C	12,0	19,1	0,0 (-12,7)

Note: * Negative values for reserve taken as zero

5.2.5 Discussion and Conclusions

With regard to limitations of the results, Kleynhans (Kleynhans,1999) has provided the following:comments :

- An aspect that has become glaringly obvious is the paucity of knowledge on many of South Africa’s rivers. While the regional experts were able to supply useful input on many river systems, there were also many systems that had little or no published ecological data and were not familiar to the relevant regional experts. There is a need therefore, to provide some sort of forum for the continual updating of the information and data.

- The database and its data needs to be modified as and when additional (research) information becomes available. An allowance, to a certain extent, is made for this by Kleynhans’s (Kleynhans,1999) assertion that “...it can be expected and considered mandatory that the information required for the determination of the ecological Reserve under these situations should improve in confidence and detail compared to that of the desktop estimate, e.g. in all probability information beyond desktop level will be required.”

- Related to the above point, it would be useful if there could be some sort of linkage between quaternary catchment confidence ratings and the generation of the various indices. It became apparent, during the regional workshops, that the difference in assessment expertise and experience between the regional experts needed to be levelled. Confidence ratings perhaps need to play a greater role in determining a particular management class. At present they are merely recorded in the EcoInfo Programme, and their relative importance have perhaps been understated. A role for confidence ratings within the algorithmic sequences of means and medians that Kleynhans (Kleynhans,1999) developed to determine the quaternary catchment management classes should be investigated, particularly for any future versions of this procedure.

This procedure for the determination of the ecological Reserve constitutes a solid, workable foundation that may provide a springboard for the development of other procedures, for instance for the rapid determination method. Although general and conservative in nature, it does provide a synthesis of flow related (ecological) data and a means for providing a general estimate of ecological flow requirements.

5.3 URBAN AND RURAL

5.3.1 Introduction

Since political change occurred in 1994 and with the new National Water Act, 1998 (Act No. 36 of 1998) in place, new considerations emerged in urban and rural water use and return flows. About 1200 new water service systems have been augmented based on the Reconstruction and Development Program (RDP). Although some of these new trends have not actually been implemented yet, it can be stated that the demand for water in urbanised areas is generated mainly by the following criteria:

- Population growth.
- Price of water development and services.
- Technological choices based on the socio-economic situation of various water users.
- Climate.

There are many other variables such as mandatory restrictions, water use legislation, subsidies etc., which can significantly influence the demand for water. However, all these factors are of a secondary nature.

The reconciliation of water requirements generated primarily by the growth in population, urbanisation and technology changes against available water resources is an essential component of any planning of any planning process.

In general the development and management of regional water resources in this WMA over the last four decades were influenced by political decisions with the result that the industrial and mining sectors tended to receive priority. The result is well developed water supply infrastructure in certain areas that are managed by large public and private water providers e.g. municipalities, water boards, etc. In the rural areas the only real development is related to farming. As a result, the development of rural, semi-urban and even some small urban community water supply was lacking. This situation in the 1990’s has been aggravated with the influx of the rural population into the vicinity of formal urban settlements resulting in numerous informal settlements without water supply and sanitation facilities.

Table 5.3.1 summarises the urban and rural domestic water requirements for key areas.

TABLE 5.3.1: 1995 URBAN AND RURAL DOMESTIC WATER REQUIREMENTS.

CATCHMENT				URBAN (1) (10^6 m^3/a)	RURAL (1) (10^6 m^3/a)	TOTAL (10^6 m^3/a)	1:50 YEAR ASSURANCE (10^6 m^3/a)	HUMAN RESERVE (AT 1:50 YEAR) (2) (10^6 m^3/a)
SECONDARY		TERTIARY						
No.	Description	No.	Key Area Description					
C7	Rhenoster	C70	Rhenoster (C70A-K)	3,2	0,4	3,6	3,8	1,0
C6	Vals	C60	Vals (C60A-J)	15,8	0,5	16,3	16,4	1,8
C2	Johan Neser	C24	Johan Neser (C24C-G)	1,4	0,4	1,8	1,8	0,5
	Vaal	C24,25	Vaal (C24A,B, H,J, C25A-C)	26,2	1,0	27,2	27,5	4,5
	Bloemhof	C25	U/s Bloemhof (C25D-F)	2,1	0,3	2,4	2,4	0,7
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	1,4	0,1	1,5	1,6	0,3
	Erfenis	C41	Erfenis (C41A-E)	1,3	0,3	1,6	1,6	0,4
	Vet	C41-43	Vet (C41F-J, C42F-L, C43A-D)	30,6	1,6	32,3	32,5	4,7
Total in Free State				**57,8**	**3,5**	**61,2**	**61,5**	**9,4**
Total in North-West				**24,2**	**1,1**	**25,5**	**26,0**	**4,5**
TOTAL IN WMA				**82,0**	**4,6**	**86,7**	**87,5**	**13,9**

Note: (1) The values include conveyance and distribution losses.

(2) The Human Reserve is the minimum water requirement of the population, estimated at 25 ℓ/capita/ day (DWAF criterion).

5.3.2 Urban

Introduction

This WMA is not heavily urbanised. Most urbanisation has taken place in the vicinity of the Free State Goldfields (Welkom, Virginia etc) and the North West Goldfields (Klerksdorp, Orkney, etc). The bulk of potable water is delivered by Sedibeng Water and MidVaal Water Company and is sold to local councils and subsequently to the end users for residential, industrial, municipal and commercial purposes. The end users vary significantly in size of water use and technological level of water utilisation. Some urban centres in this WMA are abstracting water from local sources, e.g. Senekal.

A study (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 and indirect use by the commercial, industrial, institutional and municipal sectors that relate to the direct use.

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 **(Table 5.3.2.1)**. The populations of the urban centres that had been determined were allocated to these categories by Schlemmer (Schlemmer et al, 2001), on the basis of socio-economic category characteristics of each centre. Refer to **Section 3.2** and **Appendix A.1** for details of urban demographic data.

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/capita/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

These default categories of estimated unit water use were reviewed by the situation assessment consultants and adjusted if information for 1995 was available. Generally data of total urban usage (excluding losses) was available. This urban usage data was used to override the default data.

Table 5.3.2.2 summarises the direct water use 'pattern' for the different residential categories within key areas and **Appendix F.8** lists per capita water use for all TLC's. The water use pattern for the WMA is generally only about 75 % of the national default water pattern. This is caused by a number of factors, namely that the default consumption pattern represents the various classes of urban centres that exist

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.

TABLE 5.3.2.2: DIRECT WATER USE: ESTIMATED UNIT WATER USE FOR RESIDENTIAL CATEGORIES FOR KEY AREAS.

Key area	Res_Cat 1 Water use (ℓ / c / d)	Res_Cat 2 Water use (ℓ / c / d)	Res_Cat 3 Water use (ℓ / c / d)	Res_Cat 4 Water use (ℓ / c / d)	Res_Cat 5 Water use (ℓ / c / d)	Res_Cat 6 Water use (ℓ / c / d)	Res_Cat 7 Water use (ℓ / c / d)
Rhenoster	264	264	132	74	8	5	74
Vals	242	242	121	68	8	5	68
Johan Neser	269	269	135	76	9	5	76
Vaal	236	236	118	67	7	4	67
Bloemhof	162	162	80	45	5	3	45
Allemanskraal	227	227	114	64	7	4	64
Erfenis	329	329	165	93	10	6	93
Vet	251	251	126	71	8	5	71
Average usage	**247**	**247**	**124**	**70**	**8**	**5**	**70**
Default usage	**320**	**320**	**160**	**90**	**10**	**6**	**90**

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 5.3.2.3**.

TABLE 5.3.2.3: 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.

Default profiles of indirect water use in relation to total water use were developed by the DWAF on the basis of available information for these classes, and are given in **Table 5.3.2.4**. Water use information for the various categories of indirect use was generally not available. This pattern of indirect water use was not adjusted in the urban sub-model.

TABLE 5.3.2.4: INDIRECT WATER USE AS A COMPONENT OF TOTAL DIRECT WATER USE.

URBAN CENTRE CLASSIFICATION	COMMERCIAL	INDUSTRIAL	INSTITUTIONAL	MUNICIPAL
Metropolitan	0,2	0,3	0,15	0,08
Cities	0,2	0,3	0,15	0,08
Towns Industrial	0,2	0,3	0,15	0,08
Towns Isolated	0,2	0,3	0,15	0,08
Towns Special	0,30	0,15	0,08	0,03
Towns Country	0,10	0,15	0,03	0,10
New Centres	0,15	0,08	0,08	0,08

However for most urban centre there was generally information about total indirect water use. Where applicable this total figure over-rides the default indirect total in the Urban sub-model, but the pattern of usage by the various indirect categories remained as given in **Table 5.3.2.4**.

The ratio of direct to indirect water usage is different depending on the classification of the urban centre. Generally large TLCs and MLCs have a ratio of 58 % direct usage to 42 % indirect usage. Smaller TLC's have a ratio of 72 % direct usage to 28 % indirect usage.

Appendix F.8 provides direct – indirect ratio details for all urban centres.

Unaccounted for Water Use: In most urban water systems the total bulk water supplied is generally well documented and is often the more reliable measurement of water used by a TLC. The difference between metered water and bulk water supplied is generally referred to as unaccounted-for-water and is made up of physical leakages within the water distribution system and in some situations also of un-metered or under-metered water. Unaccounted-for-water is therefore a component of direct and indirect urban water requirements.

In the Middle Vaal WMA unaccounted for water can be significant in the larger TLCs and MLCs. Unaccounted-for-water is estimated to range from 15% to 25% (Barta, 2000).

Water losses

Water losses in urban areas can be divided into two components:

- Bulk conveyance losses and
- Distribution system losses within an urban centre.

Bulk conveyance losses

Bulk conveyance losses are losses that occur during the transfer of urban water from the water source (dam, river, borehole) to the urban area. Bulk supply losses consist of purification and transmission losses. Purification losses are generally of the order of 1% to 3%, although losses can be as high as 10% in the case of turbidities caused by the silt content in the water. Transmission losses can be in the order of 1% to 7% of bulk water supplied.

In this WMA the main bulk water suppliers are Sedibeng Water and MidVaal Water Company. The confirmed water loss within the bulk supply systems is 3% for MidVaal Water Company and 6 % for Sedibeng Water (Sedibeng Water and MidVaal Water Company, 1999). For towns that supply their own bulk water little information is available. These losses are estimated to range from 5 % (for urban centres without water treatment works) to 8 % (for urban centres with water treatment works, which have both purification losses (3 %) and transmission losses (5 %). **Table 5.3.2.6** summarises the bulk losses for key areas within the WMA.

Losses in the water distribution system of an urban area.

Within the water distribution system of an urban area, there are losses associated with the distribution of water (unavoidable, estimated at 10 %) and losses that are caused by the maintenance of the distribution infrastructure (pipes and reservoirs). In many cases the poor maintenance of infrastructure results in significant losses.

Information about distribution losses is not readily available and in many instances the DWAF recommended that a default of 20 % had to be applied. In the Middle Vaal WMA the distribution losses can range from 3 % (Stilfontein TLC) to 20 % (DWAF default). **Table 5.3.2.6** summarises distribution losses for the key areas.

Return flow

The evaluation of return flows to determine net consumptive uses is a critical component of the urban water cycle. The Return flows from urban areas can be divided into three categories:

- Effluent return flows from direct users (residential) and indirect users (municipal, industrial, etc).
- Return flows due to leakage of potable water.

- Stormwater returns.

Effluent return flows

The return flows from urban water systems can be manifested in two distinct ways:

- As wastewater (effluent) concentrated by means of waterborne sewage that is treated and released into the surface river network. Effluent generated from residential and industrial areas is directly proportional to the water used. The water returned is further dependent on the standard of living of an area (level of sewage service) and the type of industries.
- As wastewater diffused locally by means of pit toilets (eg. Loflos, aquaprivies, etc), septic tanks / french drains, or more complex methods such as soil bucket systems.

In South Africa wastewater is often regarded as a supplementary source of water. The return flows generated from the urban water service systems of the Upper Vaal WMA supplement the base flow of the Vaal River, thus benefiting all downstream users.

Although concentrated treated waterborne sewage is gradually increasing, vast amounts of diffuse untreated effluent are still released locally. Previous research has shown that some 16 % of total urban water supply is diffused annually (Barta, 1993). This water is generally untreated and is polluting to a large extent the local groundwater and surface water resources.

The return flows generated in the operated urban water services systems (i.e. most urban centres in this WMA) are commonly metered by the water services authorities for its quality and quantity. The actual return flows metered after treatment include this amount of stormwater.

The proportion of urban water that does not contribute to effluent returns is a function of the sewage infrastructure within the various urban categories as well socio-economic factors (for example in more affluent areas water for gardening can be significant, thus increasing consumption).

Default consumption factors for direct and indirect urban usage were defined by the DWAF and are listed in **Table 5.3.2.5** . These factors were used to estimate the annual returns by urban centres.

These factors had to adjusted (calibrated) in the following circumstances:

- For urban centres with no known returns these factors were all increased to 1 reflecting that consumption or usage is 100 %. The smaller TLC’s generally fell into this category. Many of this TLC’s have some sewage infrastructure but effluent is returned to evaporation ponds and in some cases re-used as irrigation for sports fields and parks.

TABLE 5.3.2.5: DWAF DEFAULT CONSUMPTION FACTORS FOR URBAN WATER USERS.

CATEGORY		CONSUMPTION FACTOR
Direct : 1	Full service : Houses on large erven > 500m^2	0,45
Direct : 2	Full service: Flats, Town Houses, Cluster Houses	0,2
Direct : 3	Full service : Houses on small erven <500m^2	0,35
Direct : 4	Small houses, RDP houses and shanties with water connection but minimal or no sewage service	0,8
Direct : 5	Informal houses and shanties with service by communal tap only, no sewage service	1,0
Direct : 6	No service from any water distribution system	1,0
Direct : 7	Other/Miscellaneous	0,5
Industrial	Full service	0,15
Commercial	Full service; sewage service dependent on toxicity of returns,	0,4
Institutional	Full service	0,1
Municipal	No sewage service	1,0

- For a number of the urban centres the 1995 sewage returns were known. The sewage generated using the default consumption factors was reviewed against the known sewage returns. If the generated figure was within about 10 % of the known figure the consumption factors were not adjusted. If adjustment was required the following calibration procedure was followed:

  1. The consumption factor for residential category 4 was adjusted. This category is defined as having no to minimal sewage infrastructure. For Orkney, Wolmaranstad, Winburg, Welkom, Virginia and Henneman TLC's this factor was adjusted to 1,0 (no sewerage system). For Stilfontein and Klerksdorp TLC's this factor was reduced indicating the presence of more adequate sewage systems. **Appendix F.8** lists the consumption factors for all urban centres.

  2. If further adjustments were required the industrial consumption factor was adjusted. This adjustment was considered acceptable because some industries do not return water to the system but rather to evaporation ponds. For Stilfontein, Orkney, Klerksdorp, Wolmaranstad, Winburg, Welkom and Virginia TLC's the industrial consumption factor was adjusted.

  3. For a number of urban centres adjustments to other consumption factors was required, namely Stilfontein, Orkney, Klerksdorp, Wolmaranstad, Winburg and Welkom. In the case of Stilfontein and Klerksdorp the consumption factors had to be reduced significantly to generate the known returns. Both TLC's could possibly process effluent from Gold Mines in the area. For the other TLC's consumption factors had to be increased to generate known returns. This was often caused when two TLC's in a quaternary catchment had different consumption patterns that had to be combined. For example Wolmaranstad and Makwassie TLC's are located in the same area (quaternary catchment) but there are no known returns from Makwassie while Wolmaranstad does return treated effluent to Makwassiespruit.

Appendix F.8 lists the consumption factors for all urban centres. **Table 5.3.2.6** summarises effluent return flows for the key areas of this WMA. Total urban effluent returns for 1995 are estimated at about 25 x 10^6m^3. Consumptive use ranges from 100 % in the Johan Neser key area to 45 % in the Vaal and Vals key areas. For the WMA as a whole consumptive use is about 60 % of net urban requirements (excludes losses).

Return flow due to leakage of clean water

Some of the potable water that leaks from the water distribution system can flow into the river system.

Due to the semi-arid nature of this WMA it is assumed that there are no significant clean returns.

Stormwater returns

Additional rainfall runoff is created due to the impervious areas created in urban areas. On average one eighth of the urban areas in the WMA are effectively paved and it is assumed 84% of rain falling on these areas runs off into the river system. (WR90 values). **Appendix D.2** lists the urbanised centres and the area urbanised (km^2). The impervious area in the WMA is about 252 km^2 and the return flow generated from these areas is 13,8 x10^6m^3/a.

It should be noted that most sewage works are designed to receive 115 % of known returns (BKS, 1999)). This over design is to accommodate the ingress of storm water into the sewage system during the rainy season.

Table 5.3.2.6 lists the stormwater returns for all in key areas within the WMA.

Sources of data

In order to calculate urban water use to the required level of detail, it was necessary to obtain information from the relevant water supply authorities, e.g. Transitional Local Councils (TLC's), Water Boards etc. A number of TLC's were selected by Markdata and were surveyed by the Situation Assessment Consultant. The survey was done by means of a questionnaire and supplemented by personal communication via telephone and telefax.

All TLC's were taken to be totally within whichever quaternary catchment the majority of the TLC is located.

Other sources of information were also investigated such as municipal yearbooks and existing reports. Various problems were experienced with all the sources of information. It was difficult to obtain the level of detail required, it was difficult to compare information from different sources due to different dates of records and other conceptual differences and there was also a lack of co-operation from some information sources. About 70% of the questionnaires were eventually returned and of these 20% were of no practical use.

Information on waterborne influent and effluent were obtained directly from the TLC's.

Additional information was sourced from the Vaal River System Analysis (BKS et al, 1998d,e,f) reports and situation assessment reports, e.g. WRC report for the Lower Vet River (1996).

From the information obtained from the various sources, data for parameters related to water use and return flow were estimated for all the quaternary catchments in this WMA

TABLE 5.3.2.6: 1995 URBAN WATER REQUIREMENTS BY KEY AREA AND PROVINCE

CATCHMENT				URBAN WATER REQUIREMENTS		LOSSES			TOTALS		RETURN FLOWS			
SECONDARY		TERTIARY												
No.	Description	No.	Key Area Description	DIRECT (10^6 m^3/a)	INDIRECT (10^6 m^3/a)	BULK CONVEYANCE LOSSES (%)	DISTRIBUTION LOSSES (%)	TOTAL LOSSES (10^6 m^3/a)	TOTAL (10^6 m^3/a)	TOTAL AT 1:50 YR ASSURANCE (10^6 m^3/a)	EFFLUENT(2) (10^6 m^3/a)	IMPERVIOUS URBAN AREA(3) (10^6 m^3/a)	TOTAL RETURN FLOW (10^6 m^3/a)	RETURN FLOW AT 1:50 YEAR ASSURANCE(1) (10^6 m^3/a)
C7	Rhenoster	C70	Rhenoster (70A-K)	1,7	0,8	3 to 8	13 to 20	0,7	3,2	3,3	0,6	0,0	0,6	0,6
C6	Vals	C60	Vals (C60A-J)	7,0	4,6	6 to 8	9 to 20	4,2	15,8	15,9	6,4	2,4	8,8	8,8
C2	Johan Neser	C24	Johan Neser (C24C-G)	0,5	0,5	5	20	0,4	1,4	1,4	0,0	0,0	0,0	0,0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	12,6	8,2	3 to 6	3 to 20	5,4	26,2	26,4	11,5	4,5	16,0	16,0
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,9	0,7	6	5 to18	0,5	2,1	2,1	0,3	0,0	0,3	0,3
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,6	0,4	5 to 8	20	0,4	1,4	1,4	0,4	0,0	0,4	0,4
	Erfenis	C41	Erfenis (C41A-E)	0,8	0,3	5 to 8	10 to 20	0,2	1,3	1,3	0,1	0,0	0,1	0,1
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	14,7	10,2	6 to 8	12 to 20	5,7	30,6	30,8	6,0	6,9	12,9	12,9
Total in Free State				**27,6**	**17,6**	**3 to 6**	**3 to 20**	**12,6**	**57,8**	**58,2**	**11,8**	**9,3**	**22,8**	**22,8**
Total in North-West				**11,2**	**8,1**	**3 to 8**	**5 to 20**	**4,9**	**24,2**	**24,4**	**13,5**	**4,5**	**16,3**	**16,3**
TOTAL IN WMA				**38,8**	**25,7**	**3 to 8**	**3 to 20**	**17,5**	**82,0**	**82,6**	**25,3**	**13,8**	**39,1**	**39,1**

Note: [A1](1) Assurance data provided by the DWAF.
(2) Effluent returns include clean returns.
(3) Returns from impervious areas provided by DWAF.

5.3.3 Rural

Rural usage can be categorised into domestic rural use, livestock watering and subsistence irrigation. The main requirements in this WMA are domestic rural use and livestock use. There is no known significant subsistence irrigation in this WMA.

Water Requirements

Domestic rural water requirements

There was little information available on the 1995 rural domestic requirements in this WMA. There is no significant rural infrastructure in the WMA. The water usage is estimated to be 25 ℓ/capita/day. **Section 3.2.4** has information on the rural population in the WMA. **Table 5.3.3.1** summarises the daily rural domestic usage for various rural categories. There was no information in this WMA about the domestic requirements of commercial farmers and the developing urban category. **Table 5.3.3.2** summarises the rural domestic usage for key areas for 1995 and at 1: 50 year assurance.

TABLE 5.3.3.1: 1995 PER CAPITA WATER REQUIREMENTS IN RURAL AREAS.

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct use (ℓ/capita/d)	Distribution losses		Total (ℓ/capita/d
		(%)*	(ℓ/capita/d)	
Rural	25	20	6,2	31,2
Advanced rural	25	20	6,2	31,2
Developing urban	25	20	6,2	31,2
Commercial farming	25	20	6,2	31,2

Note: * DWAF recommended distribution losses.

Livestock and game requirements

Livestock and game farming is a relatively insignificant activity within the WMA. The source of water for this activity is expected to derive mainly from boreholes (groundwater) and from small farm dams. **Table 5.3.3.2** summarises the livestock requirements.

TABLE 5.3.3.2: 1995 RURAL WATER REQUIREMENTS BY KEY AREA.

CATCHMENT				RURAL DOMESTIC WATER REQUIREMENTS					LOSSES #		TOTALS		RETURN FLOW	
SECONDARY		TERTIARY		DOMESTIC		SUBSIST. IRRIG-ATION (10^6 m^3/a)	LIVE-STOCK (10^6 m^3/a)	TOTAL (10^6 m^3/a)	(%)	(10^6 m^3/a)	TOTAL (10^6 m^3/a)	TOTAL AT 1:50 YR ASSUR-ANCE (10^6 m^3/a)(1)	RETURN FLOW (10^6 m^3/a)	RETURN FLOW AT 1:50 ASSURANCE (10^6 m^3/a)(1)
No.	Description	No.	Key Area Description	(ℓ/capita/d) (2)	(10^6 m^3/a)									
C7	Rhenoster	C70	Rhenoster (70A-K)	31,2	0,3	0,0	4,4	4,7	20	1,2	5,9	6,0	0	0
C6	Vals	C60	Vals (C60A-J)	31,2	0,4	0,0	3,2	3,6	20	0,9	4,5	4,5	0	0
C2	Johan Neser	C24	Johan Neser (C24C-G)	31,2	0,3	0,0	2,3	2,6	20	0,6	3,2	3,2	0	0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C	31,2	0,8	0,0	3,0	3,8	20	1,0	4,8	4,8	0	0
	Bloemhof	C25	U/S Bloemhof (C25D-F)	31,2	0,2	0,0	2,2	2,4	20	0,6	3,0	3,1	0	0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	31,2	0,1	0,0	1,8	1,9	20	0,5	2,4	2,4	0	0
	Erfenis	C41	Erfenis (C41A-E)	31,2	0,2	0,0	2,2	2,4	20	0,6	3,0	3,0	0	0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	31,2	1,3	0,0	5,3	6,6	20	1,6	8,2	8,3	0	0
Total in Free State				**31,2**	**2,8**	**0,0**	**19,1**	**21,9**	**20**	**5,5**	**27,4**	**27,6**	**0**	**0**
Total in North-West				**31,2**	**0,8**	**0,0**	**5,3**	**6,1**	**20**	**1,5**	**7,6**	**7,7**	**0**	**0**
TOTAL IN WMA				**31,2**	**3,6**	**0,0**	**24,4**	**28,0**	**20**	**7,0**	**35,0**	**35,3**	**0**	**0**

Note : # Loss is applicable to all three categories of rural water requirements

(1) Per capita requirement including losses, refer to **Table 5.3.3.1**

.

Refer to **Section 3.5.4** and **Appendix F.3** for details about livestock and game species, sources of data and the conversion of livestock species to Equivalent Large Stock Units (ELSU).

The average water use by a ELSU was estimated at 45 ℓ/ELSU/day).

Water losses

Information on rural distribution losses for 1995 was not readily available. The DWAF recommended default of 20 % was applied throughout the WMA. **Tables 5.3.3.1** and **5.3.3.2** summarise rural losses.

Return flows

The return flow generated by rural consumers is negligible and in most cases can be taken as zero.

5.4 BULK WATER USE

5.4.1 Introduction

This section deals with the water requirements of strategic, industrial and mining bulk water users that have individual bulk water systems, or that receive water directly from water boards, or the DWAF. Industries, power stations and mines supplied with potable water by municipalities are included in urban water requirements.

The bulk water requirements for each bulk water sector are described in terms of the requirement (on-site), the associated conveyance losses and return flows to the Middle Vaal River network.

5.4.2 Strategic Users

For the purpose of this study, strategic bulk users were taken to only apply to operational power stations that require a high assurance of water supply. There are **no** operating thermal power stations in this WMA.

5.4.3 Mining

Water requirements

The mining sector requires a level of assurance of water supply of 98 % to 99 % **(Appendix F.9)**. Mining activities ranging from deep underground mining (gold, coal) to surface mining (quarrying).

Details about mines can be found in **Section 3.7** and **Appendix F.6** lists all the known operating mines that could impact on the hydrology and water quality of the Middle Vaal system. **Table 5.4.3.1** summarises the 1995 water requirement of mines for key areas. This list of mines can be divided into mines that receive water from Sedibeng Water or MidVaal Water Company and mines that abstract directly from rivers in the WMA.

During 1995 only one mine (Vaal Reefs Gold Mine) abstracted water directly from the Vaal river system (5,02 x $10^6 m^3$). Vaal Reefs Gold Mine has a permit (No. 35/16/2/88) to abstract 10,69 x $10^6 m^3$/a from the Vaal River and it also receives purified water from the Midvaal Water Company (about 17 x $10^6 m^3$ in 1995).

Water losses

Transmission and purification losses by mines are estimated to range from 3% for mines supplied by MidVaal Water Company to 6% for mines supplied by Sedibeng Water. **Table 5.4.3.1** provides a summary of conveyance losses for mines for key areas in the WMA.

Return flows

Returns by mines to the river systems have been divided into:
- Treated effluent returns and
- Groundwater pumpage (decanting).

During 1995, mining operations discharged some 17,6 x $10^6 m^3$ of water directly into the catchment river systems. These discharges are into tributaries of the Vaal River and they can impact significantly on both the hydrology and water quality of the Middle Vaal system. For example the Buffelsfontein and Stilfontein mines decanted 16,4 x $10^6 m^3$/a of groundwater into the Koekemoerspruit. Groundwater decanted / seeped from Beatrix, Joel and Oryx Gold Mines into Theron and Bosluisspruits. The impact in terms of water quality is generally negative for downstream users.

TABLE 5.4.3.1: 1995 WATER REQUIREMENTS OF MINES.

CATCHMENT				ON-SITE MINE USE	CONVEYANCE LOSSES		TOTAL WATER REQ.	TOTAL AT 1:50 YEAR ASSURANCE	RETURN FLOW ($10^6 m^3$)			
SECONDARY		TERTIARY		(10^6 m^3/a)	(%)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)[(1)]	SURFACE RETURNS	GROUND-WATER DECANTING	TOTAL	TOTAL AT 1:50 YEAR ASSURANCE
No.	**Description**	**No.**	**Key Area Description**									
C7	Rhenoster	C70	Rhenoster (70A-K)	0	0	0	0	0	0	0	0	0
C6	Vals	C60	Vals (C60A-J)	0	0	0	0	0	0	0	0	0
C2	Johan Neser	C24	Johan Neser (C24C-G)	0	0	0	0	0	0	0	0	0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	42,5	3 to 10	1,4	43,9	45,4	0	16,4	16,4	16,4
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0	0	0	0	0	0	0	0	0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0	0	0	0	0	0	0	0	0
	Erfenis	C41	Erfenis (C41A-E)	0	0	0	0	0	0	0	0	0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	35,4	6	2,3	37,7	38,6	0	1,2	1,2	1,2
Total in Free State				**37,6**	**6**	**2,4**	**40,0**	**41,0**	**0**	**1,2**	**1,2**	**1,2**
Total in North-West				**40,3**	**3 to 10**	**1,3**	**41,6**	**43,0**	**0**	**16,4**	**16,4**	**16,4**
TOTAL IN WMA				**77,9**	**3 to 6**	**3,7**	**81,6**	**84,0**	**0**	**17,6**	**17,6**	**17,6**

Note: (1) Assurance data provide by the DWAF.

5.4.4 Other Bulk Water Users

Water requirements

This category includes large and small non-strategic industrial users. The assurance of supply for these users ranges from 95 % to 98 % **(Appendix F.9).** For further details on other bulk water users refer to **Section 3.6.3, Table 5.4.4.1 and Appendix F.5**.

The only other non-strategic bulk users in this WMA are small consumers supplied by Sedibeng Water and the MidVaal Water Company. The users include rural users such as farmers, schools and business's that are within the supply network of the water companies.

Water losses

Conveyance losses by other bulk users range from 3 % (consumers supplied by MidVaal Water Company) to 6 % (consumers supplied by Sedibeng Water). **Table 5.4.4.1** provides a summary of conveyance losses for other bulk users for key areas in the WMA.

Return flows

There no known return flows from other bulk users in this WMA.

5.5 NEIGHBOURING STATES

There is no neighboring state within the WMA. This WMA does not have to satisfy any neighboring state requirements.

TABLE 5.4.4.1: 1995 OTHER BULK WATER REQUIREMENTS

CATCHMENT				ON-SITE USE (10^6 m^3/a)	CONVEYANCE LOSSES		TOTAL WATER REQ. (10^6 m^3/a)	TOTAL 1:50 YEAR ASSURANCE (10^6 m^3/a)	RETURN FLOW (10^6 m^3/a)	RETURN FLOW AT 1:50 ASSURANCE
SECONDARY		TERTIARY			(%)	(10^6 m^3/a)				
No.	Description	No.	Key Area Description							
C7	Rhenoster	C70	Rhenoster (70A-K)	0	0	0	0	0	0	0
C6	Vals	C60	Vals (C60A-J)	0	0	0	0	0	0	0
C2	Johan Neser	C24	Johan Neser (C24C-G)	0	0	0	0	0	0	0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	3,5	3 to 6	0,1	3,6	3,7	0	0
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0	0	0	0	0	0	0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0	0	0	0	0	0	0
	Erfenis	C41	Erfenis (C41A-E)	0	0	0	0	0	0	0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D	0	0	0	0	0	0	0
Total in Free State				**0,8**	**6 %**	**0,03**	**0,8**	**0,8**	**0**	**0**
Total in North-West				**2,7**	**3 %**	**0,07**	**2,8**	**2,9**	**0**	**0**
TOTAL IN WMA				**3,5**	**3 to 6**	**0,1**	**3,6**	**3,7**	**0**	**0**

5.6 IRRIGATION

5.6.1 Introduction

Detailed observed data on water use for irrigation was not available therefore irrigation water requirements were estimated from available information on irrigated areas or reaches, typical quotas and assurances of supply. The source of information on irrigation water use in this WMA is the Vaal River Irrigation Study (Loxton et al., 1999b).

Typical quotas and calculated crop water use data are provided in **Section 8** of the report (Loxton et al., 1999b). Section 3.5.2 of this report details how irrigated area data was disaggregated to quaternary catchment area data. **Table 5.6.2.1** summarises the irrigation requirements in 1995 for key areas in the WMA.

In this WMA most of the irrigation is defined as controlled irrigation. The total field irrigation area in this WMA is 207,9 km^2 **(Table 3.5.2.1**.) The scheduled irrigation occurs in the Vet key area - Sand-Vet Government Water Scheme (GWS), the Rhenoster key area - Rhenoster River GWS and Weltevrede Management Board (MB), the Johan Neser key area - Schoonspruit GWS and the Vaal key area - Klerksdorp Irrigation Board (IB). These areas require that water be released from dams or rivers, to the canals or pipelines that convey the water to the irrigation areas. The assurance of supply in these areas can be assumed to be higher than in other irrigated areas.

The remaining controlled irrigation areas include the Vaal River Government Water Control Area (GWCA), Ventersdorp Eye Subterranean GWCA, part of Klerksdorp IB and Taaibosspruit Irrigation area. In these areas abstractions are run of river irrigation abstractions or groundwater abstractions and no special releases of water are made.

Only irrigation in the Vals key area is regarded as diffuse with run of rivers abstractions by irrigators.

5.6.2 Water Use Patterns

The water requirement for irrigation was calculated by means of the irrigation pre-processor of the Water Situation Assessment Model and was based on the following well known equation.

IRR(1-CLI) = AIR*(EVT*CRC-REF)*0,001*LER/IRC

Where
IRR: Irrigation water requirement ($10^6 m^3/m$).
AIR: Irrigation area (km^2).
EVT: Evapotranspiration (A-Pan equivalent in mm/m).
CRC: Crop factor.

REF: Effective rainfall (mm/m).
LER: Leaching factor.
IRC: Irrigation efficiency.
CLI: Irrigation conveyance loss (Proportion of IRR).

The irrigation pre-processor calculates the irrigation water requirement for every crop separately for each of the 12 months, using the appropriate climatic quaternary catchment mean monthly data obtained from the CCWR. This detailed methodology is essential to eliminate the considerable errors that can be made by combining crop factors. The final annual water requirements are then obtained by simple summation of the various crop water requirements. **Appendix D.1** lists crops, crop factors, crop areas etc.

However a second method has been used to calculate the 1995 irrigation requirement using the quota information for this WMA, from the report (Loxton et al., 1999b).

The quotas are listed in **Appendix D.1** in the summary table called Irrigation Water Requirements. Two types of quotas were identified in the Vaal River Irrigation Study (Loxton et al., 1999b). and are shown in the summary table. They are the typical or guideline quotas, which were used to calculate the average water allocation for an irrigation area and the calculated crop water use, which was used to determine the actual crop water use during 1995.

Assurance of supply for irrigation ranges from 80 % (1 in 5 yr assurance) to 98 % (1 in 50 yr assurance) and also varies according to value of crop. Higher value crops receive greater assurance of supply in the scheduled irrigation areas.

The irrigation requirement using the typical quotas and field area was 154,3 x 10^6m^3. The actual crop water use in 1995 was 153,8 x 10^6m^3 for all areas (Loxton et al., 1999b). In the Sand Vet GWS actual water use for irrigation was higher then the quotas indicating the importance of this area. In all other areas it is apparent that 1995 was a dry year in which water restrictions appear to have been applied.

Figure 5.6.2.1 shows irrigation water requirements at 1:50 year equivalent assurance per key area and is estimated at 94.6 x 10^6m^3/a. The sources of irrigation water for the various irrigation areas are listed in **Table 5.6.2.2**.

TABLE 5.6.2.1: 1995 IRRIGATION WATER REQUIREMENTS

CATCHMENT				FIELD EDGE WATER REQUIREMENT[3]	CONVEYANCE LOSS		TOTAL THEORETICAL WATER REQUIREMENT[1]	TOTAL ACTUAL WATER USE[1]	TOTAL ACTUAL WATER USE AT 1:50 YR ASSURANCE[1]	RETURN FLOW	RETURN FLOW AT 1:50 YEAR
SECONDARY		TERTIARY		(10^6 m^3/a)	(%)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a)	(%)	(10^6 m^3/a)
No.	Description	No.	Key Area Description								
C7	Rhenoster	C70	Rhenoster (70A-K)	12,8	25	4,2	17,5	17,0	15,3	0	0
C6	Vals	C60	Vals (C60A-J)	1,6	10	0,2	2,1	1,8	1,6	0	0
C2	Johan Neser	C24	Johan Neser (C24C-G)	20,6	10 to 20	5,5	35,8	26,1	21,7	0	0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	5,9	10 to 20	1,2	11,1	7,1	6,0	10	0,2[4]
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,0	0	0	0,0	0,0	0,0	0	0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	0	0	0	0,0	0,0	0	0
	Erfenis	C41	Erfenis (C41A-E)	0,0	0	0	0	0,0	0,0	0	0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	72,8	20 to 30	29,0	87,8	101,8	50,0	0	0
Total in Free State				**92,2**	**10 to 30**	**34,4**	**115,0**	**126,6**	**72,4**	**0 to 10**	**0,1**
Total in North-West				**21,5**	**10 to 20**	**5,7**	**39,3**	**27,2**	**22,2**	**0 to 10**	**0,1**
TOTAL IN WMA				**113,7**	**10 to 30**	**40,1**	**154,3**	**153,8**	**94,6**	**0 to 10**	**0,2**

Note :
1. Using guideline water quota, Table 8.2 (Loxton et al., 1999b).
2. Calculated crop water use, Table 8.2, (Loxton et al., 1999b).
3. Field edge requirement (Crop water use – conveyance losses) and includes irrigation system application losses.
4. Irrigation returns only effective along Vaal River.

TABLE 5.6.2.2: SOURCE OF IRRIGATION WATER

KEY AREA DESCRIPTION	IRRIGATION AREA[1]	SOURCE OF IRRIGATION WATER.
Rhenoster	Rhenoster River GWS	Koppies and Rooipoort Dams / Rhenoster River
	Weltevrede MB	Weltevrede Dam
Vals	Vals River	Vals River
Johan Neser	Schoonspruit GWS	Rietspruit and Elandskuil Dams
	Ventersdorp Eye Subterranean GWCS	Ventersdorp Eye
	Taaibosspruit	Taaibosspruit
Vaal	Vaal River GWCA	Vaal River
	Klerksdorp IB	Johan Neser Dam
Vet	Sand-Vet GWS (Vet)	Erfenis Dam, Vet River
	Sand-Vet GWS (Sand)	Allemanskraal Dam, Sand River
	Vet River GWS (Vet)	Groot Vet River

Note: (1) (Loxton et al., 1999b), Tables 7.2 / 8.2 .

5.6.3 Water losses

Water losses from irrigation are divided into conveyance losses and irrigation application efficiencies.

Conveyance losses

This is the loss (leakage and evaporation) experienced during conveyance of water from the source, (i.e. river, dam or borehole) via canals, dams or pipelines, to the edge of the area under irrigation. This loss is expressed as a portion of the annual irrigation water use.

In this WMA conveyance losses could range from 10 % in the case of run of river abstractions to 15 % in the case of maintained, concrete lined canal distribution schemes to 20 % in the case of older, unlined and poorly maintained systems. The conveyance losses to field edge for irrigation are shown for key areas and provinces in **Table 5.6.2.1**.

Irrigation efficiency

Irrigation application efficiency is mainly a function of the irrigation application method used. Irrigation efficiencies typically associated with the common irrigation methods are as follows:

- Flood irrigation 65 %.
- Sprinkler systems 75 %.
- Mechanical systems 80 %.
- Micro systems 85 %.
- Drip systems 90 %.

Where more than one method was used in an area, the efficiencies were combined to determine an average efficiency for the area. The dominant irrigation methods in this WMA are mechanical and sprinkler application systems, therefore average losses range from 20 % to 25 %.

Refer to **Section 3.5.2** and **Table 3.5.2.1** for more details.

5.6.4 Return flows

Return flows to the river system from irrigation are divided into returns due to leaching and increased returns caused by rainfall.

Return flow due to leaching beyond the root zone.

Irrigation water not used by the plant is returned to the groundwater or streams due to leaching and is largely dependent on the soil characteristics and water quality. Information about these returns was not readily available therefore 0 % return flow due to leaching was used throughout the WMA.

Additional return flow

The return flow from irrigation can further increase due to the increased rainfall run off due to the higher level of soil moisture when compared with the natural state. This increased return flow can be calculated for a seasonal or yearly crop. Based on the climatic conditions and the different crops under irrigation in the WMA the additional return flow generated is of the order of 10 %. In this WMA only irrigation returns along the Vaal River are considered to contribute to the yield of the Middle Vaal system.

Return flows as a result of irrigation are shown in **Table 5.6.2.1**.

5.7 DRYLAND SUGAR CANE

Except for sugar cane, all the dry land crops produced in South Africa are assumed to practically use the same water as that of the natural vegetation it replaces. This implies that the water use of dry land crops is already accounted for in the surface water hydrology. Because of the considerable annual variation in dry land cultivation (due to climatic conditions) reliable dry land data are also not always readily available. For the above reasons only dry land sugar cane was therefore investigated for the purpose of this study.

There is no dry land sugar cane in this WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

5.8.1 Rivers and wetlands

Losses from rivers, wetlands and dams consist primarily of evaporation losses from the river, wetland or dam surface area, but also include seepage losses. The naturalised catchment hydrology often implicitly accounts for channel losses under natural conditions.

Of interest are the additional channel losses that are associated with releases from reservoirs. These losses expressed as incremental losses arising from river regulation (i.e. the additional loss associated with maintaining a fully wetted channel throughout the year). These losses influence the water balance of a system and have to be taken into account in determining releases from dams and the yield of the system.

The main stem of the Vaal River is regarded as regulated. Assessment of river losses is also important when return flows artificially increase base flow (such as urban and mining discharges to the Koekemoerspruit sub-catchment in the Klerksdorp area). In all such instances regulated dry weather flows result in increased channel losses.

River loss data was provided by the DWAF. Information of evaporation losses from dams in the WMA was also provided by the DWAF.

In the absence of information, estimates were based on the potential evapotranspiration loss from free water surfaces and riparian vegetation. Estimates of the incremental losses were based on comparisons of calculated river losses based on naturalised flow sequences with calculated losses assuming a fully wetted channel reach.

Table 5.8.1 summarises the water losses from rivers, wetlands and dams for key areas. Total additional river and dam losses of about 433 x $10^6 m^3$/a were estimated for this WMA of which evaporation from dams (over 80 %) are the most significant.

TABLE 5.8.1: WATER LOSSES FROM RIVERS, WETLANDS AND DAMS.

CATCHMENT				LOSSES FROM RIVERS AND WETLANDS (10^6 m^3/a)	EVAPORATION FROM DAMS (10^6 m^3/a)	TOTAL (10^6 m^3/a)
SECONDARY		TERTIARY				
No.	Description	No.	Key Area Description			
C7	Rhenoster	C70	Rhenoster (70A-K)	0,0	24,3	24,3
C6	Vals	C60	Vals (C60A-J)	0,0	28,6	28,6
C2	Johan Neser	C24	Johan Neser (C24C-G)	0,0	10,4	10,4
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	40,0	11,5	51,5
	Bloemhof	C25	U/S Bloemhof (C25D-F)	40,0	206,5	246,5
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	21,7	21,7
	Erfenis	C41	Erfenis (C41A-E)	0,0	35,9	35,9
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	0,0	14,5	14,5
Total in Free State				**47,8**	**266,9**	**314,7**
Total in North-West				**32,2**	**86,5**	**118,7**
TOTAL IN WMA				**80,0**	**353,4**	**433,4**

5.9 AFFORESTATION

There is no afforestation in this WMA.

5.10 HYDROPOWER AND PUMPED STORAGE

There are no hydro power stations or pumped storage schemes in this 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 - Environmentek (Versfeld et al, 1997).

It has been assumed that water consumption of 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 in the same manner as for afforestation (refer to **Section 5.9**).

Table 5.11.1 summarises the 1995 water use by alien vegetation for key areas and **Figure 5.11.1** shows the reduction in runoff caused by alien vegetation for key areas.

TABLE 5.11.1: 1995 WATER USE BY ALIEN VEGETATION

CATCHMENT				AVERAGE REDUCTION IN RUNOFF		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
SECONDARY		TERTIARY		(10^6 m^3/a)	(mm/a)	(10^6 m^3/a)	(mm/a)
No	Description	No.	Key Area Description				
C7	Rhenoster	C70	Rhenoster (70A-K)	0,0	0,00	0,00	0,00
C6	Vals	C60	Vals (C60A-J)	0,1	0,01	0,04	0,00
C2	Johan Neser	C24	Johan Neser (C24C-G)	0,2	0,04	0,07	0,00
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	0,4	0,04	0,01	0,00
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,8	0,16	0,03	0,01
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	0,0	0,0	0,00
	Erfenis	C41	Erfenis (C41A-E)	0,0	0,0	0,0	0,00
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	0,0	0,0	0,0	0,00
Total in Free State				**0,6**	**0,09**	**0,05**	**0,00**
Total in North-West				**0,9**	**0,17**	**0,1**	**0,01**
TOTAL IN WMA				**1,5**	**0,26**	**0,15**	**0,01**

5.12 WATER CONSERVATION AND WATER DEMAND MANAGEMENT

5.12.1 Introduction

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and water 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 Water 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 water 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 water demand management can be achieved.

This section describes the National Water Conservation and Water 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 water demand management. This section also describes the platform on which the National Water Conservation and Water 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 water 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 33% of total water use in the Middle Vaal Water Management Area. Irrigation losses are often quite significant and it is estimated that often no more than 60% to 70% of water abstracted from water resources 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.

Forestry

There is no afforestation in this WMA.

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, 1997 (Act No. 108 of 1997) and the National Water Act, 1998 (Act No. 36 of 1998) variously require and provide for the implementation of water conservation and water demand management measures. One of the functions of the National Water Conservation and Water 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, 1997 (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 water demand management.

National Water Act

The purpose of the National Water Act, 1998 (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 water demand management

Security of supply

The role of water conservation and water 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 resources 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 water 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 water demand measures

There are a number of categories of water conservation and water 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 water demand management strategy

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

- Create a culture of water conservation and water 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 Middle Vaal WMA

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.

Sedibeng Water is currently busy with water balances on all main delivery lines in order to assess possible water losses (Sedibeng Water, 1998).

5.13 WATER ALLOCATIONS

5.13.1 Introduction

For details of the National Water Act, refer to **Section 3.4.2** on Legal Aspects

In terms of Section 34 of the old Water Act, 1956 (Act No 54 of 1956), Water Courts are established to apportion water and to determine individual water rights. In order to control the use of water, the Minister, subject to the conditions of various sections of the Water Act, issued permits or authorisations to water users.

The various types of allocations are summarised below. Allocation information that is readily available is detailed in **Appendix C**.

5.13.2 Permits which could have been issued under the old Water Act

Authorisations in terms of Section 9B and 9C of the Water Act

A permit is required for the construction, operation or enlargement of any water work which will enable more than 110 ℓ/s of water to be abstracted or diverted from a public stream (river). A permit is required for the impoundment on any piece of ground of more than 250 000 m^3 of water from a public stream.

Any dam having a storage capacity greater than 50 000 m^3 and a wall height greater than 5m is deemed to be a dam with a safety risk and no person may design, construct, operate, alter, enlarge or use such a dam without a permit. All such dams have to be registered at the Dam Safety Office of DWAF. Data about these dams can be obtained from the Dam Safety Database.

Appendix C.1 lists some of the information on dams that was extracted from the Dam Safety Database (the volume of information is too great to include it all).

Authorisations in terms of Sections 11 and 12 of the Water Act

Section 11: Use of water for industrial purposes is subject to permission of a Water Court, except where water is supplied by a local authority or by the Minister from a Government Water Scheme, or where water is allocated by the Minister in a Government Water Control Area.

Section 12: If use of water for industrial purposes is greater than 150m^3 on any one day, a permit of authority is required for the use of the water regardless of the source of the water. This permit must accompany the application to a Water Court as provided for in Section 11.

Information about these permits can be obtained from the PCPolman Database, DWAF. Examples of these permits, relevant to the Middle Vaal WMA can be found in **Appendix C.2.**

Authorisations in terms of Section 13 of the Water Act

A local authority requires a permit to construct, alter or enlarge any water work by means of which more than 5 000 m^3/d can be abstracted or diverted from a public stream. Section 13/3 states that a local authority requires a permit to construct, alter or enlarge any water work by means of which more than 125 000 m^3 of public water can be impounded.

Examples of these types of permits can be found in **Appendix C.1** and have been extracted from the Dam Safety database.

Authorisations in terms of Section 30 (2) of the Water Act

The Minister can control the abstraction of underground water in a Subterranean Water Control Area. The Ventersdorp Eye Subterranean Water Control Area is located in this WMA within the Johan Neser key area. The annual allocated abstraction for irrigation is estimated at 22,4 x 10^6m^3 (DWAF, 1999) for 2 723 ha with a quota of 8 225 m^3/ha/a.

Authorisations in terms of Section 56 (3) of the Water Act

The Minister may supply water from a Government Water Work. In the Middle Vaal WMA, section 56 (3) authorisations allow various water users to abstract water in terms of the Vaal River Development Scheme Act, 1934 (Act No. 38 of 1934). **Appendix C.3** lists the known authorisations. The most important of these are the Sedibeng Water and the MidVaal Water Company abstractions from the Vaal River.

Authorisations in terms of Section 62 (B) of the Water Act

Control of public water in a Government Water Control Area vests in the Minister and no person may construct, alter, enlarge or use a water work for abstraction except under permit from the Minister. The Minister may allow the abstraction of water from a Government Water Control Area for prescribed purposes to anyone within or outside the control area.

5.13.3 Government Water Control Areas in the Study Area

There are two Government Water Control Areas in this WMA, namely:

- Vaal River GWCA.
- Ventersdorp Eye Subterranean GWCA.

The following areas are also controlled in terms of irrigation abstractions (DWAF, 1999):

- Sand-Vet GWS (consisting of the Sand-Vet GWS (Vet), Sand-Vet GWS (Sand) and Vet River GWS).
- Rhenoster River GWS (d/s Vaal Barrage).
- Klerksdorp IB.
- Weltevrede MB.
- Taaibosspruit Irrigation Area.

5.13.4 Permits and other allocations

Comprehensive and reliable information on permits, authorisations and allocations was not readily available. This is because the data for different permits or allocations is not centrally located.

A summary of the irrigation scheduling and quotas (Article 63 permits) from Government Water Schemes is provided in **Table 5.13.4.1**. The Sand-Vet GWS is the most important Government Water Scheme is this WMA.

The irrigation areas and quotas for Government Water Control Areas (Article 62 permits) are provided in **Table 5.13.4.2**.

TABLE 5.13.4.1: ARTICLE 63 – IRRIGATION SCHEDULING AND QUOTAS FROM GOVERNMENT WATER SCHEMES.

SCHEME	QUATERNARY CATCHMENTS	SCHEDULED(1) (ha)	QUOTA(1)	ALLOCATION
			(m^3 /ha/a)	(10^6 m^3/a) (2)
Rhenoster River GWS (Free State)	C70	2 576	6 100	15,7
Weltevrede MB (Free State)	C70	288	6 100	1,8
Schoonspruit GWS (North West Province)	C24	114	7 700	0,9
Klerksdorp IB (North West Province)	C24	1 239	6 100	7,6
Sand-Vet GWS (Vet) (Free State Province)	C41	5 245	7 200	37,8
Sand-Vet GWS (Sand) (Free State Province)	C42	5 172	7 200	37,2
Vet River GWS (Free State Province)	C43A	1 779	7 200	12,8
Total for Free State	**C70, C41, C42, C43**	**1 353**	**7 700**	**105,3**
Total for North West	**C24**	**15 060**	**6 100 to 7 700**	**8,5**
Total for WMA		**16 413**	**6 100 to 7 700**	**113,8**

Note: (1) From Table 8.2 of the report (Loxton Venn et al, 1999b)
(2) Refer to appendix D.1 for quaternary catchment crop area data.

TABLE 5.13.4.2: ARTICLE 62 – IRRIGATION SCHEDULING AND QUOTAS IN GOVERNMENT WATER CONTROL AREAS.

WATER CONTROL AREA	QUATERNARY CATCHMENTS	IRRIGATION AREA [(1)] (ha)	QUOTA[(1)] (m^3/ha/a)	ALLOCATION (10^6m^3/a)
Vaal River GWCA (Free State and North West)	C24	576	6 100	3,5
Schoonspruit GWS (North West)	C24	1 589	7 700	12,2
Ventersdorp Eye Subterranean GWCA (North West)	C24	2 723	8 225	22,4
Taaibosspruit (North West	C24	63	5 309	0,3
Total for Free State	**C24**	**288**	**6 100**	**1,8**
Total for North West	**C24**	**4663**	**5 309 to 8 225**	**36,6**
Total for WMA		**4951**	**5 309 to 8 225**	**38,4**

Note: (1) From Table 8.2 of the report (Loxton et al., 1999b)

Data for Section 56 (3) water allocations to other users from Government Water Schemes was provided by the DWAF for the Free State Province. Therefore section 56 (3) allocations for key areas in the North West Province are not known. The available information does not represent the whole of the WMA. **Table 5.13.4.3** summarises the available data. All known data is listed in **Appendix C.3**.

The most important water allocations are for Sedibeng Water and MidVaal Water Company abstractions from Vaal River of 125 x 10^6m^3/a and 86,9 x 10^6m^3/a respectively.

Data for water allocations in Subterranean Water Control Areas was not made available to the WRSA consultant. There is one Subterranean GWCA in this WMA, namely the Ventersdorp Eye Subterranean GWCA. Individual allocation information is not known however available information is summarised in **Table 5.13.4.4**.

TABLE 5.13.4.3: ARTICLE 56(3) - ALLOCATIONS FROM GOVERNMENT WATER SCHEMES.

Scheme	Catchments	Allocation ($10^6 m^3/a$)
MidVaal Water Co	C24	86,9
Sedibeng Water (Vaal)	C25	125,0
Municipalities and Industries		[9,4]
Institutions		[0,1]
Mining		[66,1]
Domestic; irrigation and stockwatering		[0,0017]
Middle Vaal	C24 – C25	
Municipalities and Industries		8,1
Institutions		17,6
Mining		10,8
Domestic, irrigation and stockwatering		0,003
Sand-Vet key area		
Sedibeng Water (Sand)	C42	12,8
Municipalities and Industries	C41, 42 and 43	4,5
Institutions		3,6
Mining		1,2
Domestic; irrigation and stockwatering		0,2
Vals	C60	No data
Rhenoster key area:		
Municipalities and Industries	C70	0,9
Institutions	C70	0,1
Mining	C70	0,0
Domestic; irrigation and stockwatering	C70	0,6

TABLE 5.13.4.4: ARTICLES 32A AND 32B - ALLOCATIONS IN SUBTERRANEAN WATER CONTROL AREAS.

SUBTERRANEAN WATER CONTROL AREA		QUATERNARY CATCHMENTS	IRRIGATION			OTHER WATER USE (m^3 /ha/a)
			CONTROLLED (ha)	QUOTA (m^3 /ha/a)	ALLOCATION ($10^6 m^3/a$)	
Ventersdorp Eye	North West	C24C	2 723	8 225	22,4	unknown
Totals for WMA			**2 723**	**8 225**	**22,4**	

Note: Allocation information from the report (Loxton et al., 1999b).

5.13.5 Allocations in Relation to Water Requirements and availability

Knowledge of total allocations in this WMA is important. However it is impossible with the available information to compare allocations with water requirements and or water resources. The Situation Assessment consultant has a digital database that could be used as a base to set up a comprehensive allocations database for this WMA.

5.14 WATER TRANSFERS

5.14.1 Introduction

The water resources of a catchment can be exported by pipeline or canal out of the catchment. This transfer out is described as a water requirement from the catchment's water resources. Conversely the water resources of a catchment can be augmented by the import of water by canal or pipeline. This transfer is described as contributing to the resource or source of supply of the catchment.

Water transfers to augment the supply of water for rural, urban, bulk and agricultural requirements are categorised as follows:

- Transfers to or from neighbouring states (none in this WMA).
- Transfers between Water Management Areas (e.g. Heilbron TLC transfer).
- Transfers within WMAs are transfers between quaternary catchments (e.g. transfers by Sedibeng Water to various MLCs and TLCs within the Middle Vaal WMA).

Figure 5.14.1 shows the positions of the major water transfer schemes and the quantity of water transferred per annum under average conditions at 1995 levels of development. All known inter-basin transfers (including effluent transfers) are listed in **Appendix F.4**.

5.14.2 Transfers to and from neighbouring states

There are no transfers from this WMA to or from any neighbouring state.

5.14.3 Transfers Between Water Management Areas

There are no major inter-WMA exports or imports. There are some minor transfers, which are listed in **Table 5.14.3.1**. These are:

- an import of water from Vaal Dam (Upper Vaal WMA) for the Heilbron TLC in the Rhenoster key area.
- an export of water from Erfenis Dam in the Vet key area to the Brandfort TLC in the Upper Orange WMA.

TABLE 5.14.3.1: AVERAGE INTER-WATER MANAGEMENT AREA TRANSFERS UNDER 1995 DEVELOPMENT CONDITIONS.

DESCRIPTION OF TRANSFER	SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY ($10^6 m^3/a$)		
			RECEIVER WMA	LOSSES	SOURCE WMA
Transfers to and from neighbouring states:					
Inter-WMA IMPORTS:					
Heilbron bulk supply	Upper Vaal Vaal Dam	Middle Vaal Heilbron TLC	(+) 0,86	0,04	0,9
Inter-WMA EXPORTS:					
Brandfort bulk supply	Middle Vaal Erfenis Dam	Upper Orange Brandfort TLC	(-) 2,1	0,2	2,3

NOTE : A (+) in the transfer column indicates a surplus in the receiver quaternary catchment that is routed through the system, while a (-) symbol represents the supply of a demand in the receiving quaternary catchment.

5.14.4 Transfers Within Water Management Area

Within the WMA there are numerous transfers between and within quaternary catchments. The Sedibeng Water and the MidVaal Water Company bulk water transfers represent the great majority of these transfers. Significant transfers are summarised in **Table 5.14.4.1** and all known transfers are listed in **Appendix F.4**. Transfers out of the Vaal key area in 1995 were in the region of 65 x $10^6 m^3$, mostly by Sedibeng Water and mainly to the Vet key area (61 x $10^6 m^3$) for urban centres (Welkom, Virginia etc) and mines in the Free State Goldfields.

TABLE 5.14.4.1: AVERAGE TRANSFERS WITHIN THE MIDDLE VAAL WMA AT 1995 DEVELOPMENT LEVELS.

DESCRIPTION OF TRANSFER	SOURCE	DESTINATION	QUANTITY ($10^6 m^3/a$)
SEDIBENG WATER TRANSFERS:			
Sedibeng Water – Free State Gold Fields - urban	Vaal River [Balkfontein]	Welkom; Virginia and Henneman TLCs	24,6
Sedibeng Water – Free State Gold Field - Mines	Vaal River [Balkfontein]	Harmony, President Steyn, Bambanani, Tshepong, Beatrix, Joel, Oryx, Anglo Gold etc	39,4
Sedibeng Water – Free State towns	Vaal River [Balkfontein]	Odendaalsrus, Allenridge; Wesselsbron; Ventersburg; Bothaville, Witpoort and small users	7,4
Sedibeng Water – North West towns	Vaal River [Balkfontein]	Wolmaranstad; Makwassie and Leeudoringstad	1,6
MIDVAAL WATER COMPANY TRANSFERS:			
MidVaal Water Company – urban supply	Vaal River [MidVaal]	Klerksdorp, Stilfontein and Orkney	16,5
MidVaal Water Company - mine supply	Vaal R [MidVaal]	Vaal Reefs; Buffelsfontein; Hartebeesfontein and Stilfontein GMs and small consumers	20,1
OTHER TRANSFERS:			
Senekal Bulk supply	Cyferfontein Dam	Senekal TLC	0,6

Notes : Transfers by Sedibeng Water include conveyance losses of 6 %
Transfers by MidVaal Water Company include conveyance losses of 3 %.

5.14.5 Effluent transfers

There are no significant transfers of effluent within this WMA.

5.15 SUMMARY OF WATER REQUIREMENTS, LOSSES AND RETURN FLOWS

The 1995 water requirements, water losses and return flows for the various user categories in the WMA are summarised in **Table 5.15.1**. Evaporation from dams, rivers and wetlands dominate water requirements (about 55 % of total requirement) of this WMA. Irrigation water requirements (about 19 %) are the next most significant users of water in the WMA. Conveyance losses from irrigation (about 59 %) represent the most significant conveyance losses in the WMA. Urban returns (about 69 %), which combine effluent returns, stormwater returns and clean returns, are the most significant returns to the system.

Pie diagrams of on-site water requirements, losses and return flows are given in **Diagrams 5.15.1, 5.15.2** and **5.15.3**.

TABLE 5.15.1: SUMMARY OF 1995 WATER REQUIREMENTS, LOSSES AND RETURN FLOWS.

CATEGORY		ON-SITE WATER REQUIREMENT (10^6 m^3/a)	CONVEYANCE LOSSES[3]		GROSS WATER REQUIREMENT (10^6 m^3/a)	RETURN FLOW (10^6 m^3/a)
			(%)	(10^6 m^3/a)		
Irrigation		113,7	10 to 30	40,1	153,8	0,2
Urban (Direct and indirect users)		64,5	3 to 20	17,5	82,0	39,1[1]
Rural (Domestic, livestock and subsistence irrigation)		28,0	20	7,0	35,0	0,0
Bulk	a) Strategic (Power Stations)	0,0	0	0	0,0	0,0
	b) Mining	77,9	3 to 10	3,7	81,6	17,6[2]
	c) Other (Industrial etc,)	3,5	3 to 6	0,1	3,6	0,0
Hydro-power		0,0	0	0,0	0,0	0,0
Transfers (export)		2,1[4]	8	0,2	2,3	0,0
Alien vegetation		1,5	n/a	n/a	1,5	n/a
Afforestation (runoff reduction)		0,0	0	0,0	0,0	0,0
Rivers, wetlands, dams		433,4	n/a	n/a	433,4	n/a
TOTAL WMA		**724,6**	**3 to 30**	**68,6**	**793,2**	**56,9**

Note : (1) Urban returns includes effluent returns (25,3) and stormwater (13,8) returns and clean returns.
(2) Mining returns includes groundwater decanted by mines into rivers of WMA.
(3) Only losses associated with the conveyance and distribution of potable water.
(4) Only inter-WMA transfers.

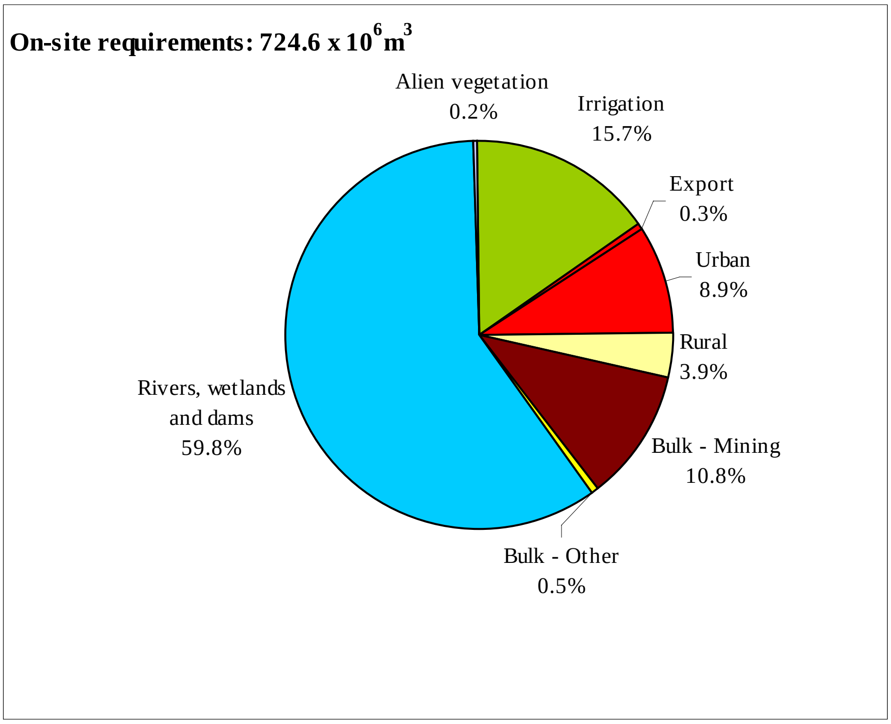


Diagram 5.15.1: 1995 on-site Water requirements in the Middle Vaal WMA in 1995.

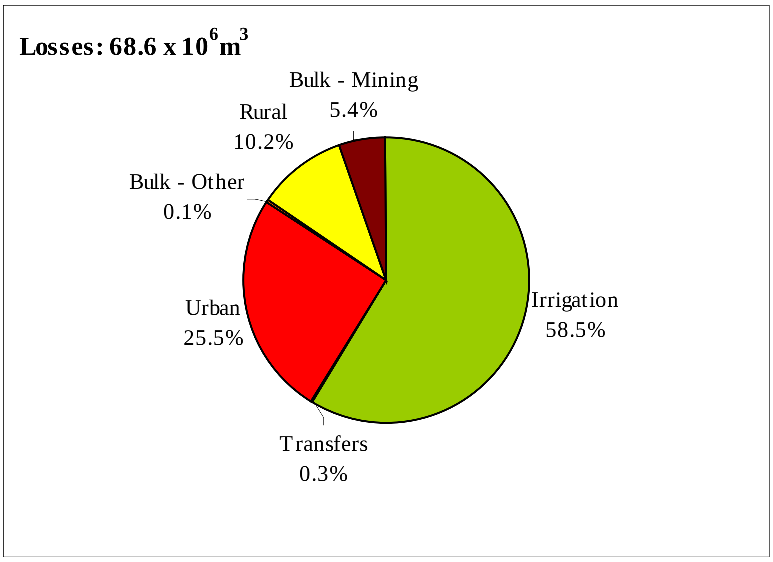


Diagram 5.15.2: 1995 conveyance losses in the Middle Vaal WMA in 1995

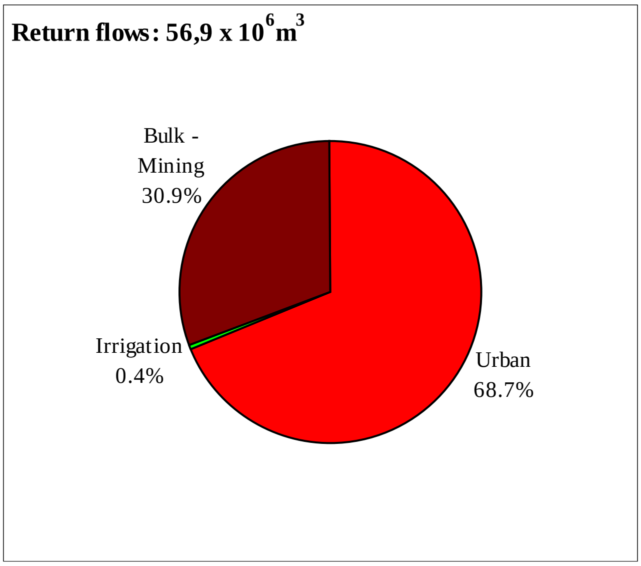


Diagram 5.15.3: 1995 return flows in the Middle Vaal WMA in 1995.

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

Natural mean annual runoff (MAR) from the total Vaal River catchment is approximately 4 000 x 10^6m^3/a. When expressed as an equivalent unit runoff from the 196 000 km^2 Vaal River catchment, the MAR averages out at about 15 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 associated with an increase in evaporation rates. Unit runoff varies from about 30 mm in the western and southern parts of the WMA to as little as about 3 mm in the vicinity of the Bloemhof Dam. Equivalent figures for mean annual rainfall (MAP) are 700 mm (east) and 500 mm (west) and, for mean annual evaporation (MAE) are1 800 mm (east) and 2 600 mm (west).

The developed yield from surface water at 1:50 year assurance in 1995 totals 245,4 x 10^6m^3 and the total potential surface water yield is the same due to the fact that the Middle Vaal WMA as part of the total Vaal system is fully developed. The developed yield from groundwater in 1995 is 56,7 x 10^6m^3 and the potential yield is 370,0 x 10^6m^3. If the existing surface water and groundwater yield is taken into account, the total developed yield in 1995 is 302,1 x 10^6m^3 and the total potential yield is 615,4 x 10^6m^3. Surface water yields have not had the ecological Reserve deducted from them, i.e the yield is calculated as if the ecological Reserve is zero and there is no development in the catchments.

The full existing yield was determined by adding the surface water and groundwater yields.

Table 6.1.1 gives a summary of the water resources per key area. The net 1:50 year yield of the total water resource as developed in 1995 is given in **Figure 6.1.1**

TABLE 6.1.1: WATER RESOURCES.

CATCHMENT				SURFACE WATER RESOURCES ($10^6 m^3/a$)			SUSTAINABLE GROUNDWATER RESOURCE		TOTAL WATER RESOURCE ($10^6 m^3/a$)	
SECONDARY		TERTIARY		NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED IN 1995	1:50 YEAR TOTAL POTENTIAL
No.	Description	No.	Key Area Description							
C7	Rhenoster	C70	Rhenoster (70A-K)	138,3	27,0	27,0	9,1	41,7	36,1	68,7
C6	Vals	C60	Vals (C60A-J)	156,6	12,7	12,7	3,3	59,1	16,0	71,8
C2	Johan Neser	C24	Johan Neser (C24C-G)	87,7	25,2	25,2	16,4[(1)]	60,8	41,6	86,0
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	65,8	26,5	26,5	10,1	54,1	36,6	80,6
	Bloemhof	C25	U/S Bloemhof (C25D-F)	16,5	39,7	39,7	1,2	28,3	40,9	68,0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	96,1	41,2	41,2	1,7	27,3	42,9	68,5
	Erfenis	C41	Erfenis (C41A-E)	167,4	55,0	55,0	2,9	42,5	57,9	97,5
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	159,1	18,1	18,1	12,0	56,2	30,1	74,3
Total in Free State				**743,6**	*****	*****	**30,6**	**261,6**	*****	*****
Total in North-West				**143,9**	*****	*****	**26,1**	**109,4**	*****	*****
TOTAL IN WMA				**887,5**	**245,4**	**245,4**	**56,7**	**370,0**	**302,1**	**615,4**

Note : (1) Groundwater use for irrigation from Ventersdorp Eye Subterranean GWCA (DWAF, 1999).
(*) Provincial split not readily available.

6.2 GROUNDWATER RESOURCES

Groundwater is an important part of the total water resources of South Africa and must be seen as part of the total hydrological cycle. The information provided here gives an overview of the groundwater resources, it's interaction with surface water, the present use, (1995) and it's 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 G**. All information was collated on a quaternary catchment basis.

The Ground Water 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**).

Groundwater, surface water interaction was determined by evaluating the base flow or more specifically the contribution of 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 impact on surface water has been qualitatively evaluated (see **Figure 6.2.3**) ie where the contribution is 0 the impact will be negligible where the contribution is ≤ 30% of the baseflow the impact will be low where the contribution is 30% - 80% of the baseflow, the impact will be moderate and a high impact has been evaluated where the contribution to baseflow is > 80%.

The existing groundwater use was determined by Baron and Seward 2000. The information was then verified at a workshop held in the WMA by the Water Resources Situation Assessment team. This provided local input to the groundwater use numbers 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 Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilized (see **Figure 6.2.5**) ie, if total use was greater then the Harvest Potential, the catchment was considered over-utilized, if the total use was greater than the exploitation potential but less than the Harvest Potential, the catchment was considered heavily utilized, if the total use was more than 2/3 of the Exploitation Potential the catchment was considered moderately-utilized and if the total us was less than 2/3 of the exploitation potential the catchment was considered under-utilized.

TABLE 6.2.1: GROUNDWATER RESOURCES AT 1 IN 50 YEAR ASSURANCE OF SUPPLY.

CATCHMENT				GROUNDWATER EXPLOITATION POTENTIAL ($m^3 \times 10^6/a$)	GROUNDWATER USE IN 1995 ($m^3 \times 10^6/a$)	UNUSED GROUNDWATER EXPLOITATION POTENTIAL IN 1995 ($m^3 \times 10^6/a$)	GROUNDWATER CONTRIBUTION TO SURFACE BASE FLOW ($10^6 m^3/a$)	PORTION OF GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE BASE FLOW ($10^6 m^3/a$)
SECONDARY		TERTIARY						
No.	Description	No.	Key Area Description					
C7	Rhenoster	C70	Rhenoster (70A-K)	55,7	9,1	41,7	4,9	50,8
C6	Vals	C60	Vals (C60A-J)	68,7	3,3	59,1	6,3	62,4
C2	Johan Neser	C24	Johan Neser (C24C-G)	85,2	16,4(1)	60,8	8,0	77,2
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	64,9	10,1	54,1	0,7	64,2
	Bloemhof	C25	U/S Bloemhof (C25D-F)	29,5	1,2	28,3	0,0	29,5
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	34,2	1,7	27,3	4,3	29,0
	Erfenis	C41	Erfenis (C41A-E)	45,4	2,9	42,5	0,0	45,4
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	72,5	12,0	56,2	5,2	68,2
Total in Free State				**312,1**	**30,6**	**261,6**	**20,9**	**291,2**
Total in North-West				**144,0**	**26,1**	**109,4**	**8,5**	**135,5**
TOTAL IN WMA				**456,1**	**56,7**	**370,0**	**29,4**	**426,7**

Note: (1) Adjusted from 13,6 to 16,4 by WRSA consultant. Abstractions for irrigation from Ventersdorp Eye Subterranean GWCA (Loxton et al.,1999b).

6.3 SURFACE WATER RESOURCES

6.3.1 Streamflow data

The basis for the analysis of surface water resources for all WMAs was the synthesised streamflow data at quaternary catchment level developed for the Water Research Commission funded study of the water resources of South Africa (Midgley et al, 1994), which is commonly referred to as WR90. Certain adjustments, as described below, were made to these flow sequences.

The WR90 naturalised flows have taken account of afforestation-related streamflow reductions according to the “Van der Zel curves”. Recently these curves have been seen as too simplistic, and have been superseded by the “CSIR curves”. These curves allow the species, age and site conditions of the afforested area to be taken into account in estimating the streamflow reduction, and are currently the preferred estimation method.

For the purpose of the Water Situation Assessment Model it was decided to adjust the WR90 quaternary naturalised flows to reflect the CSIR afforestation-related streamflow reduction effects. An investigation to determine a method of making the adjustments without serious time or cost implications was conducted (Ninham Shand, 1999). The selected method consisted of the following steps:

(1) The afforestation water use time series based on the Van der Zel 15-year rotation curve was generated.

(2) This time series (the result of (1)) was then subtracted from the Van der Zel-based naturalised flow time series generated for the whole calibration catchment.

(3) The naturalised flow from the afforested portion of the catchment (Van der Zel-based) was used to obtain an afforestation water use time series based on the CSIR curves. This result was added to the result of (2), yielding a time series of adjusted (CSIR-based) naturalised flows.

These adjusted flows have been used for the catchments that contain afforestation.

A validation of this adjustment method was carried out for five gauged catchments from three geographically different regions, which had full hydrological studies available from recent basin studies. Calibration configurations were obtained from these studies. An identical configuration was set up to include the CSIR afforestation-related flow reduction function, and the Pitman model was recalibrated. This resulted in two “calibrated” sets of Pitman model parameters for each catchment, the one using the Van der Zel, and the other using the CSIR afforestation-related streamflow reduction functions.

Monthly naturalised flows were simulated using the two calibrated parameter sets. The CSIR series was used as the “true” series for validation and compared with the Van der Zel time series after it was adjusted as described above.

Differences between the MARs of the adjusted (CSIR-based) naturalised flows and the re-calibrated “true” naturalised flows were within 5%, which was considered to be acceptable.

Based on the three steps described above, the WR90 naturalised flow series were then adjusted for all the afforested quaternary catchments in the country. If the runoff reduction due to afforestation estimated by means of the CSIR curves was lower than the runoff reduction estimated by means of the Van der Zel curves, the virgin runoff of WR90 would have been reduced and vice versa. The difference between the adjusted MARs and the original WR90 values ranges between a reduction of 18% and an increase of 28%. For most of the catchments the difference varies between zero and an increase of 7%.

The proposed methodology ensures that the calculated runoff from an afforested catchment (which would be observed at a streamflow gauge) is the same, irrespective of the afforestation water use model that has been used.

The most important limitations of the method described above are :

- The updated afforestation water use was estimated by means of the CSIR curves (as described in (3)), but the uncorrected naturalised flows based on the original Van der Zel curves were used as an input into this calculation. As a refinement, one could consider the possibility of repeating the process, but this time estimating afforestation water use, not using the original WR90 naturalised flows, but rather the newly adjusted ones. This could then be used to make a second estimate of the CSIR-based natural flows. Further re-iterations of this process might improve the accuracy.

- Catchments upstream of some calibration gauges contained quaternaries with and without afforestation. Changing the MARs of only afforested quaternary catchments therefore made the naturalised MAR of the total catchment less accurate, as the MARs of unafforested catchments were not adjusted.

The perfect solution is to re-calibrate all affected catchments. However, this is not necessary in this WMA because there is no appreciable afforestation.

The primary source of information was the “Surface Water Resources of South Africa 1990”, hereinafter referred to as WR90 which was undertaken by a consortium involving Steffen, Robertson and Kirsten Inc., Stewart Scott Inc. and Watermeyer, Legge, Piesold and Uhlmann (now Knight Piesold) for the Water Research Commission which was completed in 1994. This publication is the only one that provides water resources information down to the quaternary catchment level. It is of interest to report on some of the more important problems encountered by the WR90 team, as they give an insight as to the reliability of the hydrology of the Vaal River catchment.

The increasing aridity of the catchment with progress westwards presented a problem in preserving a mass balance as more rivers converge towards the western portion of the catchment. In this area channel losses are significant and the contribution from tributaries are difficult to define because they are relatively insignificant in relation to the flow in the Vaal River.

A further problem was the lack of information on small unregistered dams in the Vaal River catchment.

The latter two problem areas (i.e. modification of hydrology by effluent discharges and by small dams) were addressed to a large extent in the "Vaal River System Analysis Update" study (BKS et al, 1998d, 1998e, 1998f) hereinafter referred to as the VRSAU study. As part of this study the hydrology of the Vaal River catchment was studied in some detail. Four reports were issued, covering the following catchment sub-divisions: Upper Vaal, Vaal Barrage, Middle Vaal and Lower Vaal. This study was undertaken by a consortium involving BKS Inc., Stewart Scott Inc. and Ninham Shand Inc. for DWAF and reports were finalised in January 1999. Information on small dams was obtained from satellite imagery (Upper Vaal River catchment only) and from 1:50 000 scale mapping (remainder of catchment). In modelling the Vaal Barrage catchment, account was taken of all known abstractions and discharges. Furthermore, an attempt was made to simulate the enhanced runoff from the urbanised areas.

A summary of some of the more important problems encountered in the VRSAU study (in addition to those of the WR90 study) is given below.

Middle Vaal catchment

The hydrological analysis was hampered by the lack of reliable streamflow gauges where they were most needed, namely in the lower reaches of the main tributaries. Some of these gauges yielded flows in conflict with those upstream, consequently some judgement was called for in arriving at an acceptable solution.

The lack of suitable streamflow gauges in the Schoonspruit presented some problems. Strategically located gauges in other sub-catchments that were identified as being unreliable are listed below.

- Rhenoster River at Arriesrust (C7H006).
- Vals River at Roodewal (C6H001) and at Mooifontein (C6H003).
- Vet River at Floorsdrift (C4H002) and at Nooitgedacht (C4H004).

Assessment of MAR

As stated in the previous section, only the WR90 information is presented at a quaternary catchment level. However, as the VRSAU study was undertaken at a greater level of detail, the hydrological assessments should be the more reliable.

Accordingly, the VRSAU estimates of MAR were used to verify/adjust the WR90 data on the basis of comparisons at key points in the Vaal River catchment.

Prior to any adjustments an assessment was made concerning the impact on MAR of the different periods adopted in the WR90 and VRSAU studies. WR90 covered the period 1920 to 1989 and VRSAU covered the period 1920 to 1994. The additional five years included by VRSAU had a minimal impact, resulting in reductions of about one percent in natural MAR. It was, therefore, considered unnecessary to make any adjustments to cater for the different periods.

The method of adjustment is very simple, as shown below:

Let MK_{WR90} = Incremental MAR at key point from WR90
MK_{VRSAU} = Incremental MAR at key point from VRSAU
MQ_jK_{WR90} = MAR of j^{th} Quaternary catchment in incremental catchment

Then, for each of the quaternaries making up the incremental catchment, the adjusted natural MAR is as follows:

MQ_jK_{ADJ} = Adjusted MAR of j^{th} Quaternary catchment in incremental catchment

$= MQ_jK_{WR90} \times MK_{VRSAU} / MK_{WR90}$

Table 6.3.1.1 summarises the adjustments made on the basis of natural MAR comparisons at key points. The adjusted MARs of each quaternary catchment are given in **Appendix G.1**.

TABLE 6.3.1.1: ADJUSTMENT OF QUATERNARY CATCHMENT MAR'S

Key gauge point	Quaternary catchments making up incremental catchment	Natural Incremental MAR ($10^6m^3/a$)		Adjustment ratio
		WR90	**VRSAU**	
C2R002	C24C – C24G	110,7	87,5	0,790
C2H061	C24A,B,H,J; C70K	74,0	57,2	0,773
C9R002	C25; C43D	38,8	55,4	1,428
C4R002	C41A – C41E	236,7	166,8	0,705
C4R001	C42A – C42E	120,3	95,7	0,796
C4H004	C41F – C41J; C42F – C42L; C43A	188,4	150,6	0,799
C4H002	C43B,C	5,0	4,5	0,900
C6H001	C60A – C60G	161,3	143,7	0,891
C6H003	C60H,J	4,6	11,4	2,478
C7R001	C70A – C70C	75,6	59,1	0,782
C7H003	C70G	24,9	15,3	0,614
C7H006	C70D,E,F,H,J	91,8	52,4	0,571
Total		**1 132,1**	**899,6**	

The MAR's were not adjusted for afforestation because there is no afforestation in this WMA. The original WR90 MAR's were used for the determination of non-dimensionalised yield curves (by the firm WRP). This does not give rise to any inconsistency because they are non-dimensionalised.

Table 6.3.1.2 summarises natural MAR at the tertiary catchment level and gives a comparison between the original MARs of the WR90 study and the adjusted values. Reasons are given for cases where the adjusted MAR differs substantially from the WR90 estimate.

TABLE 6.3.1.2: TERTIARY CATCHMENT MAR

Tertiary Number	Description	Net area (km^2)	Natural MAR ($10^6 m^3/a$)		
			WR90	Adjusted	Change
C24	Schoonspruit	8 433	173,9	137,8	-36,1
C25	Middle Vaal	7 055	35,4	51,3	+15,9
C41	Upper Vet	6 994	317,3	217,8	-99,5[4]
C42	Sand	7 555	225,9	192,3	-33,6[4]
C43	Lower Vet	2 765	10,6	11,6	+1,0
C60	Vals	6 765	165,8	155,1	-10,7
C70	Rhenoster	6 157	192,3	126,8	-65,5[5]
TOTAL		**45 724**	**1 121,2**	**892,7**	**-245,53**

Notes:
1. Station C4H002 found to overestimate high flows
2. Early portion of C7R001 (Koppies Dam) found to overestimate spillages

The mean annual natural surface runoff is shown in **Figure 6.3.1**.

Diagram 6.3.1 gives a comparison of natural MAR at the secondary catchment level. The diagram shows the revised MARs to be generally lower than the WR90 values.

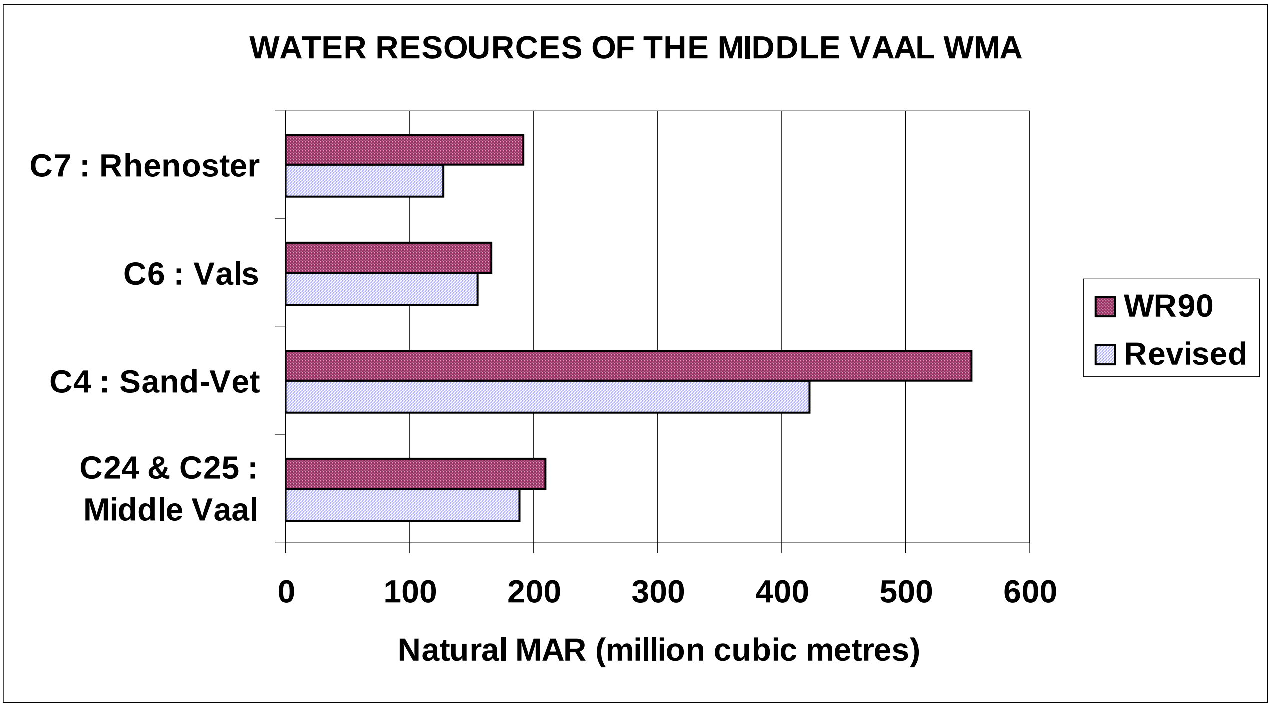


Diagram 6.3.1: Water Resources of the Middle Vaal WMA

6.3.2 Yield Analysis

In order to estimate the total potential yield available from the catchments within the WMA, future storage dams of a particular maximum net storage capacity have been postulated. The net incremental storage capacities that have been adopted within the WMA are given in **Appendix G.1** for all the quaternary catchments. These normally range from lower percentages of MAR for higher rainfall catchments to higher percentages of MAR in the drier catchments but the presence of dolomitic outcrops in the Middle Vaal WMA affects this trend in the range from 100% to 300% of the MAR. **Table 6.3.2.1** shows the comparison between actual dam storage (major and farm dams) and postulated dam storage based on estimates of maximum feasible storage for the tertiary catchments in the Middle Vaal WMA.

Dams that will capture and regulate all the runoff from a catchment are not economical to build. In the drier areas where the runoff is more variable the sizes of such dams also become prohibitive. A simple technique, based on past experience, has therefore been developed whereby plausible estimates of maximum feasible dam size have been derived for the entire South Africa and which will provide consistent results throughout the country. The water balance model will however, be enhanced in future to contain additional functionality to allow users to optimise the likely maximum storage capacity.

TABLE 6.3.2.1: COMPARISON BETWEEN POSTULATED DAM STORAGE AND ACTUAL STORAGE.

Tertiary Number	Description	Existing Storage (10^6m^3)	Postulated storage (10^6m^3)
C24	Schoonspruit	38,09	314,15
C25	Middle Vaal (including Bloemhof Dam)	1 279,94	153,90
C41	Upper Vet	254,75	435,60
C42	Sand	215,27	384,60
C43	Lower Vet	1,29	34,80
C60	Vals	51,05	321,60
C70	Rhenoster	75,57	273,60
TOTAL		**1 915,96**	**1 918,25**

Note : It is unrealistic to compare existing storage and postulated storage in this WMA. The C25 tertiary catchment shows a higher existing storage than postulated storage because of Bloemhof Dam. In all the otrher key areas, existing storage is lower than postulated storage but this does not mean that the key area is underdeveloped. The entire Vaal catchment is fully developed on a macro scale.

The technique that was adopted introduces a limit line to the net storage-gross yield relationship for a 50-year recurrence interval, as shown in **Diagram 6.3.2.1**. The net total incremental quaternary catchment storage capacity used to estimate the potential contribution to the yield by a quaternary catchment has been determined from the intersection of the net storage–gross yield relationship for a 50-year recurrence interval for a particular hydrologic zone, and the limit line shown in **Diagram 6.3.2.1**. This is illustrated by means of the typical net storage-gross yield relationships shown in **Diagram 6.3.2.1** for rivers of low, moderate and high flow variability, which generally correspond to rivers draining high, moderate and low rainfall catchment areas respectively. The net total incremental storage capacities derived by means of this method have been rounded off to 100%, 125%, 150%, 200%, 250% and 300% of the MAR as appropriate.

Figure 6.3.1 gives the mean annual naturalised runoff per quaternary catchment. **Table 6.3.2.2** gives details on surface water resources.

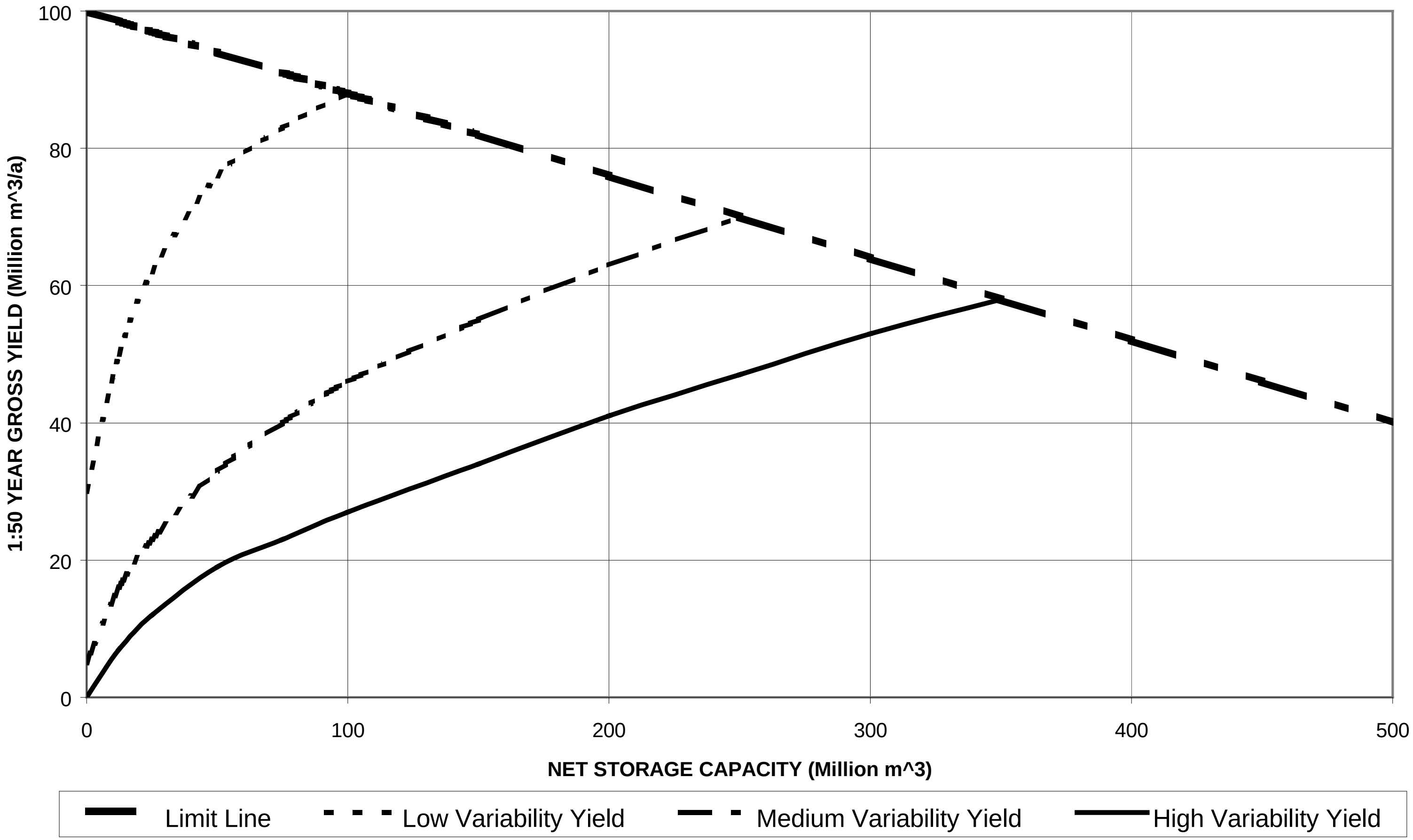


DIAGRAM 6.3.2.1: DAM STORAGE LIMITS

TABLE 6.3.2.2: SURFACE WATER RESOURCES

CATCHMENT				CATCHMENT AREA (km²)	MAP (mm)	GROSS MEAN ANNUAL SYMONS PAN EVAPORATION (mm)	NATURALISED MAR		YIELD (1:50 YEAR)	
SECONDARY		TERTIARY					INCREMENTAL (10^6 m^3)	CUMULATIVE (10^6 m^3)	DEVELOPED IN 1995 ($10^6 m^3$)	TOTAL POTENTIAL (10^6 m^3)
No.	Description	No.	Key Area Description							
C7	Rhenoster	C70	Rhenoster (70A-K)	6 656,0	588,8	1 609,0	138,3	138,3	27,0	27,0
C6	Vals	C60	Vals (C60A-J)	7 871,0	562,5	1 603,0	156,6	156,6	12,7	12,7
C2	Johan Neser	C24	Johan Neser (C24C-G)	5 644,0	577,8	1 796,0	87,7	87,7	25,2	25,2
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	8 281,0	543,1	1 802,0	65,8	2 871,0	26,5	26,5
	Bloemhof	C25	U/S Bloemhof (C25D-F)	4 959,0	500,7	1 939,0	16,5	3 310,0	39,7	39,7
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	3 628,0	593,1	1 477,0	96,1	96,1	41,2	41,2
	Erfenis	C41	Erfenis (C41A-E)	4 724,0	578,8	1 561,0	167,4	167,4	55,0	55,0
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	10 800,0	503,1	1 615,0	159,1	422,6	18,1	18,1
Total in Free State				**38 940,8**	**563**	**1 615**	**743,6**	**#**	*****	*****
Total in North-West				**13 622,2**	**541**	**1 809**	**143,9**	**#**	*****	*****
TOTAL/AVERAGE IN WMA				**52 563,0**	**556**	**1 675**	**887,5**	# [N1]	**245,4**	**245,4**[A2]

Note : * Provincial split not readily available
 # Not applicable.

Using WR90 information, present day gross yields (1995) were determined for selected areas and have been shown in **Diagram 6.3.2.2**. These figures are gross yield and therefore cannot be compared with the net yields in **Table 6.3.2.2.**

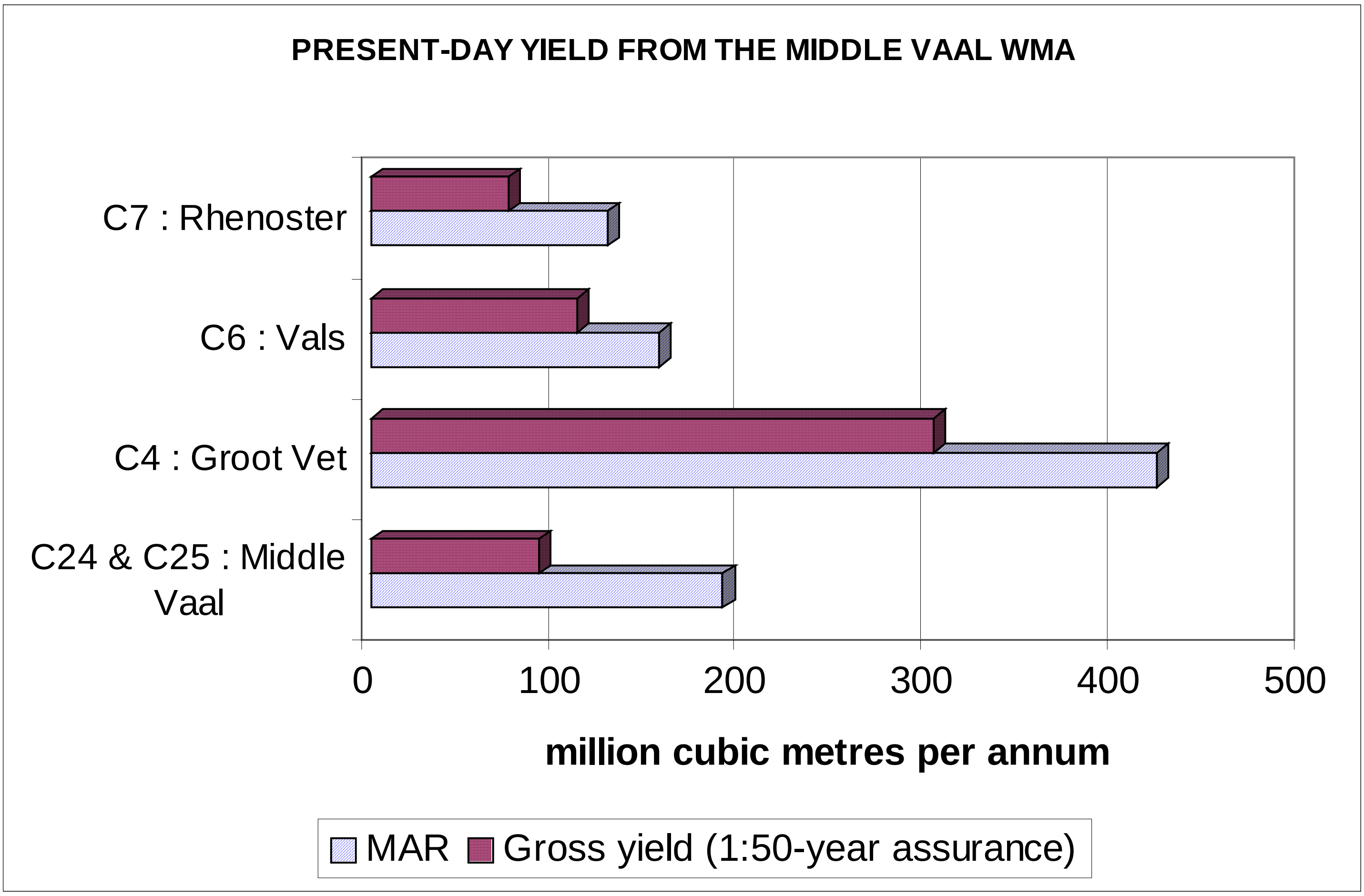


Diagram: 6.3.2.2: Present day yield from the Middle Vaal WMA.

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 WMA.

The mineralogical water quality of the surface water bodies is only described in terms of total dissolved salts (TDS). Data for the assessment were obtained from the water quality data base 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** . There are two water quality monitoring networks in the study area both belonging to DWAF. Water quality monitoring is carried out at streamflow gauging stations and reservoirs. There is also a more informal network of certain points where mine effluent is returned to streams, canals etc. and this monitoring is carried out by various industries and/or mines. In the Middle Vaal WMA there are of the order of 13 DWAF flow measuring stations of which about 12 have water quality measurements of some frequency taken. DWAF have about 8 reservoirs most of which have weekly quality measurements taken.

Sampling of water quality should preferably take place at flow monitoring stations. Sampling frequency can be divided into the following four classes, namely:

- Continuous.
- Weekly.
- Monthly.
- Irregular.

Full details of the water quality monitoring networks can be found in the DWAF reports on the Vaal River Salinity Study: Water quality monitoring requirements for salinity modelling Volumes I to III (DWAF, 1993).

Only data sets that had data for the last five years (1990 to 1995) were used. The data sets were filtered to monthly data, and various techniques were used to fill in missing values where possible. Only those data sets that spanned at least two years and contained at least 24 data points were eventually selected for analysis. These were used to derive the mean and maximum TDS concentrations.

Details of the TDS and electrical conductivity (EC) for the various catchments are given in **Appendix G.4**.

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 of 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 – 1 800
3	Red	Poor water quality	1 801 – 3 400
4	Purple	Completely unacceptable water quality	>3 400

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 observed. 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 Purple
Green	Green Yellow Red Purple	Green Yellow Yellow Purple
Yellow	Yellow Red Purple	Yellow Red Purple
Red	Red Purple	Red Purple
Purple	Purple	Purple

The surface water quality class of the Middle Vaal WMA is summarised in **Table 6.4.1.3**. The surface water class is shown in **Figure 6.4.1.1**.

TABLE 6.4.1.3: SUMMARY OF MINERALOGICAL SURFACE WATER QUALITY OF THE MIDDLE VAAL WMA.

Secondary Catchment	No. of Quaternary Catchments	No of Quaternary Catchments in Class					
		Blue	Green	Yellow	Red	Purple	No Data
C2	16	0	6	5	0	0	6
C4	26	2	1	0	0	0	23
C6	10	0	1	0	0	0	9
C7	11	2	2	0	0	0	7

The mineralogical surface water quality of the Middle Vaal WMA is generally not good. **Section 6.4.4** deals with the issues of concern.

6.4.2 Mineralogical Groundwater 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 (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 (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 ground water resources considered potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) and according to Quality of Domestic Water Supplies, Volume I (DWAF, 1998). Water classified as poor and unacceptable (Class 3 and 4) has been considered **not** potable.

In catchments where no information was available estimates of the portion potable 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 % potable water 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. (Refer to **Appendix G.3** for details of the study). Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution. 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 Middle Vaal WMA is given 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 resources

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 catchment scale. The portion applicable to the Upper Vaal WMA is given 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.

6.4.4 Water Quality Issues

The water quality of the Vaal River in the Middle Vaal WMA is of particular concern. Salinity problems in the Middle Vaal River originate largely from the polluted release from Vaal Barrage, which contributed an annual load of 343 000 t over the 20-year period ending September 1995. A further 18 000 t was contributed by the Mooi River. The Upper Vaal WMA contributed 68% of the salt load leaving Bloemhof Dam, leaving 172 000 t from local sources. Hence the Upper Vaal WMA, which has a similar surface area, produced more than twice the salt load per unit area.

From the above it is clear that water quality in the Middle Vaal River is dominated by the release from Vaal Barrage, which in turn is determined by the system operating strategy.

The Renoster, Vals, Upper Sand (Allemanskraal Dam) and Upper Vet (Erfenis Dam) catchments are largely undeveloped. Despite increasing aridity in a westerly direction the salinity of the runoff from these catchments is low. They are also devoid of other significant pollution sources.

Gold mining in the Welkom-Virginia area elevates the salinity of the lower Sand River below Allemanskraal Dam. Bacterial pollution and eutrophication is also associated with sewage effluent and diffuse pollution from informal settlements. Various pans are also highly saline due to their use as evaporation pans. The salinity of the groundwater in this area is also elevated. Concern has arisen regarding radionuclides.

The Lower Vet River appears to be affected by saline irrigation return flows from the Sand-Vet irrigation scheme. Lack of data, the dominance of upstream mining sources and the aridity of the catchment with no obvious signs of surface seepage impair definitive quantification of the impact.

Gold mining adjacent to and north of the Vaal River in the Klerksdorp-Orkney area results in significant saline pollution. The Koekemoerspruit tributary (just west if the Vaal-Mooi River confluence) is particularly affected. High salinity levels are experienced in the Skoonspruit River before its confluence with the Vaal. Radionuclides have been identified as a potential problem associated with gold mining activities. The presence of mine dumps in close proximity to the northern bank of the Vaal River is particularly problematic. A density current rich in manganese has caused problems for water purification at Midvaal Water. This led to the installation of an ozination plant to oxidise the manganese.

TDS concentrations in the Middle Vaal River are unacceptably high. Although highly beneficial for Pretoria-Witwatersrand-Vereeniging consumers, the 300 mg/ℓ Blending Option for the abovementioned areas does little to reduce TDS peaks in the Middle Vaal River. The dilution option for the abovementioned areas (whereby Vaal Barrage is diluted to below 600 mg/ℓ) provides some relief, but the salinity in the Middle Vaal River remains unacceptably high for Midvaal Water and Sedibeng Water users.

The Middle Vaal River is also subject to severe eutrophication, with frequent algal blooms and dense growth of water hyacinth. This leads to greatly increased water purification costs at Midvaal Water and Sedibeng Water. Eutrophication is promoted by nutrient enrichment of Vaal Barrage water, although the Mooi River and local effluent sources could contribute to this problem. The long retention time in the Vaal River appears to promote algal blooms.

Water quality issues are shown in **Figure 6.4.4.1**.

6.5 SEDIMENTATION

Introduction

Sedimentation was originally analysed according to river basin (by the consultant using data from Rooseboom) i.e. the Upper Orange Basin and Vaal Basin. Sediment yield from the Middle Vaal WMA varies from less than 5 tonnes/km^2/a in dolomitic catchments and areas of very low runoff to almost 300 tonnes/km^2/annum in the southern and south eastern regions. For the Middle Vaal WMA the average sediment yield is about 118 tonnes/km^2/a (refer to **Appendix G.2**, sediment yield (t/a) divided by the total gross area(km^2). The total sediment load is of the order of 4,5 million tonnes per annum, which is equivalent to an average annual volume of about 3 million cubic metres after 25 years of deposition. For the Middle Vaal WMA, this volume amounts to about 0,4 % of the mean annual runoff.

Sources of information

The primary source of information was the report entitled “The development of the new sediment yield map of southern Africa” (Rooseboom et al., 1975) The results of this investigation were incorporated into the “Surface Water Resources of South Africa 1990” (WR90) set of reports (Steffen et al., 1994). The WR90 reports were the most convenient to use as the sediment map was superimposed on the quaternary catchment sub-divisions.

Another useful source of data is to be found in the periodic surveys of major reservoir basins, undertaken by DWAF. This information can be used to detect the rate of decrease in storage capacity over time, which can be attributed to the accumulation of sediment in the reservoir basins.

Sediment yields from map by Rooseboom et al

The sediment map is based on two layers of information. The first layer divides the country into 9 sediment yield regions with an associated medium yield, expressed in tonnes/km^2/annum. The second layer depicts the erodibility index, which varies between 1 (highest erodibility) to 20 (lowest erodibility). These indices have been grouped into three classes, namely HIGH (1 to 8), MEDIUM (9 to 15) and LOW (16 to 20). Each sediment yield region has factors to apply to the medium yield, depending on whether the erodibility is high or low. (A factor of unity is applied in cases of medium erodibility.)

Each region has a family of confidence bands to indicate how, in most regions, the degree of confidence deteriorates as the catchment area decreases. However, as this study covers the entire Vaal basin only the mean yield has been used.

Sediment yield for each quaternary catchment was determined using the data from the sediment map. For the Middle Vaal WMA, the results of this analysis appear in **Appendix G.2** and a brief summary of the results is given below.

Total sediment yield:	6,222 million tonnes/a
Gross catchment area:	52 563 km^2
Average yield:	118 tonnes per km^2 /a

Sediment yields from reservoir basin surveys

An important factor in the conversion of sediment volumes determined from basin surveys into mass is the variable density of sediment deposits. In order to overcome this problem an indirect method was developed by Rooseboom (1975) for converting volume into mass, which overcomes the difficulties involved in estimating average density at a given stage. The sediment volume in a reservoir (with high sediment trap efficiency) after a period of time has been found to follow a logarithmic relationship for accumulations longer than about 10 years. It was found that for a number of South African and USA reservoirs it was possible to express the volume of sediment deposit after t years (V_t), in relation to the sediment volume after 50 years (V_{50}), as follows:

$$V_t = V_{50} \times 0,376 \times \ln (t/3,5)$$

By means of this equation it is possible to convert the volume after t years into an equivalent volume after 50 years and vice versa. Choice of the 50 year volume as a reference is arbitrary but it is possible to estimate the average density after 50 years more accurately than after say 10 years. A density of 1 350 kg/m^3 for the 50 year sediment was found to be appropriate for South African reservoirs.

The formula given above was used to determine the equivalent sediment volume after 25 years. The appropriate density after 25 years accumulation was then determined proportionately. For the Middle Vaal WMA it was found to be 998 kg/m^3. Sediment yield (in tons/km^2/a) was then determined using the density for the 25 year accumulation period.

The calculations for sediment yields based on available reservoir surveys are set out in **Table 6.5.1,** which lists the dam name, record period, sediment volume at end of period (V_t), equivalent 50-year volume (V_{50}), net catchment area, equivalent 25-year volume (V25) and average sediment yield. Also listed for purposes of comparison are the sediment yields derived from the Rooseboom's map (as published in WR90).

The potential for sediment accumulation in reservoirs in a 25 year period (as a percentage of MAR) is shown in **Figure 6.5.1**. In a few quaternary catchments with very low runoff, the value exceeded 100%. This is probably because the sediment map was based on soil characteristics. However, the great majority of quaternary catchments show realistic values and the few isolated over-estimations are in quaternary catchments where water resources are insignificant.

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENTATION RATES FOR RESERVOIRS IN THE MIDDLE VAAL WMA.

Dam name And quaternary catchment	Year Constructed or last raised	Year of last survey	Original Capacity (10^6 m3)	Surveyed Capacity (10^6 m3)	Sediment Volume (10^6m3)	Number of years	V50 (10^6m3)	Volume per year (10^6m3/a)	Net catchment area (km2)	Sediment Yield (m3/km2/a)	V25 (10^6m3)	Sediment yield (t/km2/a)	Yield from map (t/km2/a)
Allemanskraal (C42E)	1959	1988	220	179,9	40,1	29	50,44	1,00872	3 665	275,23	37,29	274,68	82
Erfenis (C41E)	1959	1988	235,6	212,3	23,3	29	29,31	0,58612	4 750	123,39	21,66	123,15	82
Bloemhof (C91A)	1968	1980	1275	1269	6	12	12,95	0,25902	55 557	4,66	9,57	4,65	153
						Totals	93	1,85386	63 972	28,97	68,52	29,04	118

The surveyed sedimentation rates display a wide variation among the reservoirs, ranging from as low as 5 tonnes/km^2/a to as high as 275 tonnes/km^2/a. This wide range is attributable more to the inaccuracies inherent in assessing small differences between successive surveys than to actual differences in sediment yield. Another factor, which impacts on short record periods in particular, is the high variation in sediment load from year to year. Significant sediment deposits are associated with the major floods; thus several years may elapse with negligible sediment volumes being deposited.

The average sediment yield for all reservoirs was calculated to be 29 tonnes/km^2/a, which is about 75 % below the figure derived from the sediment map.

Reconciliation of sediment yields from surveys and map

The difference between the two estimates of total sediment yield is considered to be acceptable in the light of the difficulties associated with measurement of sediment. As the sediment map produced the higher estimate for the Vaal catchment it was decided to accept the sediment loads obtained from this source. **Table 6.5.2** summarises the sediment data at the tertiary catchment level. **Appendix G.2** contains details of sediment load calculations for each quaternary catchment.

TABLE 6.5.2: SEDIMENT YIELD FROM TERTIARY CATCHMENTS.

Tertiary Number	Description	Net area (km^2)	Sediment yield		
			(t/km^2/a)	(10^6t/a)	(10^6m^3/a)
C24	Schoonspruit	8 433	153	1,293	1,296
C25	Middle Vaal	7 055	153	1,082	1,084
C41	Upper Vet	6 994	93	0,653	0,654
C42	Sand	7 555	125	0,947	0,949
C43	Lower Vet	2 765	153	0,313	0,314
C60	Vals	6 765	146	0,990	0,992
C70	Rhenoster	6 157	153	0,944	0,946
TOTAL	**Middle Vaal WMA**	**45 724**	**139***	**6,22**	**6,235**

* Higher than figure of 133 t/km^2/a quoted earlier, which is based on gross catchment area.

CHAPTER 7: WATER BALANCE

7.1 METHODOLGY

7.1.1 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.

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.
- 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 external 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 requirements

The water requirements determined by the WSAM are generally not correct. In order to facilitate the production of the WRSA reports, the database created by the consultant was compared with the data abstracted from the WSAM into a spreadsheet and various worksheets set up, which reference this abstracted data. These worksheet were structured so as 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 resources

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:

The so-called effective yield balance produced by WSAM, as described in **Section 7.1.2** above, was mostly assumed correct (WRSA consultants estimates were preferred). There are a few instances where it was clearly incorrect and 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 minor dams

It appears as if the WSAM assumes that the runoff into minor dams is equal to the entire incremental flow generated within a quaternary catchment. Considering the definition of a minor dam, i.e. a dam that is not situated on the main stream of the catchment, this is not possible. An assumption was made that only 50% of the runoff of a catchment flows into minor dams and this assumption was applied throughout the WMA.

Impact of alien vegetation on catchment yield

The WSAM seems to determine the impact of alien vegetation on yield in a realistic manner. However, it does not report correctly on what this impact is. This problem was resolved by adopting zero alien vegetation in the catchments when running the WSAM and calculating these impacts external to the model. The impacts on the yield of the catchments were then accounted for external to the model when determining the water balance.

- The available water resource was then assumed to be the difference between the water balance and the water requirements 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

Key areas were selected on the basis that they represented major dams, tertiary catchments or the outflows from tributaries into major rivers. **Table 7.2.1** lists the selected key areas for the Middle Vaal WMA.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION.

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT NO.	
NO.	KEY AREA NAME AND POINT		
C	Rhenoster – C70K outlet	C70A-K	C7 Secondary catchment
	Vals – C60J outlet	C60A-J	C6 Secondary catchment
	Johan Neser – C24G outlet	C24C-G	Johan Neser Dam
	Vaal – C25C outlet	C24A-B, C24H-J, C25A-C	Remaning C24 Tertiary catchment
	U/S Bloemhoef – C25F outlet	C25D-F	Bloemhof Dam
	Allemanskraal – C42E outlet	C42A-E	Allemanskraal Dam
	Erfenis – C41E outlet	C41A-E	Erfenis Dam
	Vet – C43D outlet	C41F-J, C42F-L, C43A-D	Bloemhof Dam and remainder of C4 Tertiary catchment

The 1995 water requirements (at equivalent 1:50 year assurance) for key areas are summarised in **Table 7.2.2** . The total water requirements (consumptive and non-consumptive) for this WMA were estimated to be about 565 x $10^6 m^3/a$. **Table 7.2.3** summarises the water balance for key areas. There is a surplus yield from the upstream Upper Vaal WMA of about 678 x $10^6 m^3/a$, this yield is ‘transferred’ downstream into the Vaal and Bloemhof key areas within the Middle Vaal WMA. This results in a surplus yield of about 472 x $10^6 m^3/a$ of which about 500 x $10^6 m^3/a$ is required by the downstream Lower Vaal WMA.

There are no major transfers into or out of this WMA.

The cumulative water use and availability at equivalent 1:50 year assurance at each key area area outlet has been shown by pie diagrams (in units of 10^6 m^3/a)

in **Figure 7.2.1**. Categories shown are the consumptive requirements (urban, rural, irrigation, bulk, alien vegetation, afforestion and exports), ecological Reserve requirement and losses. Where there is a surplus of water (includes imports and re-usable return flows), a larger circle has been superimposed on the pie diagram and where there is a deficit, a smaller circle has been superimposed. The water balance in each key area is described below.

7.3 RHENOSTER KEY AREA

In 1995 this key area had a small surplus of about 12,8 x $10^6 m^3$. This key area is rural in nature and has significant controlled irrigation and rural requirements (87 % of total requirements). Heilbron and Viljoenskroon TLC's are the most significant urban centers in the area. Water is imported from the Upper Vaal WMA (Vaal Dam) to supply the needs of Heilbron TLC. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently less then 10 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.4 VALS KEY AREA

In 1995 this key area had a small surplus of about 4,9 x $10^6 m^3$. While the key area is rural in nature, it has significant urban requirements (73 % of total requirements). The urban requirements are dominated by the requirement of Kroonstad TLC (13,2 x $10^6 m^3$). Water is imported from the Vaal key area (Vaal River) by Sedibeng Water to supply the needs of the Bothaville TLC. Treated sewage and stormwater returns from Kroonstad in particular contribute significantly (33 % of total resource) to the water resources of the Vals key area. All irrigation in the Vals catchment is regarded as diffuse (DWAF, 1999) and is not significant. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is limited to the exploitation of the groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently less then 5% of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.5 JOHAN NESER KEY AREA

In 1995 this key area had a small surplus of about 13,5 x 10^6m^3. The area is rural in nature and has significant controlled irrigation and rural requirements (90 % of total requirements). Ventersdorp and Coligny TLC's are the most significant urban centres in the area. This key area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently about 20 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.6 VAAL KEY AREA

In 1995 this key area had a surplus of about 556,5 x 10^6m^3, which includes the surplus yield from the Upper Vaal WMA of about 678 x 10^6m^3 which was 'transferred' downstream to this key area.

Located within this key area is the North West Goldfields, therefore urban and bulk water requirements account for 40 % of total requirements. The main urban centres are Klerksdorp, Orkney and Stilfontein in the NW Goldfields and Odendaalsrus in the Free State. The requirements of Stilfontein, Buffelsfontein, Vaal Reefs and Hartebeesfontein Gold Mines make up over 90 % of bulk requirements in the area. Effluent returns from these towns and mines increase the water resources of the area significantly.

This area also exports water (33 %) from the Vaal River to a number of adjacent key areas, the most significant being Sedibeng Water export of water at Balkfontein to the Free State Goldfields in the Vet key area. River losses account for 20 % of total requirements.

The potential for water resources development within this area is dependent on the availability of water from the Upper Vaal WMA and on the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently about 15 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.7 BLOEMHOF KEY AREA

In 1995 this key area had a surplus of about 450,8 x $10^6 m^3$ (including the surplus from the Upper VaalWMA) which was transferred downstream to the Lower Vaal WMA.

The requirements of this key area are dominated by non-consumptive requirements. These are the ecological reserve requirement of the Vaal River (70 % of total requirement) and river losses (29 %). Consumptive requirements by urban and rural users are small in comparison (3 %). Wolmaransstad and Wesselsbron are the most important urban centres in the area. There is no significant irrigation in this area.

The potential for water resources development in this area is controlled by requirements in the Upper Vaal WMA and upstream Vaal key area and by the scheduled irrigation requirements of the downstream Lower Vaal WMA and is probably limited to the exploitation of groundwater resources.

Currently less then 5 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.8 ALLEMANSKRAAL KEY AREA

In 1995 this key area had a surplus of about 34 x $10^6 m^3$. The key area is rural in nature and water requirements are dominated the ecological reserve requirement of the upstream Sand River (59 %). Consumptive requirements by urban and rural users make up the rest of the requirements. Irrigation water requirements are not significant. Senekal is the most important urban center in the area.

This key area does contribute to the downstream yield of the Sand River. Due to scheduled irrigation requirements in the downstream Vet key area the potential for water resources development within this area is probably limited to the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently less then 5 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.9 ERFENIS KEY AREA

In 1995 this key area had a surplus of about 44,2 x $10^6 m^3$. The key area is rural in nature and water requirements are dominated by the ecological reserve requirement of the upstream Vet River (52 %). Consumptive requirements by urban and rural users make up 31 % of total requirements. There is an export (17 %) of water from Erfenis Dam to Branfort TLC in the Upper Orange WMA. Irrigation water requirements are not significant. Winburg and Marquard are the most important urban centers in the area.

This key area does contribute to the downstream yield of the Vet River. Due to scheduled irrigation requirements in the downstream Vet key area the potential for water resources development within this area is probably limited to the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently less then 10 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

7.10 VET KEY AREA

In 1995 this key area had a surplus of about 55,6 x $10^6 m^3$. Although the water resources of this key area are augmented by transfers from Vaal River (Vaal Key area) by Sedibeng Water for urban and bulk use in the Free State Goldfields and by the upstream yields of Erfenis and Allemanskraal key areas.

The mining (30 %) and urban water requirements (24 %) of the Free State Goldfields dominate the water requirements of this key area. The main urban centres are Welkom and Virginia and the main mines are Harmony, President Steyn, African Rainbow Minerals and Bambanani Gold Mines. Returns from these users contribute ± 10 % to the water resources of the key area.

Irrigation water requirements (40 %) for controlled irrigation are significant and are the most important in the WMA as a whole. Approximately 122 km^2 is scheduled for irrigation in three areas, namely Sand-Vet GWS (Sand), Sand-Vet GWS (Vet) and Vet River GWS.

Actual irrigation requirement are significant therefore this key area does not contribute to the yield of the Lower Vaal WMA. The potential for water resources development within the key area is limited to the exploitation of groundwater resources.

Locally there appears to be potential for the development of additional surface water storage **(Table 6.3.2.1)**. This, however, is subject to downstream users being affected because the Vaal macro system is fully developed.

Currently about 16 % of the exploitable groundwater has been developed **(Table 6.2.1)**.

TABLE 7.2.2: 1995 WATER REQUIREMENTS BY KEY AREA (AT 1:50 YEAR ASSURANCE).

CATCHMENT				STREAMFLOW REDUCTION ACTIVITIES ($10^6 m^3/a$)		WATER USE ($10^6 m^3/a$)		WATER REQUIREMENT ($10^6 m^3/a$)						ECOLOGICAL RESERVE ($10^6 m^3/a$)	TOTAL ($10^6 m^3/a$)
SECONDARY		TERTIARY													
No.	Description	No.	Key Area Description	AFFOREST-ATION	DRYLAND SUGAR CANE	ALIEN VEG.	RIVER LOSSES[(2)]	BULK	IRRI-GATION	RURAL	URBAN	WATER TRANSFERS OUT[(1)]	NEIG-HOURING STATES		
C7	Rhenoster	C70	Rhenoster (70A-K)	0,0	0,0	0,00	0,0	0,0	15,3	6,0	3,3	0,0	0,0	0,0	24,6
C6	Vals	C60	Vals (C60A-J)	0,0	0,0	0,04	0,0	0,0	1,6	4,5	15,9	0,0	0,0	0,0	22,0
C2	Johan Neser	C24	Johan Neser (C24C-G)	0,0	0,0	0,07	0,0	0,0	21,7	3,2	1,4	0,0	0,0	1,7	28,1
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	0,0	0,0	0,01	40,0	49,1	6,0	4,8	26,4	64,9	0,0	0,0*	191,2
	Bloemhof	C25	U/S Bloemhof (C25D-F)	0,0	0,0	0,03	40,0	0,0	0,0	3,1	2,1	0,0	0,0	103,8	149,0
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	0,0	0,0	0,00	0,0	0,0	0,0	2,4	1,4	0,0	0,0	5,5	9,3
	Erfenis	C41	Erfenis (C41A-E)	0,0	0,0	0,00	0,0	0,0	0,0	3,0	1,3	2,3	0,0	7,2	13,8
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	0,0	0,0	0,00	0,0	38,6	50,0	8,3	30,8	0,0	0,0	0,0*	127,7
Total (Free State)				**0,0**	**0,0**	**0,05**	**47,8**	**41,8**	**72,4**	**27,6**	**58,2**	**66,0**	**0,0**	**50,2**	**364,1**
Total (North-West)				**0,0**	**0,0**	**0,10**	**32,2**	**45,9**	**22,2**	**7,7**	**24,4**	**1,2**	**0,0**	**68,0**	**201,7**
TOTALIN WMA				**0,0**	**0,0**	**0,15**	**80,0**	**87,7**	**94,6**	**35,3**	**82,6**	**67,2[(3)]**	**0,0**	**118,2**	**565,8[(4)]**

Notes: * Negative values for ecological reserve taken as zero.

(1) Only potable water transfers.

(2) Evaporation losses from dams, rivers and wetlands are not included because they are part of the available yield.

(3) Total transfers in 1995 = 67,2 x $10^6 m^3$, transfers out of WMA was 2,3 x $10^6 m^3$ to Brandfort TLC in the Upper Orange WMA. The remainder is within WMA transfers = 64,9 x $10^6 m^3$.

(4) Total requirement in 1995 at 1:50 assurance: 565,8 x $10^6 m^3$ – 64,9 x $10^6 m^3$ = 500,9 x $10^6 m^3$ because the within WMA transfers are accounted for in the water requirements of key areas.

TABLE 7.2.3: WATER BALANCE BY KEY AREA (AT 1:50 YEAR ASSURANCE).

CATCHMENT				AVAILABLE 1:50 YEAR YIELD IN 1995 ($10^6m^3/a$)			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQ. AT 1:50 YEAR ASSURANCE(2) ($10^6m^3/a$)	WATER BALANCE AT 1:50 YEAR ASSURANCE ($10^6m^3/a$)
SECONDARY		TERTIARY										
No.	Description	No.	Key Area Description	SURFACE WATER	GROUNDWATER USE IN 1995	TOTAL	IMPORTS (1)	EXPORTS (1)	RE-USABLE	TO SEA		
C7	Rhenoster	C70	Rhenoster (70A-K)	(+) 27,0	(+) 9,1	(+) 35,9	(+) 0,9	0,0	(+) 0,6	n/a	(-) 24,6	(+) 12,8(7)
C6	Vals	C60	Vals (C60A-J)	(+) 12,7	(+) 3,3	(+) 16,2	(+) 1,9	0,0	(+) 8,8	n/a	(-) 22,0	(+) 4,9(7)
C2	Johan Neser	C24	Johan Neser (C24C-G)	(+) 25,2	(+) 16,4	(+) 41,6	0,0	0,0	0,0	n/a	(-) 28,1	(+) 13,5(7)
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	(+) 26,5	(+) 10,1	(+) 36,6	(+) 678,5(3)	(-) 64,9	(+) 32,6	n/a	(-) 126,3	(+) 556,5(4)
	Bloemhof	C25	U/S Bloemhof (C25D-F)	(+) 39,7	(+) 1,2	(+) 40,9	(+) 558,6(4)	0,0	(+) 0,3	n/a	(-) 149,0	(+) 450,8(6)
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	(+) 41,2	(+) 1,7	(+) 42,9	0,0	0,0	(+) 0,4	n/a	(-) 9,3	(+)34,0(5)
	Erfenis	C41	Erfenis (C41A-E)	(+) 55,0	(+) 2,9	(+) 57,9	0,0	(-) 2,3	(+) 0,1	n/a	(-) 11,5	(+) 44,2(5)
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	(+) 18,1	(+) 12,0	(+) 30,1	(+) 139,1(5)	0,0	(+) 14,1	n/a	(-) 127,7	(+) 55,6(6)
Total (Free State)				**&**	**&**	**&**	**&**	**&**	**&**	**n/a**	**&**	**&**
Total (North-West)				**&**	**&**	**&**	**&**	**&**	**&**	**n/a**	**&**	**&**
TOTAL in WMA				**(+) 245,4**	**(+) 56,7**	**(+) 302,1**	**(+) 1 379,0**	**(-) 67,2**	**(+) 56,9**	**n/a**	**(-) 498,5**	
Surplus yield from Middle Vaal WMA for Lower Vaal WMA												**(+) 506,4(6)**

Note: (1) Potable water transfers only.
(2) Requirements include ecological reserve, river losses, urban, rural, irrigation, bulk , alien vegetation and afforestation.
(3) Transfer surplus yield from the upstream Upper Vaal WMA (Stewart Scott, 2002).
(4) Transfer surplus yield from upstream Vaal key area to downstream key area.
(5) Surplus yields from Allemanskraal and Erfenis key areas are transferred to the downstream Vet key area.
(6) Surplus yields from u/s Bloemhof and Vet key areas are available for downstream Lower Vaal WMA.
(7) Yields not available to downstream key areas (Pitman, 1999).
(&) Provincial split not readily available.

CHAPTER 8 : COSTS OF WATER RESOURCE DEVELOPMENT

8.1 METHODOLOGY

Although not as highly developed as the Upper Vaal WMA, there is not much potential for the further development of surface water resources in the Middle Vaal WMA. Surface water developments are dependent on the availability of water from the upstream Upper Vaal WMA and the downstream requirements of the Lower Vaal WMA.

Some potential does exist for the further development of groundwater resources. The estimated groundwater potential is 228 x $10^6 m^3/a$ of which about 25 % is currently exploited (refer to **Section 6.2**).

There is a subterranean area, the Ventersdorp Eye Subterranean GWCA that provides groundwater for irrigation. It is, however, not known whether there is any further potential for developing this resource. The potential for developing well fields on a major scale is not known.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The Middle Vaal WMA is not as highly developed as the Upper Vaal WMA but there is still a significant amount of development. There are no transfer schemes directly into this WMA but certain urban, rural, industrial, mining, ecological and irrigation requirements benefit from transfers upstream into the Upper Vaal WMA. At the 1:50 year level of assurance as at 1995, the Middle Vaal WMA transferred about 506 x $10^6 m^3$ to the Lower Vaal WMA. This surplus is required and used by the Lower Vaal WMA. According to the DWAF the Lower Vaal WMA requires about 500 x $10^6 m^3/a$ from the Middle Vaal WMA (Mallory, 2001).

The following table summarises available yield and water requirements.

CATCHMENT				AVAILABLE 1:50 YEAR YIELD IN 1995 ($10^6 m^3/a$)	WATER TRANSFERS AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)		RETURN FLOWS AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)	WATER REQ. AT 1:50 YEAR ASSUR-ANCE(2) ($10^6 m^3/a$)	WATER BALANCE AT 1:50 YEAR ASSUR-ANCE ($10^6 m^3/a$)
SECONDARY		TERTIARY							
No.	Description	No.	Key Area Description	TOTAL	IMPORTS(1)	EXPORTS(1)	RE-USABLE		
C7	Rhenoster	C70	Rhenoster (70A-K)	(+) 35,9	(+) 0,9	0,0	(+) 0,6	(-) 24,6	(+) 12,8(7)
C6	Vals	C60	Vals (C60A-J)	(+) 16,2	(+) 1,9	0,0	(+) 8,8	(-) 22,0	(+) 4,9(7)
C2	Johan Neser	C24	Johan Neser (C24C-G)	(+) 41,6	0,0	0,0	0,0	(-) 28,1	(+) 13,5(7)
	Vaal	C24-C25	Vaal (C24A-B, C24H-J, C25A-C)	(+) 36,6	(+) 678,5(3)	(-) 64,9	(+) 32,6	(-) 126,3	(+) 556,5(4)
	Bloemhof	C25	U/S Bloemhof (C25D-F)	(+) 40,9	(+) 558,6(4)	0,0	(+) 0,3	(-) 149,0	(+) 450,8(6)
C4	Allemanskraal	C42	Allemanskraal (C42A-E)	(+) 42,9	0,0	0,0	(+) 0,4	(-) 9,3	(+)34,0(5)
	Erfenis	C41	Erfenis (C41A-E)	(+) 57,9	0,0	(-) 2,3	(+) 0,1	(-) 11,5	(+) 44,2(5)
	Vet	C41-C43	Vet (C41F-J, C42F-L,C43A-D)	(+) 30,1	(+) 139,1(5)	0,0	(+) 14,1	(-) 127,7	(+) 55,6(6)
TOTAL in WMA				**(+) 302,1**	**(+) 1 379,0**	**(-) 67,2**	**(+) 56,9**	**(-) 498,5**	
Surplus yield from Middle Vaal WMA for Lower Vaal WMA									**(+) 506,4(6)**

Note: (1) Potable water transfers only.
(2) Requirements include ecological reserve, river losses, urban, rural, irrigation, bulk , alien vegetation and afforestation.
(3) Transfer surplus yield from the upstream Upper Vaal WMA (Stewart Scott, 2002).
(4) Transfer surplus yield from upstream Vaal key area to downstream key area.
(5) Surplus yields from Allemanskraal and Erfenis key areas are transferred to the downstream Vet key area.
(6) Surplus yields from u/s Bloemhof and Vet key areas are available for downstream Lower Vaal WMA.
(7) Yields not available to downstream key areas (Pitman, 1999).

Although every effort has been spent in obtaining accurate data, manipulation of this data and checking and verification thereof, the information presented in this report is dependent on the accuracy and quality of the numerous reports and documentation previously compiled by other organisations. It is therefore likely that some information may have to be revised in the future. A great deal of effort was spent on the metadata (which is information about the quality of data which was supplied to DWAF) for the project database in order to make future enhancements as efficient a process as possible.

9.2 RECOMMENDATIONS

The following recommendations refer to required improvements in the quality of quaternary catchment level data.

- While overall irrigation data can be considered reliable, this data is not available on a quaternary catchment basis and therefore quaternary catchment irrigation data represents an estimate only and must be considered to be of poor quality. In order to improve on quaternary catchment based information it is therefore recommended that a study is undertaken to determine the areal distribution and crop types at quaternary catchment scale.

- Information on rural water requirements was not readily available. There is a need to determine this requirement for the various categories of rural users.

- The available information on livestock and game was for 1988 and 1990. In addition this data was only available at Magisterial district level and like irrigation the data at quaternary catchment level must be considered unreliable.

- A survey of a number of TLC’s was undertaken to try and determine urban water requirements. This exercise was fairly successful and should be extended to the remaining TLC’s. Most small TLC's were not surveyed and their water requirements were estimated using estimated water requirements. It si considered that the estimated water requirements are too high for most small towns and as a consequence the water requirements have been inflated.

- The situation assessment consultant did review river losses, however this data appears to have been ignored. This is possibly a result of problems with the river losses sub-model of WSAM.

- Information on allocations, authorisations and permits needs to be centralised and reviewed by an organisation (persons) skilled in the intepretation of these allocations. Thus allowing the assessment of the available resources and the volumes allocated.

- Information concerning conveyance losses (most kinds) were generally not readily available. While estimates were provided and these were used extensively, a study of this crucial ‘requirement’ is recommended. Irrigation conveyance losses are significant in this WMA and there is a need to quantify them. In addition no information on rural losses was known and the WSAM default of 20 % was applied. There is no information indicating whether this sort of loss is acceptable.

Conservation Management and Demand Management measures need to be implemented to reduce the significant irrigation (20 %) and urban losses (25 % of on-site requirements) that do occur. Initial targets of 5 % reduction in conveyance losses for both requirements is suggested.

- Information concerning conveyance losses (most kinds) were generally not readily available. While defaults were provided and these were used extensively, a study of this crucial ‘requirement’ is recommended. Irrigation conveyance losses are significant in this WMA and there is a need to quantify them. In addition no information on rural losses was known and the WSAM default of 20 % was applied. There is no information indicating whether this sort of loss is acceptable.

- For effective Water Conservation Management and Water Demand Management measures to be implemented reliable information on conveyance losses in required. With this information it would be possible to set initial targets for Conservation Management and Demand Management. For example a 5 % reduction in conveyance losses for most requirements could impact on the available yield. This is specially true for irrigation and urban conveyance losses.

- Regarding the ecological water requirements, negative values (that were taken as zero) should be investigated

REFERENCES

Allen,RG, Pereira,L, Raes, D and Smith, M (1998). Crop Evapotranspiration. FAO Irrigation and Drain,ge Paper 56. UN-FAO, Rome, Italy.

Baron and Seward (2000). Evaluation of the Groundwater use in South Africa. Unpublished DWAF information.

Barta, B (1993) Water utilisation in urban South Africa according to the development regions, Proceedings, 1st Southern Africa water and wastewater conference, Johannesburg, 1993.

Barta, B and Hudson, J (1996) Management of return flows from urban water systems in the Gauteng province, Proceedings, IAHR African Division Biennial Congress, Sun City, 1996.

Barta, B, 2000. Personal communication

BKS Inc / Stewart, Sviridov & Oliver (1991) Orange River System Analysis, Caledon River upstream of Welbedacht Dam: Hydrology. DWAF No. PD000/00/1891, PD200/00/0391

BKS Inc / Stewart, Sviridov & Oliver (1991) Orange River System Analysis, Upper Orange River: Hydrology. DWAF No. PD000/00/0691

BKS Inc / Stewart, Sviridov & Oliver (1992) Orange River System Analysis, Demands and Return flows. DWAF No. PD000/00/0491

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1993). Orange River System Analysis: Phase 2. Evaluation of the future water demands on the Orange River Project. Department of Water Affairs, Directorate of Project Planning, Pretoria.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1995). Orange River Development Replanning Study: Hydrology and System Analysis – Eastern Cape Rivers. DWAF No. PD000/00/4795, PN000/00/0595, PQ000/00/0595.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1995). Orange River Development Replanning Study: Refinement of the Instream Flow Requirements for the Orange River. DWAF No. PD000/00/619.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Comparative Economic Impact Analysis of Optimal Water Allocation. DWAF No. PD000/00/6297.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Environmental Overview of the Eastern Cape Rivers. DWAF No. PD000/00/5397, PN000/00/0997, PQ000/00/0997.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Water Demands of the Eastern Cape Region. DWAF No. PD000/00/4397, PN000/00/0397, PQ000/00/0397.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: River Flow Management Workshop: Fish & Sundays Rivers. DWAF No. PD000/00/6597, PN000/00/1797, PQ000/00/1797.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Social Overview - Eastern Cape Region. DWAF No. PD000/00/5197, PN000/00/0897, PQ000/00/0897.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Eastern Cape Region – Calibration of the Water Quality Model. DWAF No. PD000/00/5697.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Existing Water Infrastructure in the Eastern Cape Region. DWAF No. PD000/00/4197.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Existing Water Infrastructure in the Orange River Basin. DWAF No. PD000/00/4297

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Water Demands of the Orange River Basin. DWAF No. PD000/00/4497

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Hydrology and System Analysis - Orange River Basin. DWAF No. PD000/00/4497

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Social Overview – Orange River Basin. DWAF No. PD000/00/5097

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Evaluation of Irrigation water use. DWAF No. PD000/00/4897, PN000/00/0697, PQ000/00/0697.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study: Regional Economic Assessment. DWAF No. PD000/00/5597, PN000/00/1097, PQ000/00/1097.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Agriculture Economic Analysis of Water in the Orange & Fish River Basins. DWAF No. PD000/00/6397.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Allocations of Orange River water: Social implications. DWAF No. PD000/00/6497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Sedimentation of reservoirs in the Orange River Basin. DWAF No. PD000/00/5497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Reconnaissance Phase Summary Report. DWAF No. PD000/00/5795, PN000/00/1295, PQ000/00/1295.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Water Quality Aspects: Orange River Basin. Volume 1: Expected Water, Main Report DWAF No. PD000/00/5997.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Upper Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16296.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Barage Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16396.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Middle Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16496.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Lower Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16596.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Main Report. Department of Water Affairs and Forestry, Pretoria.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Water Demand Management. Department of Water Affairs and Forestry, Pretoria. Report PD000/00/4597, PN000/00/0497, PQ000/00/0497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Potential Dam Development and Hydro Power Options. DWAF Report PD000/00/4997, PN000/00/0797, PQ000/00/0797.

BKS Inc (1998) Augmentation of the Eastern Sub-system of the Vaal River system: Desk Top Study, Vaal River System: Continuous Study. DWAF PC/000/00/19797

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Upper Vaal Catchment. DWAF No. PC000/00/18096

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Vaal Barrage Catchment. DWAF No. PC000/00/18196

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Middle Vaal Catchment. DWAF No. PC000/00/18296

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Evaporation Losses from South African Rivers (on behalf of Department of Water Affairs and Forestry and Water Research Commission.)

Bloem Water (1999) Personal communication

Botha, SJ and Viljoen, MF (1991) Die finansiele gevolge van waterbeperkings van 1983 tot en met die opheffing daarvan in 1987 vir die Vaal en Rietrivierwatervoorsieningstelsels. Deel 1. Verslag deur die Departement Landbou-Ekonomie, Universiteit van die Oranje-Vrystaat, aan die Waternavorsingskommissie, Pretoria. Verslag 288/1/91.

Burger, JH (1997) Irrigation systems. Chapter 1, Irrigation Design Manual. ARC Institute for Agricultural Engineering, Pretoria.

City Manager: Greater Soweto (1994) Soweto and Diepmeadow. Status Quo Investigation of Water and Sanitation Functions. Volume 1. Final Report by Stewart Scott. Report No. WC0035-01-00-0794. (9)

Department of Agriculture, (1990) Glen data, Food survey

Department of Agriculture, (1998) Census of Agriculture 1998, Central Statistical Services Ref 2.

Department of Agriculture, (1999) Irrigation Design Manual.

Department of Water Affairs and Forestry. (1974/1975) A Pipline to Convey Releases from Vaal Dam Investigation into the Cost.

Department of Water Affairs and Forestry. (1982) Planning for Water Resource Development in the Orange Free State – First Planning Report PD000/00/0182.

Department of Water Affairs and Forestry. (1982) Proposed Orange – Vaal Scheme – Possible Supply via the Proposed Plooysburg Irrigation Scheme Report PC000/00/0483.

Department of Water Affairs and Forestry. (1984) ‘n Bree Oorsig oor Waterbronontwikkeling vir die Vaalriverstelsel. Report No. PC000/00/0584.

Department of Water Affairs and Forestry. Vaalrivier: Rowwe Beramtng van Kostes en Ekonomiese Berekening van Skemas. Report No. PC000/00/2685, PC000/00/3585.

Department of Water Affairs and Forestry. (1985) Vaalrivieropvanggebied. Report No. PC000/00/0885.

Department of Water Affairs and Forestry. (1985) Die Ekonomiese Voordeel vir die Vaalrivierstelsel Indien die Watervoorsiening vir die Douglas-Besproeiingskema vanaf die Vaalrivier na die Oranjerivier Oorgeplaas Word. Report No. PC000/00/2985.

Department of Water Affairs and Forestry. (1985) Vaalrivieropvanggebied Verslag oor Rivierverliese Tussen Vaalharts-Stuwal en Schmidtsdrigt-Stuwal. Report No. PC000/00/3385.

Department of Water Affairs and Forestry. (1985) Vaalrivier-Benaderde Berekening van Kostes en Ekonomiese Berekening vir die Oorbring van Water. Report No. PC000/00/3285.

Department of Water Affairs and Forestry. (1990) Voorstelle vir die Verbetering van Watergehalte Probleme in die Middel-Vaalriviergebied. Report No. PC000/00/9990.

Department of Water Affairs and Forestry. (1990). List of Hydrological Gauging Stations (Volume 2) July 1990.

Department of Water Affairs and Forestry. A to Z of Water Saving Devices (22)

Department of Water Affairs. (1992) Crocodile River (Western Transvaal) Catchment Study. Urban Demands and Return Flows. Report by SS&O and BKS. Report No. PA200/00/1392. (23)

Department of Water Affairs and Forestry. (1994) Water Supply and Sanitation Policy. White Paper. November 1994. (3)

Department of Water Affairs and Forestry. (1995) Vaal Augmentation Planning Study- Orange Vaal Transfer Scheme. Special Reconnaissance Supporting Report. Conveyance Systems: Caledon Cascades Option. - Pump Stations. - Pre-feasibility Supporting Report Goedemoed and Upper Caledon Options. Report No. PC000/00/13294, PD000/00/3994.

Department of Water Affairs and Forestry. (1995) Vaal River System Analysis – Annual Operationg Analysis for the Total Integrated Vaal River System (1996/1997). Report No. PC000/00/19597.

The Department of Water Affairs and Forestry. The working for Water Programme. 1996/97 Annual Report. (21)

DWAF. (1998) Orange River Development Project. Replanning Study. Water Demand management. Report by BKS and Ninham Shand (Pty) Ltd. Report No. PD000/00/4597, PQ000/00/0497, PN000/00/0497. (19)

Department of Water Affairs and Forestry (1998). Quality of Domestic Water Supplies. Volume 1 : Assessment Guide.

Department of Water Affairs and Forestry. (1999) Free State Province. Ist Order Strategy to develop Community Water Supply and Sanitation

Department of Water Affairs and Forestry. (2000). Reservoir records

De Vallier, W and Broadhurst, DW (1997) The development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss. Water Research Commission Report No. 489/1/97. (17)

Eskom (1999) Personal Communication.

Gaffney Group (1998) Official South African Local Government Yearbook 1997-1998.

Görgens, A (1998). Methodology for incorporation of alien vegetation impacts in the national water balance model. Memorandum to Department of Water Affairs and Forestry.

Greater Johannesburg Transitional Metropolitan Council. (1995) Investigation into Water Supply in Soweto and Diepmeadow. Compiled by Stewart Scott. Report No. WC0035-02-00-1095. (10)

Greater Johannesburg Transitional Metropolitan Council. (1996) Water Quality Impact Assessment of Johannesburg's Southern Wastewater Treatment Works on the Klip River. Compiled by Stewart Scott and Pulles, Howard & De Lange. Volumes 2 & 6. GJTMC Library. Reference No. WWC0065-02-00-0896. (11)

Greater Johannesburg Metropolitan Council. (1997) Water Conservation Policy & Proposals for Implementation. Compiled by Eric Hall & Associates. Report No. WC0062-01-00-0897. (13)

Greater Johannesburg Metropolitan Council. (1998) Metro Bulk Water. Fax from Mr A Cross of 4 September 1998 to Stewart Scott. (14)

Green, G.C. Estimated irrigation requirements of crops in South Africa. Part 2. Highveld region / Free State region / Transvaal region. Memoirs on the agricultural Natural resources of South Africa. No. 2. Department of Agriculture and Water Supply, Pretoria.

Herold, CE, and Taviv, I, (1997) Modelling of long term effects of atmospheric deposition on the salinity of runoff from the Klip River Catchment.

Heyns, PJ (1997) Planning. Chapter 11, Irrigation Design Manual. ARC Institute for Agricultural Engineering, Pretoria.

Hughes, DA and Münster, F (1999). A decision support system for an initial 'low-confidence' estimate of the quantity component of the Reserve for rivers. Unpublished discussion document available at http://www.ru.ac.za.departments/iwr.

Johnson, EH (1995) Water Demand Management. Water Institute of Southern Africa. Water Sewage & Effluent. Vol. 15, No. 1, pp29-34. (5)

Kleynhans, CJ (1999). A procedure for the determination of the ecological reserve for the purposes of the National Water Balance Model for South African Rivers. Unpublished. Institute for Water Quality Studies, DWAF.

King, J and Louw, D (1998). Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management, 1, 109-124.

Le Matre, DC, Versfeld, DB, and Chapman, RA (November 1999). The impact of Invading Alien Plants on Surface Water Resources in South Africa: A Preliminary Assessment.

Linsley-Noakes, GC, Louw, M and Allan, P (1995) Estimating daily positive Utah chill units using daily minimum and maximum temperatures. *J. S. Afr. Soc. Hort. Sci.* 5, 19-23.

Loxton, Venn and Associates. (1985) Vaal River Agro-Economic Study. Preliminary Report. Department of Water Affairs, Directorate of Planning, Pretoria. Report PC000/00/1784.

Loxton, Venn and Associates. (1999) Proposed modifications to the irrigation sub-model of the national water balance model (Stewart Scott (Pty) Ltd). Department of Water Affairs and Forestry, Pretoria.

Loxton Venn and Associates, (1999) Vaal River Irrigation Study. DWAF report: PC000/00/21599

Midgley, DC, Pitman, WV and Middleton, BJ. (1994) Surface Water Resources of South Africa 1990. Users Manual. Volume 11: Appendices. Volume 11: Book of Maps. Water Research Commission, Pretoria. Reports 298/1/94, 298/2.1/94 and 298/2.2/94.

Midvaal Water Co. (1999) Personal Communication.

Nel, van Wilgen and Gelderblom (January 1999). The Contribution of Plantation Forestry to the Problem of Invading Alien Trees in South Africa: A Preliminary Assessment.

Ninham Shand (Pty) Ltd. 1999. Interim Adjustment of Water Resources 1990 (WR90) Quaternary catchment Naturalised Flows to Reflect CSIR Afforestation-Related Streamflow Reduction Activities.

Ninham Shand (1996): Lesotho Water Projects (TAMS report): Water Resources Management: Policy and Strategies (some relevant extracts). Dept. of Water Affairs and Forestry, Pretoria.

Ninham Shand Inc. (1997) Eastern Cape Water Resources Situation Assessment. DWAF No. PG000/00/0000.

Ninham Shand Inc. (1998) Vaal River System Analysis Update, Hydro-salinity Model Calibration: Lower Vaal Catchment

Ninham Shand (1998): Lesotho Highlands Further Phases. Upper Caledon Option (Overview report). Dept. of Water Affairs and Forestry, Pretoria.

Ninham Shand Inc. (1999) 1st Order Strategy to Develop Community Water Supply & Sanitation (Free State Province) DWAF: Water Services Planning.

Ninham Shand Inc. (1999) Catchment Management Strategy for the Modder & Riet Rivers. Phase 1: Situation Assessment & Draft Management Strategy. DWAF Report.

North West Water Supply Authority. (1996) Survey of Unauthorised Connections on Water Supply Schemes in the North West Province. Report by Stewart Scott. (20)

Official South African Municipal Yearbook, 1995. (16)

Proudlock, TH (1994) Proposed National Water Regulations. Written Contribution to National Water Supply and Sanitation Policy Conference. July 1994. (1)

Pulles, Howard and de Lange (1998) Mooi River Catchment Management Study: Phase 1, Situation Analysis.

Pybus, PJ (1998) Development of a National Framework for Regional Water Supply Management – Discussion Document.

Rand Water, Marketing Department. (1998) Letter dated 5 October 1998 from Mr G Constantinides to Stewart Scott. Reference DWAF-L26. (15)

Rand Water, (1999) Personal communication.

Readers Digest Association of South Africa, Capetown, (1990). Ref Illustrated Guide to the Game Parks and Nature Reserves of Southern Africa, 2nd edition.

Rooseboom. A (1975) "The development of the new sediment yield map of southern Africa"

Schlemmer, L, Stewart, G and Whittles, J (1969) The Socio-Economic Effects of Water Restrictions on Local Authorities, Selected Industrial and Commercial Establishments and other Private Agencies. Water Research Commission Report. No. WRC/68/1/89. (8)

Schreiner, B (1998) Water Demand Management – An Overview. Water Demand Management Workshop. July 1998. CSIR. (4)

Schoeman en Vennote. (1994) As-Liebenbergsvleirivier. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria. Verslag B0210/2.

Schoeman en Vennote. (1994) Wilgerivier. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schoeman en Vennote. (1995) Vaaldamopvang SWBG. Vaalrivier: Grootdraaidam-opnamegebied. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schoeman en Vennote. (1996) Ventersdorp Oog Ondergrondse Staatwaterbeheergebied. Resultate van Veldopnames. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schulze, RE. (1997) South African Atlas of Agrohydrology and -Climatology. Water Research Commission, Pretoria. Report TT82/96.

Sedibeng Water. (1998) Fax dated 12 October 1998 from ND Basson to Stewart Scott. (18)

Sedibeng Water (1999) Personal Communication.

Seward, P and Seymour, A (1996). Groundwater Harvest Potential of the Republic of South Africa.

Simonic, M (2000). Assessment of the ambient Groundwater Quality on a National scale in the Republic of South Africa. WRC Project K5/841.

Smith, M. 1992. CROPWAT, a computer programme for irrigation planning and management. FAO Irrigation and Drainage Paper 46. FAO, Rome, Italy.

Smith, M, Allen, RG, Monteith, JL, Perrier, A, Perriera, L and Segeren, A (1992) Report on the expert consultation on procedures for revision of FAO guidelines for prediction of crop water requirements. UN-FAO, Rome, Italy.

Steffen, Robertson and Kirsten Inc., Stewart Scott Inc. and Watermeyer, Legge, Piesold and Uhlmann (now Knight Piesold) (1994) “Surface Water Resources of South Africa 1990”

Stewart Scott. (1990) Water Resources of the Republic of South Africa. (SSI Library)

Stewart Scott. (1994) Water Demand Management of South Africa’s Water Resources. Written contribution to National Water Supply and Sanitation Policy Conference. July 1994. (2)

Stewart Scott, (1996) Long Term Salt Balance of the Vaalharts Irrigation Scheme. WRC Report No: 420 / 1 / 96

Stewart Scott (1996) Lower Vet River Water Quality Situation Analysis with Special Reference to the OFS Goldfields. WRC Report No: 523 / 1 /96.

Stewart Scott (1997) East Rand Water Care Company DD5A Regional Water Care Works Hydrological and Water Quality Situation Analysis. Report to East Rand Water Care Company No. DA137959/01

Stewart Scott (1998) : Report by WV Pitman - “Maximum Dam Sizes to be used in Potential Yield Analyses”

Stewart Scott (1999) Blesbokspruit Catchment, Water Quality Management Plan, Phase 1, Status Quo Analysis. DWAF No. 16/4/C212/1

Stewart Scott (2002) Upper Vaal Water Management Area, Water Resources Situation Assessment, Volume 2.

Thomson, RC (1989) Meeting and Telephonic Conversation between Representatives of Rand Water and Stewart Scott. (12)

Van Zyl, JH and Viljoen, MF. (1986) Die sosio-ekonomiese gevolge van waterbeperkings op besproeiingsboerderye, mynbou, elektrisiteitsvoorsiening en die sentrale owerheid. Verslag deur die Instituut vir sosiale en Ekonomiese Navorsing, Universiteit van die Oranje-Vrystaat, aan die Waternavorsings-kommissie, Pretoria. Verslag 288/1/91.

Van Zyl, JH and Viljoen, MF. (1986) Die Sosio-Ekonomiese Gevolge en Waterbeperkings op Besproeiingsboerderye, Mynbou, Electrisiteitsvoorsiening en die Sentrale Owerheid. Waternavorsingskomissie Verslag No. WRC167/1/87. (7)

Vegter, JR (1995). Groundwater Resources of the Republic of South Africa. WRC Project 483.

Versfeld, DB, le Maitre, DC, and Chapman, RA (1997). Alien Invading Plants and Water Resources in South Africa. Report to the Water Research Commission, Pretoria.

Viljoen, MF, Symington, HM & Botha, SJ. (1992) Verwantskap tussen waterbeperkings en finansiele gevolge in die Vaalrivierwatervoorsieningsgebied met spesiale verwysing na besproeiingsboerderye in die Vaalhartsgebied. Deel 2. Verslag deur die Departement Landbou-Ekonomie, Universiteit van die Oranje-Vrystaat, aan die Waternavorsingskommissie, Pretoria. Verslag 288/2/92.
-. 1998/1999 Rates and Tariffs. 1998. Department of Water Affairs and Forestry, Pretoria.

Viljoen, MF (1994) Research Note: The Opportunity Cost of Water for Environmental use During Water Shortages with Reference to the Vaal River system. Agrekon. Vol 33, No. 2, pp91-95. (6)

Williams, JE, Wood, CA and Dombeck, MP (1997). J.E., C.A Woods, .Dombeck (1997). Understanding watershed-scale restoration. Pp 1-16 in: J.E Williams, CA Wood & M.P Dombeck (eds.) *Watershed restoration: principles and practices*. American Fisheries Society, Bethesda, Maryland.

APPENDICES

Appendix A	**Demographics**
Appendix B	**Macro Economics**
Appendix C	**Legal Aspects**
Appendix D	**Land Use Data**
Appendix E	**Water Related Infrastructure**
Appendix F	**Water Requirements**
Appendix G	**Water Resources**
Appendix H	**Supplementary Information**

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

APPENDIX A: DEMOGRAPHICS

Comprising:

Appendix A.1   Urban population data

Appendix A.2   Rural population data

APPENDIX A.1

URBAN POPULATION DATA

Appendix A.1 URBAN POPULATION

Source of RSA population data: Markdata Demographic Study

Quaternary catchment	Province	Transitional councils	Population
Vaal River key area:			
C24A	NW	STILFONTEIN / KHUMA	55,350
C24B	NW / FS	ORKNEY / KANANA; VAAL REEFS & VIERFONTEIN	88,050
C24H	NW	KLERKSDORP / JOUBERTON & HARTBEESFONTEIN / TIGANE	160,500
C25A	NW	LEEUDORINGSTAD / KGAKALA	8,600
C25B	NW / FS	ODENDAALSRUS / KUTLWANONG & ALLANRIDGE / NYAKALONG	89,700
C25C	NW	WITPOORT / RULAGANYANG	2,500
Total			**404,700**
Johan Neser key area:			
C24E	NW	VENTERSDORP / TSHING	12,850
C24F	NW	COLIGNY/THLABOLOGANG	8,300
Total			**21,150**
Bloemhof key area:			
C25D	NW	WOLMARANSSTAD / TSWELELANG & MAKWASSIE / LEBALENG	27,550
C25F	FS	WESSELSBRON / MONYAKENG	23,650
Total			**51,200**
Urban population for Vaal area:			**477,050**
Erefenis Dam key area:			
C41A	FS	WINBURG / MAKELEKETLA & MARQUARD / MOEMANENG	19,550
C41C	FS	EXCELSIOR / MAHLATSWETSA	5,200
C41D	FS	VERKEERDEVLEI / TSHEPONG	1,750
Total			**26,500**
Allemanskraal Dam key area:			
C42A	FS	PAUL ROUX / FATENG-TSE-NTSHO / MOTLOMO	4,800
C42C	FS	SENEKAL / MATWABENG	19,350
Total			**24,150**
Vet key area:			
C41G	FS	THEUNISSEN / MASILO	19,600
C42H	FS	VENTERSBURG / MNAMAHABANE	10,900
C42J	FS	WELKOM / THABONG; VIRGINIA / MELODING & HENNENMAN / PHOMOLONG	316,100
C43A	FS	BULTFONTEIN / PHAHAMENG	18,650
C43C	FS	HOOPSTAD / TIKWANA	11,550
Total			**376,800**
Urban population for Sand-Vet area:			**427,450**
Vals key area:			

Appendix A.1 URBAN POPULATION

Source of RSA population data: Markdata Demographic Study

Quaternary catchment	Province	Transitional councils	Population
C60B	FS	LINDLEY / NTHA & ARLINGTON / LERATSWANA	12,550
C60D	FS	KROONSTAD / MAOKENG	93,400
C60E	FS	STEYNSRUS / MATLWANTLWANG	7,100
C60J	FS	BOTHAVILLE / KGOTSONG	35,000
Total			**148,050**
Rhenoster key area			
C70A	FS	PETRUS STEYN / MAMAFUEDU	8,950
C70C	FS	HEILBRON / PHIRITONA	18,850
C70D	FS	EDENVILLE / NQWATHE	4,350
C70F	FS	KOPPIES / KWAKWATSI	9,550
C70K	FS	VILJOENSKROON / RAMMULOTSI	20,650
Total			**62,350**
Urban population for Rhenoster-Vals:			**210,400**
Total urban population - Middle Vaal			**1,114,900**
Urban population - North West Province			**405,950**
Urban population - Free State Province			**708,950**

APPENDIX A.2

RURAL POPULATION DATA

Appendix A.2 RURAL POPULATION				
Quaternary catchment	**Rural population**	**Net per capita consumption [l / c / day]**	**Consumptive use**	**Comment**
Vaal River key area				
C24A	9,069	25	1	
C24B	30,550	25	1	
C24H	2,920	25	1	
C24J	11,370	25	1	
C25A	3,894	25	1	
C25B	24,370	25	1	
C25C	7,324	25	1	
	89,497			
Rural requirement (MCM /annum):			**0.82**	**NW and FS**
Johan Neser key area:				
C24C	4,157	25	1	
C24D	3,681	25	1	
C24E	7,224	25	1	
C24F	12,560	25	1	
C24G	4,293	25	1	
Total:	**31,915**			
Rural requirement (MCM /annum):			**0.29**	**All in NW**
Upstream Bloemhof Dam key area:				
C25D	6,093	25	1	
C25E	7,011	25	1	
C25F	8,857	25	1	
Total:	**21,961**			
Rural requirement (MCM /annum):			**0.20**	**FS and NW**
Rural population - Vaal River area			**143,373**	
Rural requirement - Vaal River area			**1.31**	**FS and NW**
Upstream Erefenis Dam key area:				
C41A	5,554	25	1	
C41B	2,597	25	1	
C41C	4,319	25	1	
C41D	5,129	25	1	
C41E	809	25	1	
Total:	**18,408**			
Rural requirement (MCM /annum):			**0.17**	**All in FS**
Upstream Allemanskraal Dam key area:				
C42A	3,024	25	1	
C42B	3,719	25	1	
C42C	3,323	25	1	
C42D	2,593	25	1	
C42E	4,058	25	1	
Total:	**16,717**			
Rural requirement (MCM /annum):			**0.15**	**All in FS**
Vet key area:				
C41F	1,445	25	1	
C41G	578	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
C41H	1,883	25	1	
C41J	2,815	25	1	
C42F	1,908	25	1	
C42G	1,764	25	1	
C42H	7,376	25	1	
C42J	47,890	25	1	
C42K	19,690	25	1	
C42L	5,563	25	1	
C43A	6,967	25	1	
C43B	29,350	25	1	
C43C	4,075	25	1	
C43D	5,391	25	1	
Total:	**136,695**			
Rural requirement (MCM /annum):			**1.25**	**All in FS**
Rural population - Sand-Vet area:			**171,821**	
Rural requirement - Sand-Vet area:			**1.57**	**All in FS**
Vals key area:				
C60A	4,807	25	1	
C60B	4,185	25	1	
C60C	3,118	25	1	
C60D	4,354	25	1	
C60E	3,215	25	1	
C60F	3,463	25	1	
C60G	4,346	25	1	
C60H	7,749	25	1	
C60J	5,915	25	1	
Total:	**41,152**			
Rural requirement (MCM /annum):			**0.38**	**All in FS**
Rhenoster key area:				
C70A	2,395	25	1	
C70B	2,658	25	1	
C70C	4,658	25	1	
C70D	4,210	25	1	
C70E	2,650	25	1	
C70F	3,577	25	1	
C70G	5,126	25	1	
C70H	1,363	25	1	
C70J	3,034	25	1	
C70K	8,185	25	1	
Total:	**37,856**			
Rural requirement (MCM /annum):			**0.35**	**All in FS**
Rural population - Vals - Rhenoster area:			**79,008.00**	
Rural requirement - Vals - Rhenoster area:			**0.72**	**All in FS**
Total Rural population - Middle Vaal WMA			**394,201.50**	
Rural population - Free State Province			**310,263.00**	
Rural population - North West Province			**83,939.00**	
Total Rural Requirment - Middle Vaal WMA			**3.60**	
Rural Requirment - Free State Province			**2.83**	
Rural Requirment - North West Province			**0.77**	

APPENDIX B: MACRO ECONOMICS

Comprising:

APPENDICES

SUPPLEMENTARY ECONOMIC INFORMATION

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	➾ Contribution by Magisterial District to Berg 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.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.3	➾ Composition of Berg 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.4	➾ Contribution by Sector to Berg Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	➾ Contribution by Sectors of Berg 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.6	➾ Compound Annual Employment Growth by Sector of Berg versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
	• **Shift-Share**:	
B.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).

Figure B.1: Contribution by Magisterial District to Middle Vaal economy, 1997 (%)

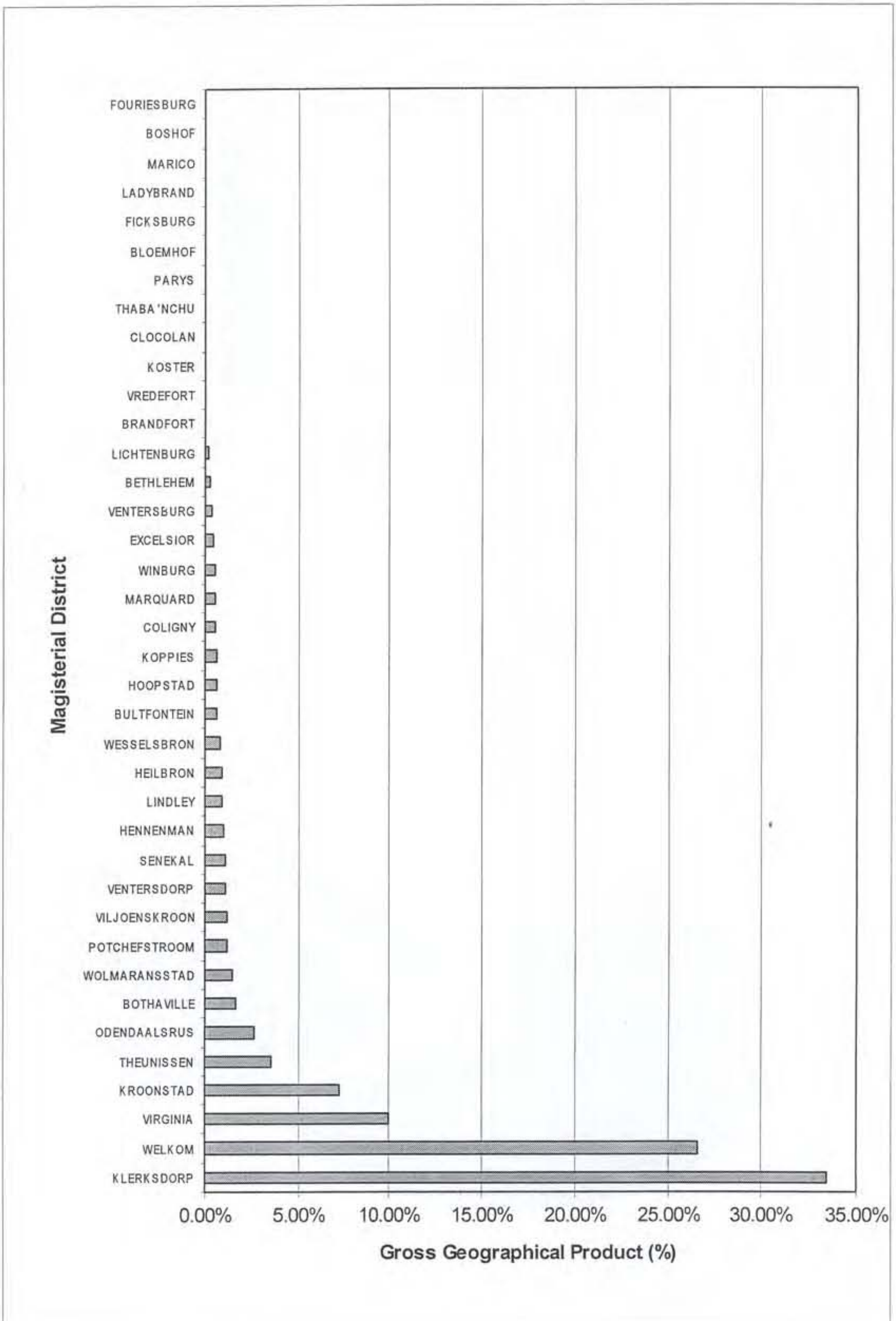


Figure B.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

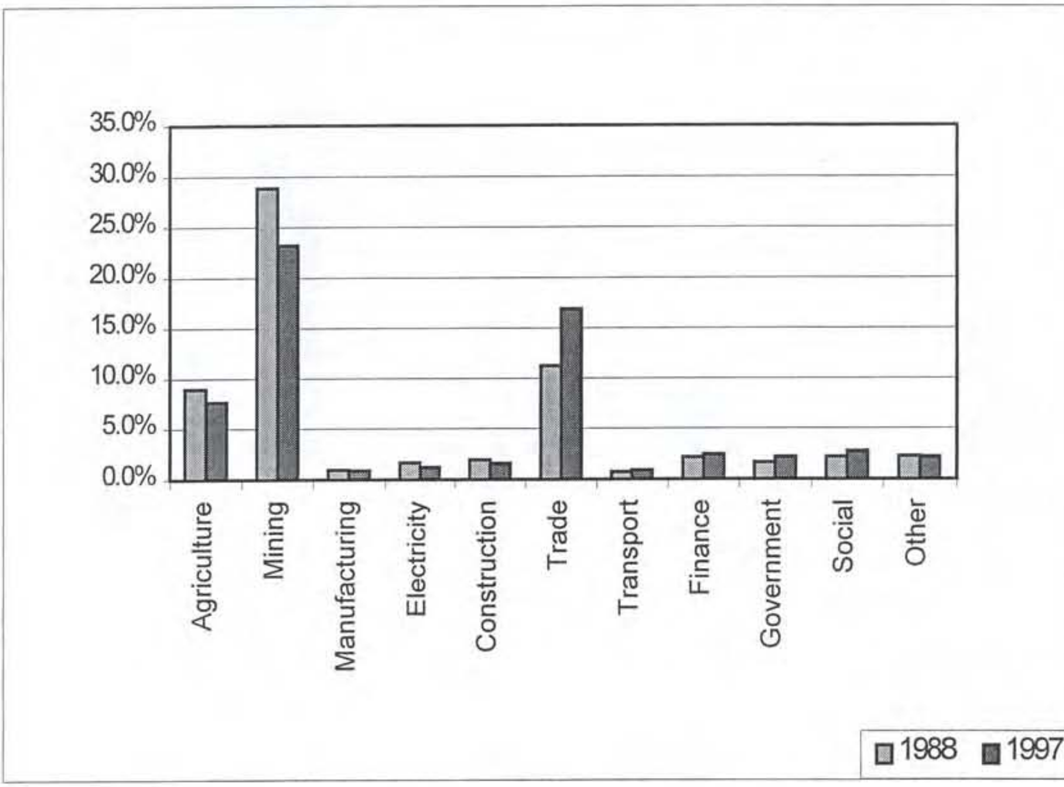


Figure B.3: Composition of Middle Vaal Labour Force, 1994 (%)

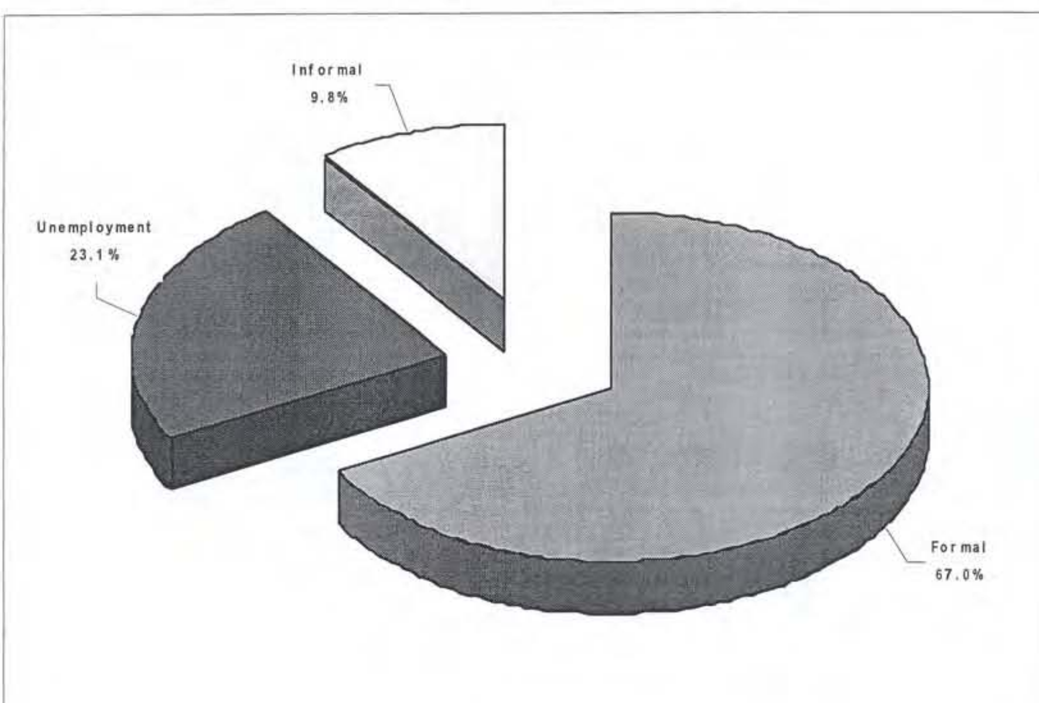


Figure B.4: Contribution by Sector to Middle Vaal employment, 1980 and 1994(%)

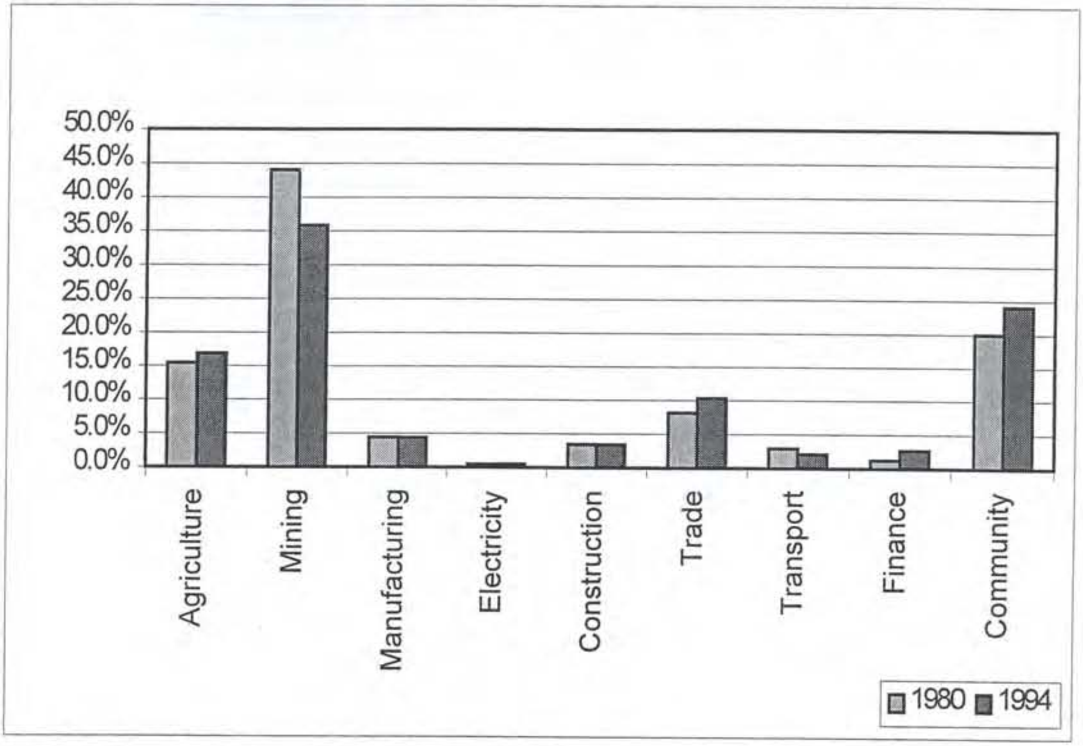


Figure B.5 Contribution by Sectors of Middle Vaal Employment to National Sectoral Employment, 1980
and 1994 (%)

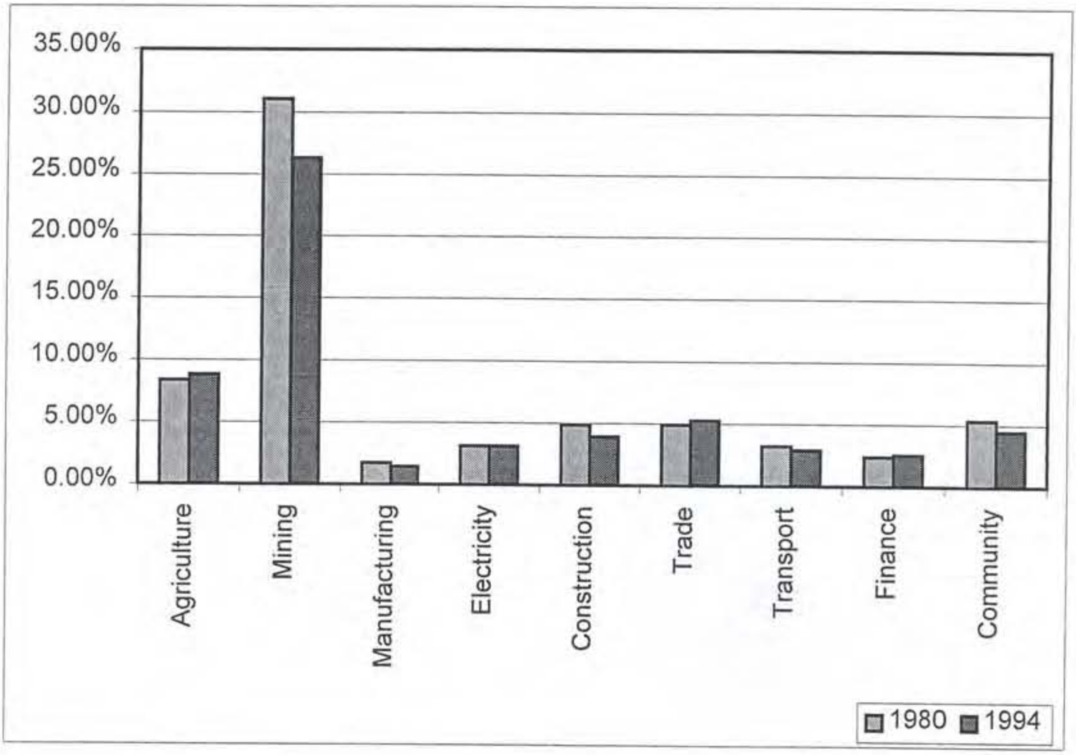


Figure B.6: Average Annual Employment Growth by Sector of Middle Vaal versus South Africa, 1980 to 1994 (%)

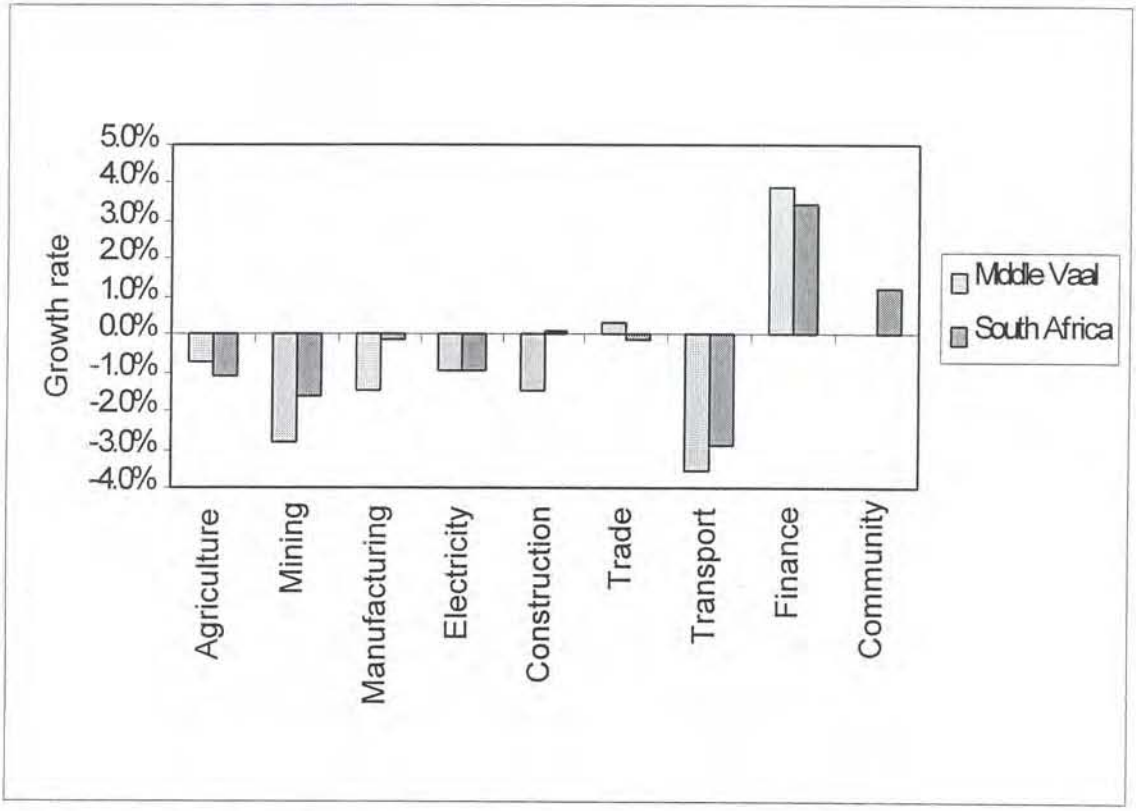
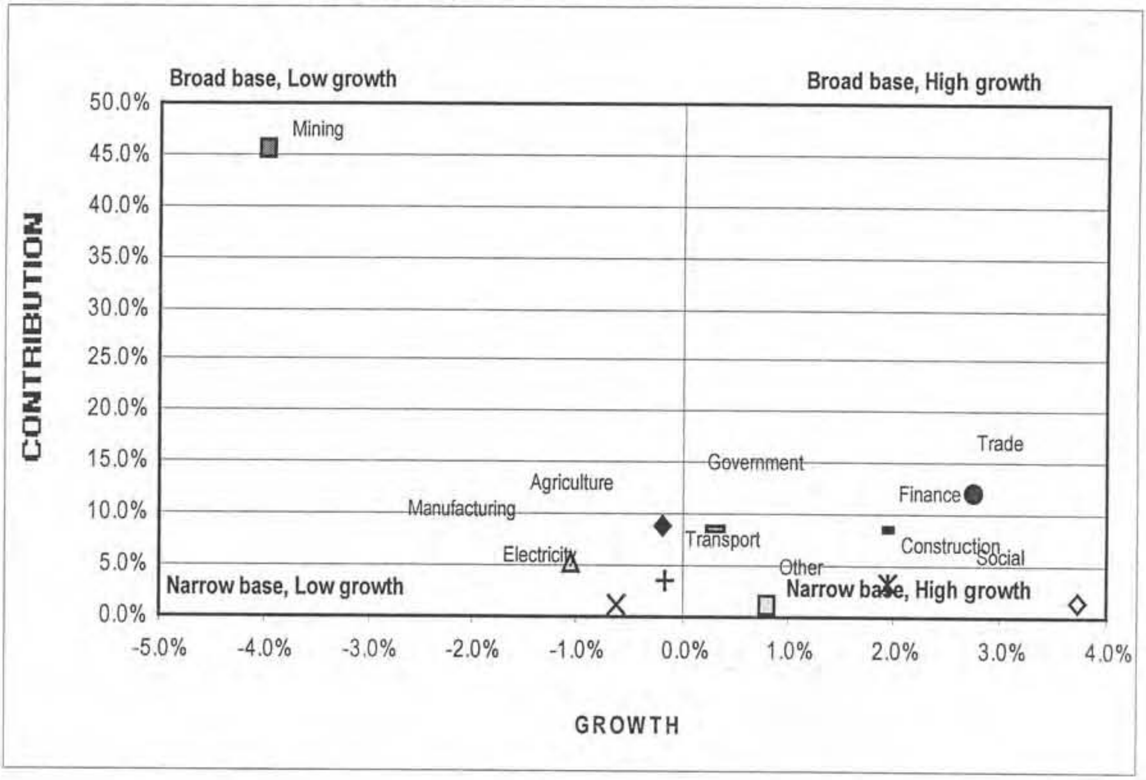


Figure B.7: Shift-Share analysis (%)



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B.1 INTRODUCTION

The purpose of this section 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.

B.2 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL ECONOMY

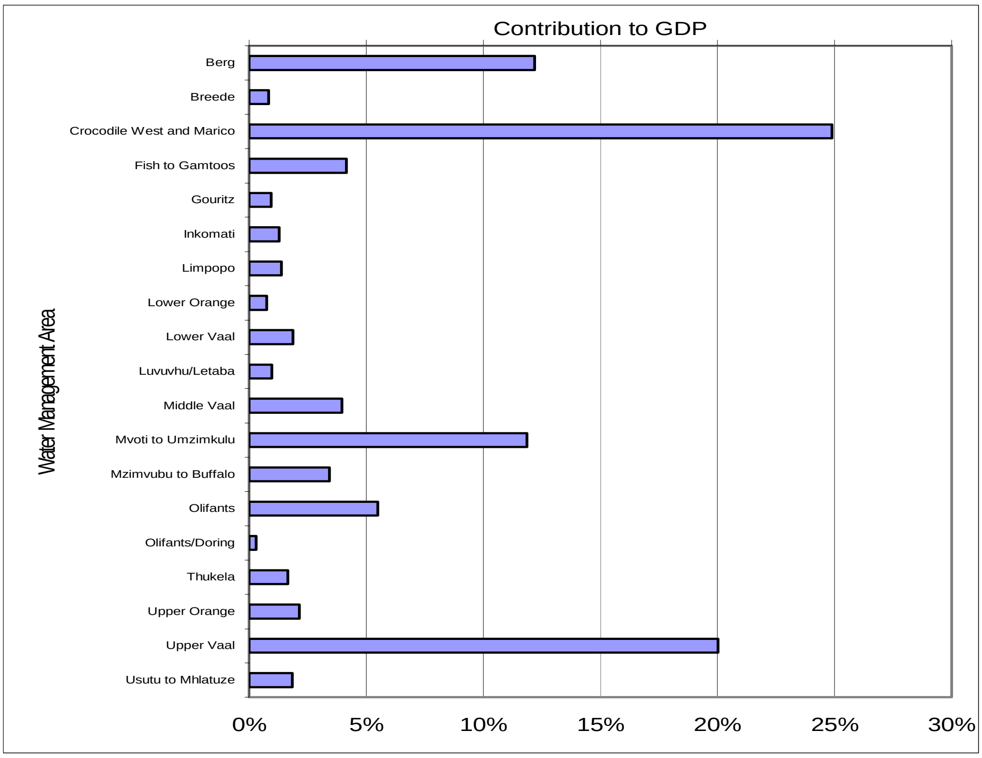
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- 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.

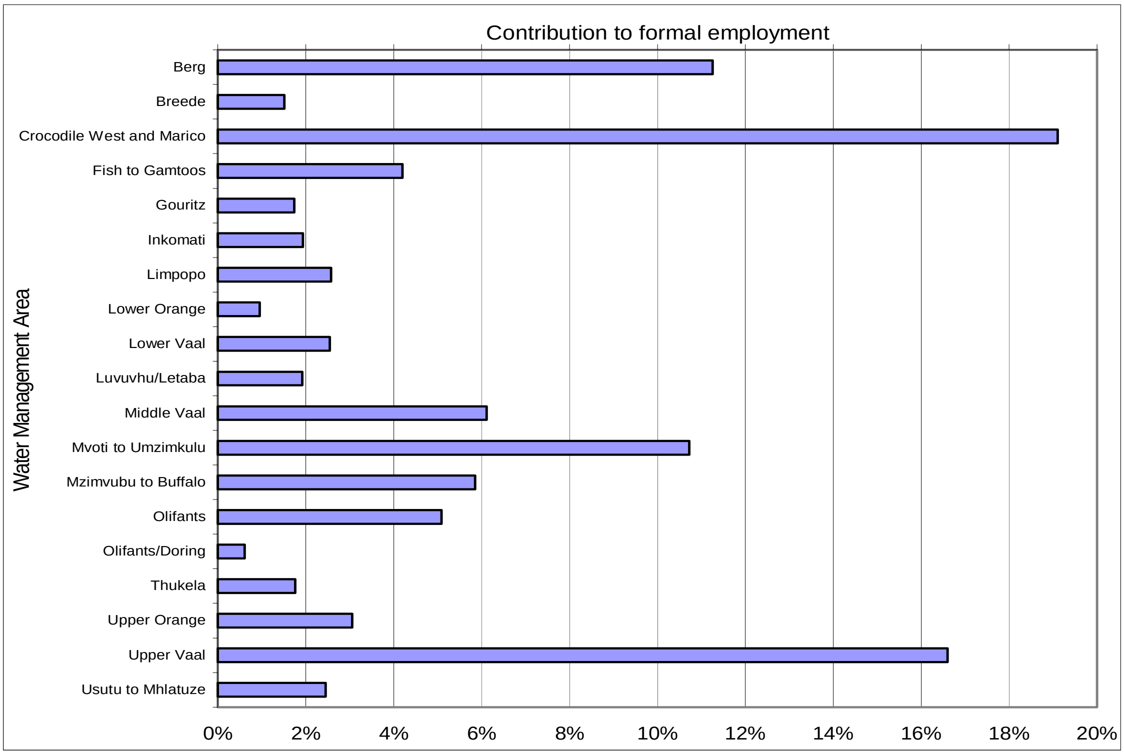
Figure B.1: Total GGP by Water Management Area (% of Country)



B.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.

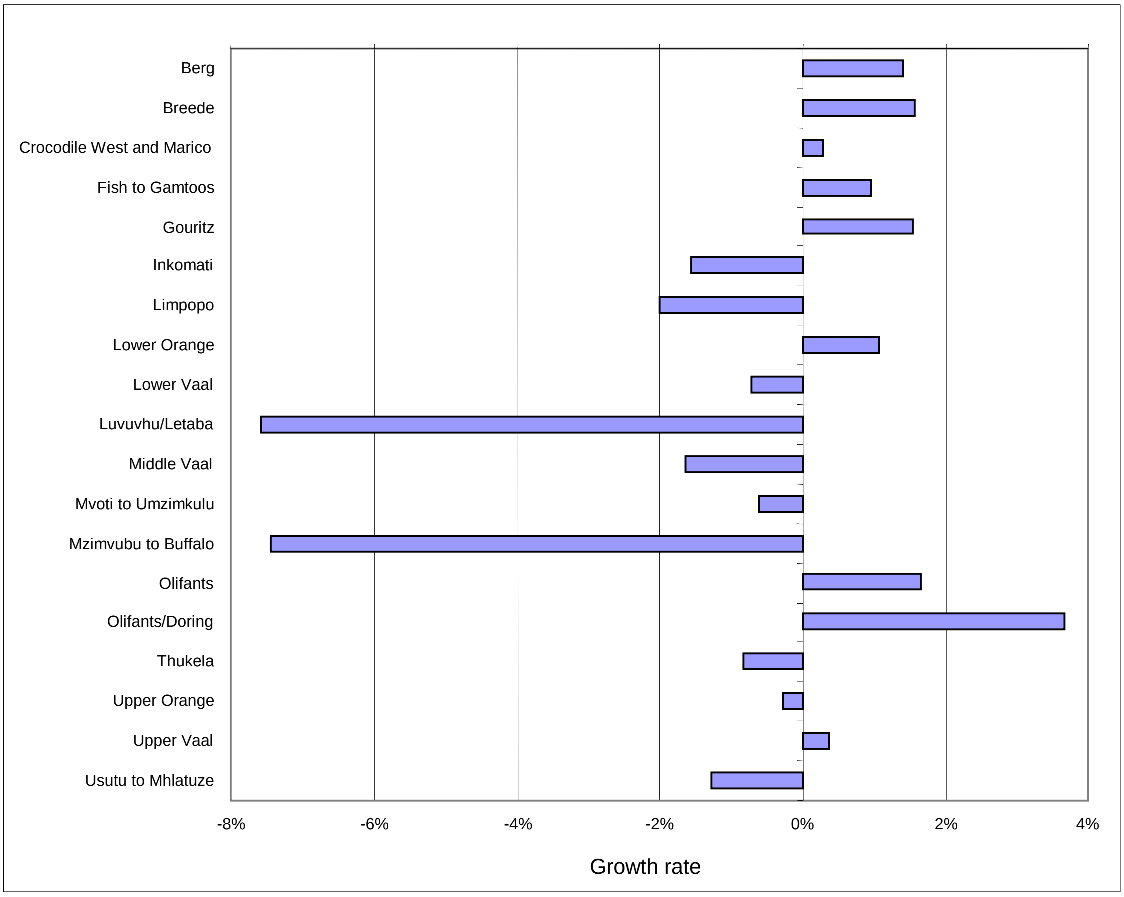
Figure B.2: Formal Employment by Water Management Area (% of country)



B.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.

Figure B.3: Average Annual Economic Growth by Water Management Area, 1988-1997 (%)



APPENDIX B.3
ECONOMIC SECTOR DESCRIPTION

ECONOMIC SECTOR DESCRIPTION

- **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 fertilizer, 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 B.4
ECONOMIC INFORMATION SYSTEM

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**
- **No framework of reference 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.

Urban-Econ collected existing data from a range of secondary sources. The following data were combined in a single database which can be queried spatially, thematically and temporally *via* a user-friendly computer interface.

Diagram 1 depicts the economic information system in a flow chart format. It is possible to display the data in:
- Tables
- Graphs

- Thematic maps (this provides a better perspective of the spatial context and significance of other spatial features relevant to the data.

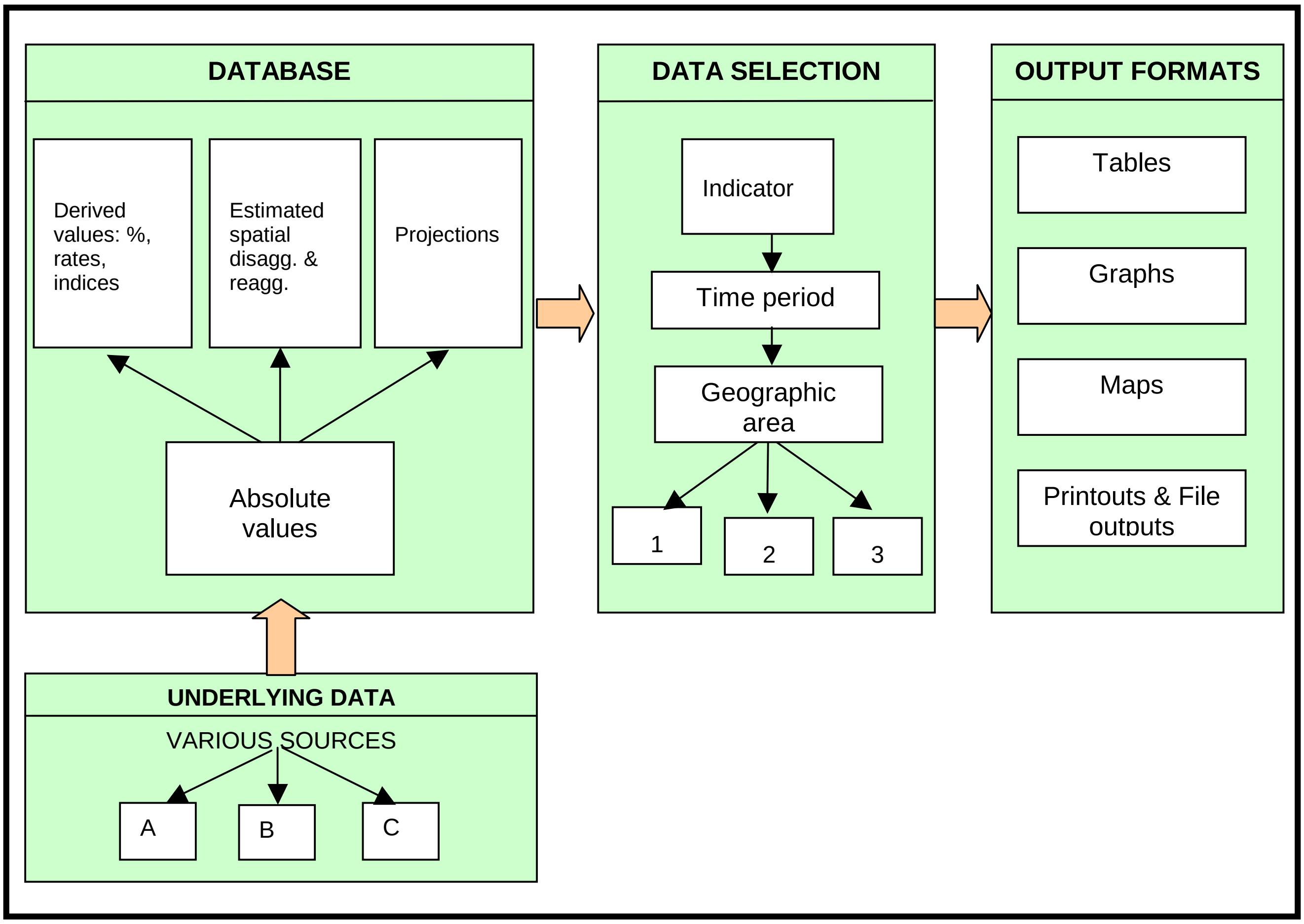
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service council area
Electricity connections	Economic sectors, domestic	1988-1997	Local authority area, service council area
Remuneration*	Economic sectors	1993-1998	Magisterial districts
Turnover*	Economic sectors	1993-1998	Magisterial districts
Number of firms*	Economic sectors	1992-1998	Magisterial districts
Tax revenue	Company, Personal, VAT	1992-1997	Tax office area
Buildings completed	Residential, office, shops, industrial	1991-1996	Local authority area, service council area
Telephone connections	Business, residence	1998 1976-1997	Magisterial district Province
Vehicle sales	Commercial, passenger	1980-1997	Towns

* Figures complete for totals, but incomplete for economic sectors

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.

Diagram 1: Overview of Economic Information System



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 C: LEGAL ASPECTS

Comprising:

APPENDIX C.1

DAM SAFETY DATABASE
(Example of section 9 and 13 permits)

	Section 9b authorisations grant permission to farmers to build dams >250 000 m^3 or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity (x10^{3}m^3)**	**Dam used for**	**Permit No.**	**Permit Conditions**
28	12/2/C231-43	DWARSFONTEIN	KOSTER	MOOI RIVER/RIVIER TR.	230	IRRIGATION		
29	12/2/C241-33	BEATRIX	KLERKSDORP	KOEKEMOER SPRUIT	200	IRRIGATION		
30	12/2/C241-34	BUFFELDOORN	KLERKSDORP	KOEKEMOER SPRUIT TR.	473	IRRIGATION		
31	12/2/C242-31	KLEINPLAAS DAM (WILKENS)	KLERKSDORP	SCHOON SPRUIT	1400	IRRIGATION		
32	12/2/C243-10	SYFERFONTEIN	KLERKSDORP	RENOSTERSPRUIT	223	IRRIGATION		
33	12/2/C400-08	MUSHROOM VALLEY	WINBURG	SAND SPRUIT	2750	IRRIGATION		
34	12/2/C401-34	BAROLONG	EXCELSIOR	LENANA SPRUIT TR.	4950	IRRIGATION		
35	12/2/C401-36	EDEN	EXCELSIOR	-	225	IRRIGATION		
36	12/2/C402-39	ORLANDO	MARQUARD	-	250	IRRIGATION		
37	12/2/C404-AT	WINDHOEK	WINBURG	MASELSPRUIT	330	IRRIGATION		
38	12/2/C405-34	CHARLOTTA	THEUNISSEN	BOSSIE SPRUIT	750	IRRIGATION		
58	12/2/C601-20	DAMFONTEIN	KROONSTAD	RANDJIES RIVER/RIVIER TR.	240	IRRIGATION		
59	12/2/C602-18	LERNA	KROONSTAD	BLOM SPRUIT	300	IRRIGATION		
60	12/2/C702-16	BANKIES	KROONSTAD	RIET SPRUIT	220	IRRIGATION		
61	12/2/C702-17	ESPERANZA	VREDEFORT	RIET SPRUIT TR.	420	IRRIGATION		
62	12/2/C702-18	VLIEGENKRAAL	VREDEFORT	-	1290	IRRIGATION		

Section 13 authorisations: Permission to municipalitities or local councils to build dams >125 000m^3 or for abstractions or diversions > 5 000 m^3/day.

	DWAF No:	Dam Name	Magisterial District	RIVER	Gross capacity (10^6m^3)	Dam used for	Permit No.	Permit conditions
41	12/2/C240-05	JOHAN NESER DAM (KLERKSDORP DAM)	KLERKSDORP	SCHOON SPRUIT	5671	IRRIGATION		
42	12/2/C301-24	DAUTH ROODE	LICHTENBURG	VLEI-HARTS RIVER/RIVIER	297	RECREATIONAL USE		
43	12/2/C301-25	EEUFEES	LICHTENBURG	VLEI - HARTS RIVER/RIVIER	440	RECREATIONAL USE		
44	12/2/C400-04	CYFERFONTEIN	PAUL ROUX	SAND RIVER/RIVIER	1065	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
45	12/2/C400-07	MARQUARD	MARQUARD	LAAI SPRUIT	515	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
46	12/2/C400-13	VIRGINIA	VIRGINIA	SAND RIVER/RIVIER	2062	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
47	12/2/C402-34	MARQUARD BUITERIVIER-OPGAAR	MARQUARD	LAAI SPRUIT TR.	520	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
48	12/2/C402-37	WOLWAS	WINBURG	LAAI SPRUIT	607	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
49	12/2/C402-38	RIETFONTEIN	WINBURG	LAAI SPRUIT	200	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
50	12/2/C403-35	DE PUT GROND	PAUL ROUX	SAND SPRUIT	1156	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
51	12/2/C403-37	CYFERFONTEIN-GRYP	PAUL ROUX	SAND RIVER/RIVIER TR.	1000	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
59	12/2/C600-05	GROBLERS	KROONSTAD	VALS RIVER/RIVIER	680	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
60	12/2/C600-06	STRYDOM	KROONSTAD	VALS RIVER/RIVIER	360	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
61	12/2/C600-15	SERFONTEIN	KROONSTAD	VALS RIVER/RIVIER	4200	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
62	12/2/C601-01	BLOEMHOEK	KROONSTAD	JORDAAN SPRUIT	26188	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
63	12/2/C601-18	PIEKNIEKDRAAI	PETRUS STEYN	VALS RIVER/RIVIER	220	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		
64	12/2/C700-06	UNIEFEES DAM (LANGDAM)	HEILBRON	ELAND SPRUIT	1350	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE		

Section 13 authorisations grant permission to industry to build dams >150 000 m^3 or for abstractions > 150m^3/day.							
DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity** (x $10^6 m^3$)	**Dam used for**	**Permit No.**	**Permit Conditions**
12/2/C241-24	KEIR & CAWDER WASTE ROCK DUMP	KLERKSDORP	-	1581	UITSKOTDAM		
12/2/C241-35	EAST STORM	KLERKSDORP	VAAL RIVER/RIVIER TR.	190	INLIGTING ONBREEK		
12/2/C404-80	FREEGOLD NEW RETURN WATER	VIRGINIA	-	780	BESOEDELINGSBEHEER		
12/2/C600-07	ARLINGTON	PETRUS STEYN	HAMMAN SPRUIT	501	INLIGTING ONBREEK		
12/2/C601-17	NAUDESKOP	BETHLEHEM	LEEUW SPRUIT & VALS RIVER/RIVIER	114	WATERVOORSIENING VIR MUNISIPALE EN/OF NYWERHEIDSGEBRUIK		

APPENDIX C.2

PCPOLMAN DATABASE (Example of permits)

Data from PCPOLMAN database (DWAF, Water Quality Section)

SOME ABSTRACTION AND DISCHARGE PERMITS

		Permit no	File no	Name	Drainage region	PERMIT STATUS	QUAT (FLOW TIPE)	FLOW	ABS/DISCHARGE	Annual abs/disc TOTAL FLOW(m^3)	TIME
1000	B	1000B	B33/2/340/45	Rosendal Municipality	Central Province (Free State)	0	C400/09/N001	FLOW	D	12400	N
1046	B	1046B	B33/2/340/28	Loraine Gold Mines Ltd	Central Province (Free State)	0	C251/00/S001	FLOW	E	0	D
1057	N	1057N	B33/2/340/45	Senekal:Midde-Vrystaatse Suiwelkooperasie Beperk	Central Province (Free State)	0	C400/09/D002	FLOW	A	215000	D
1117	B	1117B	B33/2/340/6	Municipality Of Ondedaalsrus	Central Province (Free State)	0	C250/22/L001	FLOW	E	0	D
1119	N	1119N	B33/2/340/111	Corobrick Free State (Pty) Limited	Central Province (Free State)	0	C251/00/H802	FLOW	A	77100	D
1214	N	1214N	B33/2/340/12	Free State Consolidated Gold (Welkom) Operations	Central Province (Free State)	0	C250/22/D002	FLOW	A	0	D
1214	N	1214N	B33/2/340/12	Free State Consolidated Gold (Welkom) Operations	Central Province (Free State)	0	C400/21/B011	FLOW	A	0	D
1232	B	1232B	B33/2/340/67	Allanridge Village Board Of Management	Central Province (Free State)	0	C250/23/S001	FLOW	E	1284800	D
1232	B	1232B	B33/2/340/67	Allanridge Village Board Of Management	Central Province (Free State)	0	C251/00/L001	FLOW	D	1284800	N
1339	N	1339N	B33/2/340/116	Johannesburg Consolidated Investment Company Ltd	Central Province (Free State)	0	C400/21/B011	FLOW	A	1220925	D
1433	N	1433N	B33/2/340/086	Oryx Mine,Theunissen	Central Province (Free State)	0	C400/21/B011	FLOW	E	1584100	D
201	B	201 B	B33/2/340/10	Municipality Of Virginia	Central Province (Free State)	0	C400/20/E005	FLOW	D	3068800	N
249	B	249 B	B33/2/340/21	Stadsraad Van Welkom	Central Province (Free State)	0	C400/21/E002	FLOW	E	0	D
478	N	478 N	B33/2/340/70	Unisel Gold Mines Limited	Central Province (Free State)	0	C400/21/B011	FLOW	A	627000	D
674	N	674 N	B33/15/9/3	Southern OFS Development Board : Welkom	Central Province (Free State)	0	C400/21/D004	FLOW	A	195000	D
674	N	674 N	B33/15/9/3	Southern OFS Development Board : Welkom	Central Province (Free State)	0	C400/21/F004	FLOW	A	195000	D
689	N	689 N	B33/2/340/86	Beisa Mines Limited: Gold and Urinum Mine	Central Province (Free State)	0	C400/21/B011	FLOW	A	3650000	D
718	N	718 N	B33/2/340/32	St Helena Gold Mines Limited	Central Province (Free State)	0	C400/21/B011	FLOW	A	2665000	D
776	N	776 N	B33/2/340/95	Beatrix Mine	Central Province (Free State)	0	C400/21/B011	FLOW	A	2494000	D
789	N	789 N	B33/2/340/28	Loraine Gold Mines Ltd	Central Province (Free State)	0	C400/21/B011	FLOW	A	5475000	D
827	N	827 N	B33/2/330/23	Nasionale Suiwelkooperasie Beperk:Wesselsbron	Central Province (Free State)	0	C250/27/D006	FLOW	A	140000	D
858	N	858 N	B33/2/340/97	Suncrush Limited: Welkom	Central Province (Free State)	0	C400/21/D004	FLOW	A	130000	D
866	B	866 B	B33/2/330/23	Nasionale Suiwelkooperasie Beperk:Wesselsbron	Central Province (Free State)	0	C250/27/L005	FLOW	D	160000	N
884	N	884 N	33/2/340/11	Escom (Vierfontein)	Central Province (Free State)	0	C241/00/A001	FLOW	A	8578000	D
889	N	889 N	B33/2/340/98	Dairy Belle Corporation (Pty) Ltd (Welkom)	Central Province (Free State)	0	C400/21/D004	FLOW	A	96000	D
924	B	924 B	B33/2/340/68	Hennenman-Municipality	Central Province (Free State)	0	C400/17/L001	FLOW	Q	100000	D
958	N	958 N	B33/2/340/83	Okk Foods (Pty) Ltd	Central Province (Free State)	0	C400/21/D004	FLOW	A	228950	D
1117	B					0	C250/22/S001	FLOW	E	1606000	D
1117	B				Central Province (Free State)	0	C251/00/L002	FLOW	D	8000	N
1046	B				Central Province (Free State)	0	C251/00/V801	FLOW	D	1261000	N
248	B					0	C400/21/L002	FLOW	E	0	D
248	B					0	C400/21/L003	FLOW	E	0	D
249	B					0	C400/21/L004	FLOW	E	0	D
248	B					0	C400/21/S001	FLOW	E	10840500	D
249	B					0	C400/21/S002	FLOW	E	11630000	D
250	B					0	C400/21/S003	FLOW	E	111	D

APPENDIX C.3

Section 56/3 permits

ABSTRACTIONS FROM VAAL GWS

Data checked by Mrs K Broere, DWAF, GWS, Room 631 (Sedibeng)

Permit Type	River	Quat	Source	User	Allocation Number	Amount (m^3/annum)		Sector	Date issued	Source of data
MIDDLE VAAL WMA										
Section 56 (3)	**Vaal**	**C24B**	**Vaal GWS - Vaal River**	**Midvaal (Western Transvaal Regional)**	**97/16/2/77**	**86870000**	**Water board**	**Res/Ind/Inst.**		**DWAF**
Section 56 (3)	**Vaal**	**C25C**	**Vaal GWS - Vaal River (Balkfontein)**	**Goudveld Water**	**131/11/81**	**125000000**	**Water board**	**Res/Ind/Inst.**	**1/4/1982**	**DWAF**
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Klerksdorp Munisipality	Permit 152	3028264	Mun/ind	Residential	1/8/1957	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Klerksdorp Municipality	91/16/2/80	2200000	Mun/ind	Res / Ind	10/9/1980	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Rhenoster river (Vaal River)	Viljoenskroon Municipality	63/16/2/92	1700000	Mun/ind	Res. / Ind.	7/30/1992	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Orkney Municipality - Holiday Resort	38/16/76	31824	Mun/ind	Recreational	8/2/1976	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Orkney Municipality - Orkney-Vaal Holi	5/16/2/93	60000	Mun/ind	Recreat. / Irr	2/4/1993	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Orkney Municipality - Bird Sanctury	97/16/2/92	5500	Mun/ind	Recreat. + Env.	12/28/1992	DWAF
Section 56 (3)	Vaal Rive	C24J	Vaal GWS - Vaal River (Viljoenskroon)	RA Bottomley	45/16/2/92	2500	Domestic	Domestic		DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	SA Police Resort at Orkney	Agreement 1	5455	Instituition	Residential	2/24/1974	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River (EXPIRED)	Vierfontein Power Station - ESCOM	Agreement	14767900	Instituition	Industry (station clo	8/14/1951	DWAF
Section 56 (3)	Vaal	C25C	Vaal GWS - Vaal River	General Mining Union Corp.	176/16/2/86	2816000	Instituition	Ind. / dom.	11/28/1986	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River	Vaal Reefs Expl. & Mining Co.	35/16/2/88	10694075	Mine	Ind. - Mining	3/9/1988	DWAF
Section 56 (3)	Vaal	C24H	Vaal GWS - Schoonspruit	Vaal Reefs Expl. & Mining Co.	105/16/2/81	48000	Mine	Ind. - Mining	7/1/1981	DWAF
Section 56 (3)	Vaal	C24J	Vaal GWS - Vaal River (Bothaville)	Roux & Sons Diamond Mining	19/16/2/91	15000	Mine	Mining	4/3/1991	DWAF
Section 56 (3)	Vaal	C25C	Vaal GWS - Vaal River (Bloemhof)	MJ van Staden & CNG van Vuuren	112/16/2/83	3500	Mine	Mining	9/30/1983	DWAF
Section 56 (3)	Vaal	C25C	Vaal GWS - Vaal River (Bloemhof)	IP van Heerden	46/16/2/87	25920	Mine	Mining - Ind.	4/1/1987	DWAF
Section 56 (3)	Vaal	C24B	Vaal GWS - Vaal River (Viljoenskroon)	Vierfontein Developers	23/16/2/93	700000	Mun/ind	For construction - ex	3/22/1993	DWAF
Section 56 (3)	Vaal	C24J	Vaal GWS - Vaal River (Viljoenskroon)	Viljoen and Myburgh Transport	14/16/2/82	264000	Mun/ind	Industry	3/8/1982	DWAF
Section 56 (3)	Vaal	C24J	Vaal GWS - Vaal River (Bothaville)	JJE Olchers	31/16/83	97920	Mun/ind	Industry	2/18/1983	DWAF
Section 56 (3)	Vaal	C24J	Vaal GWS - Vaal River (Bothaville)	BJM Bekker	13/16/2/97	36500	Mun/ind	Industry	5/12/1997	DWAF
Section 56 (3)	Vaal	C25C	Vaal GWS - Vaal River (Wolmaransstad)	PA Swanepoel	48/16/2/88	12000	Mun/ind	Ind. - Feedlot	2/2/1988	DWAF
Section 56 (3)*						**248384358**				

Note: **Formerly Section 6 of the Vaal River Development Scheme, 34 (Act 38 of 1934)**

Permit Type	River	Quaternary Catchment	Source of allocation	User	Permit No.	Amount (m^3/annum)	Sector
Section 56 (3)	**Sand River**	**C42E**	**Sand-Vet GWS - Allemanskraal Dar**	**Goldfields Water - Virginia Purification V**	**12/23/1980**	**12800000**	**Institutional**
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	Bultfontein municipality	Agreement	1818440	mun
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	Theunissen municipality	?	546000	mun
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	Brandfort municipality	Agreement	1818440	mun
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	Hoopstad municipality	Agreement	312000	mun
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	FS Nature Conservation - Winburg district	12/20/1994	50000	Institutional
Section 56 (3)	Sand River	?	Sand-Vet GWS - Sand Canal system	FS Provincial - Bultfontein	12/1/1995	2000	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	SA Railways - Virginia	12/1/1978	8676	Industrial
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Dept: Correctional Services (Virginia)	12/23/1982	321120	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Dept: Agric. Techncial Services (Virginia)	?	321000	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Escom: Welkom	92/12/85	1560	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Oryx Mines Ltd (Beisa)	12/1/1979	2400000	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Harmony Gold Mines[Section 11/12 permit	115/12/76	1200000	mine
Section 56 (3)	Sand - Vet Canal		Sand-Vet GWS	RUC Minings	50/12/89	2000	mine
Section 56 (3)	Sand - Vet Canal		Sand-Vet GWS	Nelsdrift Primary School	71/12/76	6720	Institutional
Section 56 (3)	Sand River	C42E	Sand-Vet GWS - Allemanskraal Dam	Willem Pretorius Wildtuin	Agreement	365051	Institutional
Section 56 (3)	Sand River		Sand-Vet GWS - Sand River	Goldfields Resorts (Pty) Ltd	12/5/1997	130550	Institutional
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	Goldfields Cementation	55/12/80	5000	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	Boart Drilling	70/12/80	7200	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	Boart Drilling	127/12/83	8554	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	Boart Drilling	104/12/84	10080	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	General Drilling Co.	137/12/81	4200	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	Uni Drilling Ltd	12/1/1993	10950	Industrial
Section 56 (3)	Sand River		Sand-Vet GWS - Sand Canal system	African Selection Trust Exploration	113/12/81	350	Mun
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Vet River	AS Meintjies	Agreement	4148	Dom + stock
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	VS Kotze	Agreement	4704	Dom + stock
Section 56 (3)	Vet River	C41E	Sand-Vet GWS - Erfenis Dam	A Appel	112/12/85	160560	Dom + stock
Section 56 (3)	Vet River		Sand-Vet GWS - Vet River	JH Slabbert	174/12/86	4300	Dom + stock
Section 56 (3)	Vet River		Sand-Vet GWS - Vet River	GS Nieuwoudt	91/12/92	4300	Dom + stock
Section 56 (3)	Sand River	C42C	Cyferfontein Dam	Senekal Municipality	?	?	Recreational?
Section 56 (3)	Sand River	C42B	De Put Buiteloop Storage Dam	Senekal Municipality	?	?	Residential?
BREAKDOWN OF GOLDFIELDS WATER ALLOCATIONS (origin of abstraction the Vaal River / Sand Rivers)							

Permit Type	River	Quaternary Catchment	Source of allocation	User	Permit No.	Amount (m^3/annum)	Sector
Total Goldfields Water allocations are: Sand River (12.8x10^{6}m^3) + Vaal River (125.0x10^{6}m^3) = 137.8x10^{6}m^3/annum							
Note:	**Most of the water supplied by Goldfields Water Originates from Vaal River (Balkfontein)**						
Section 56 (3)				PHS Bezuidenhout (house / stock watering)	61/22/78	1660	Domestic
Section 56 (3)				Boart Drilling	81/22/78	33190	Industrial
Section 56 (3)				Tvl. Provicial Admin. - Roads Division	85/22/78	730	Institution
Section 56 (3)			?	West Tvl Bantu Admin. - Wolmaranstad	69/22/78	54750	Institution
Section 56 (3)			?	West Tvl Bantu Admin. - Leeudoringstad	70/22/78	18250	Institution
Section 56 (3)				FS Provincial Admin. - Thabong Township	85/22/79	48000	Institution
Section 56 (3)				Harmony Gold Mining Co.	64/22/78	[1825000]	Mine
Section 56 (3)				Harmony Gold Mining Co.	65/22/78	[5475000]	Mine
Section 56 (3)				Harmony Gold Mining Co.	66/22/78	[4599000]	Mine
Section 56 (3)				Harmony Gold Mining Co.	67/22/78	[5110000]	Mine
Section 11/12:				**Harmony Gold Mining Co.**	**Permit 575N**	**19582250**	Mine
Section 56 (3)				FS Geduld Mines (shafts 3,5)	62/22/78	[6935000]	Mine
Section 56 (3)				FS Geduld Mines (shafts 4)	15/22/80	[730000]	Mine
Section 56 (3)				FS Saaiplaas Mines (shaft 4)	62/22/78	[4106250]	Mine
Section 56 (3)				Western Holdings (Shaft 3)	72/22/78	[2737500]	Mine
Section 56 (3)				President Brand Gold Mining Co. (Shaft 1)	73/22/78	[2190000]	Mine
Section 56 (3)				President Steyn Gold Mining Co.	84/22/78	[36500]	Mine
Section 11/12:			**Industrial Abstractions**	**Free Gold (North & South)**	**Permit 1214N**	**36736525**	Mine
Section 56 (3)				St Helena Gold Mines	71/22/78	[438000]	Mine
Section 11/12:			**Industrial Abstractions**	**St Helena Gold Mines**	**Permit 718N**	**2662675**	Mine
Section 11/12:			**Industrial Abstractions**	**Unisel Gold Mine**	**Permit 478N**	**1810400**	Mine
Section 11/12:			**Industrial Abstractions**	**HJ Joel Gold Mine**	**Permit 1339N**	**1220195**	Mine
Section 11/12:			**Industrial Abstractions**	**Beatrix Gold Mine**	**Permit 776N**	**2492220**	Mine
Section 11/12:			**Industrial Abstractions**	**Oryx Gold Mine**	**Permit 1433N**	**1584100**	Mine
Section 56 (3)				Welkom Municipality	88/22/78	8650500	Mun/Ind
Section 56 (3)				Welkom Municipality	80/22/79	713000	Mun/Ind
Total :						**75608445**	
(source of information: Lower Vet River Water Quality S.A - WRC rep.)							
Allocations listed for Rhenoster GWS							
Note:	**/34/ reference number for allocations from Koppies and Roodepoort Dams**						
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Koppies Dam + rive	Koppies Municipality	4/34/94	860000	Mun/Ind
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Koppies Dam	FS Provincial Administration - Resort	11/34/92	80000	Institutional
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Koppies Dam	JWJ van der Merwe	296/34/77	15872	Dom. / agric.
Section 56 (3)	Rhenoster River	**?**	Rhenoster GWS - From river	JJ van Schalkwyk	123/34/78	4200	Dom. / agric.

Permit Type	River	Quaternary Catchment	Source of allocation	User	Permit No.	Amount (m^3/annum)	Sector
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Koppies Dam	CW Zitske	68/34/79	8000	Dom. / agric.
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Koppies Dam	VE Zitske	69/34/79	5000	Dom. / agric.
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Northern Canal of K	JA du Toit	92/34/80	16320	Dom. / agric.
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Northern Canal of K	RE Grobbelaar	102/34/84	6000	Dom. / agric.
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Northern Canal of K	SCF du Plessis	142/34/85	6100	Dom. / agric.
Section 56 (3)	Rhenoster River	**C70C**	Rhenoster GWS - Northern Canal of K	GS du Toit	S1/34/90	1000	Dom. / agric.
Total:						**158102492**	

APPENDIX D: LAND USE DATA

Comprising:

Appendix D.1 Irrigation land use

Appendix D.2 Urban area

APPENDIX D.1

IRRIGATION LAND USE DATA

(Summary data and quaternary catchment data)

(Crop area data from WSAM, Irrigation sub-model)

WMA 9: MIDDLE VAAL WMA

WMA 8: UPPER VAAL WMA	Total harvested area	Total Green area	GUIDELINE QUOTA	CALCULATE CROP WATER USE - 1995	TOTAL WATER REQUIREMENT (SAPWAT)	TOTAL WATER REQUIREMENT FOR 1995	GUIDELINE QUOTA REQ.	TOTAL ACTUAL WATER REQUIREMENT AT 1:50 YR ASSURANCE	RETURN FLOW AT 1:50 YR ASS
	Crop area data:		Quota data:		Gross requirement [est]:				Returns:
	aIHAi+aIMAi+aILAi	aISai	Table 8.2	Table 8.2	oITRo [WSAM]	Tab: 8.2	Tab: 8.2	gIARo	EST. ONLY
	km^2	km^2	$[m^3/ha/a]$	$[m^3/ha/a]$	$[10^6m^3/a]$	$[10^6m^3/a]$	$[10^6m^3/a]$	$[10^6m^3/a]$	%
Ref: Vaal River Irrigation Study	Table: 7.2	Tab: 8.2 & 7.2	Tab: 8.2						
Rhenoster (C70A - K)	28.6	28.6	6100	5924	28.2	16.9	17.5	24.7	0
Vals (C60A - J)	3.4	3.4	6100	5394	1.9	1.8	2.1	1.6	0
Johan Neser (C24C - G)	48.3	44.9	5309/8225	4625/6025	38.2	26.1	35.8	26.7	0
Vaal (C24A, B, H, J, C25A - C)	10.9	10.9	6100	6482/6583	8.1	7.1	11.1	6.0	10
Bloemhof (C25D - F)	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0
Allemanskraal (C42A - E)	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0
Erfenis (C41A - E)	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0
Vet (C41F - J, C42F - L, C43A - D)	217.8	122.0	7200	7671/8847	121.8	101.8	87.8	50.0	0
TOTAL	309.0	209.8	5309 to 8225	4625 to 8847	198.2	153.7	154.3	109.0	0 to 10 %
Total scheduled irrigation		206.4							

Notes:

Irrigation area data taken from Vaal Irrigation Study (PC000/00/21599); Table 7.2 and 8.2 etc.

Total harvested area = total crop area in Table 7.2

Total green or field area = total irrig area in Table 7.2 & 8.2; this area used to calculate irrig req.

DWAF data from MIDDLE VAAL 2.XLS; 5621IRRIGATION (worksheet)

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
MIDDLE VAAL WMA							
Irrigation in Middle Vaal catchment:							
Johan Neser key area:							
C24C	Grapes - table	High	Line Nr (2)*(1.00)	0.06	0.2	0.79	1
C24C	Kikuyu	Low	Line Nr (8)*(1.00)	3.21	0.2	0.79	1
C24C	Lucerne	Low	Line Nr (9)*(1.00)	1.53	0.2	0.79	1
C24C	Potato	Medium	Line Nr (37)*(1.00)	0.83	0.2	0.79	1
C24C	Rye grass	Low	Line Nr (46)*(1.00)	0.37	0.2	0.79	1
C24C	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.15	0.2	0.79	1
C24C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	10.8	0.2	0.79	1
C24C	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	4.5	0.2	0.79	1
C24C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.79	0.2	0.79	1
C24E	Kikuyu	Low	Line Nr (8)*(1.00)	1.7	0.2	0.7	1
C24E	Lucerne	Low	Line Nr (9)*(1.00)	3	0.2	0.7	1
C24E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	10.4	0.2	0.7	1
C24E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.93	0.2	0.7	1
C24F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.63	0.1	0.75	1
Total irrigation in key area:				**44.9**			
Middle Vaal key area:							
C24H	Kikuyu	Low	Line Nr (8)*(1.00)	1.91	0.2	0.73	1
C24H	Lucerne	Low	Line Nr (9)*(1.00)	1.03	0.2	0.73	1
C24H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.85	0.2	0.73	1
C24H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.03	0.2	0.73	1
C24H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.48	0.2	0.73	1
C24J	Kikuyu	Low	Line Nr (8)*(1.00)	0.59	0.1	0.78	1
C24J	Lucerne	Low	Line Nr (9)*(1.00)	0.77	0.1	0.78	1
C24J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.99	0.1	0.78	1
C24J	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.22	0.1	0.78	1
Total irrigation in key area:				**10.87**			
Total irrigation in Middle Vaal catchment				**55.77**			
Irrigation in Sand-Vet catchment							
Vet key area:							
C41G	Kikuyu	Low	Line Nr (8)*(1.00)	0.2	0.2	0.8	1
C41G	Lucerne	Low	Line Nr (9)*(1.00)	0.22	0.2	0.8	1
C41G	Potato	Medium	Line Nr (37)*(1.00)	3.81	0.2	0.8	1
C41G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	7.7	0.2	0.8	1
C41G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.56	0.2	0.8	1
C41H	Kikuyu	Low	Line Nr (8)*(1.00)	0.2	0.2	0.8	1
C41H	Lucerne	Low	Line Nr (9)*(1.00)	0.22	0.2	0.8	1
C41H	Potato	Medium	Line Nr (37)*(1.00)	3.81	0.2	0.8	1
C41H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	7.7	0.2	0.8	1
C41H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.56	0.2	0.8	1
C41J	Kikuyu	Low	Line Nr (8)*(1.00)	0.2	0.2	0.8	1
C41J	Lucerne	Low	Line Nr (9)*(1.00)	0.22	0.2	0.8	1
C41J	Potato	Medium	Line Nr (37)*(1.00)	3.81	0.2	0.8	1
C41J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	7.7	0.2	0.8	1
C41J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.56	0.2	0.8	1
C42G	Kikuyu	Low	Line Nr (8)*(1.00)	0.5	0.2	0.78	1
C42G	Lucerne	Low	Line Nr (9)*(1.00)	0.45	0.2	0.78	1
C42G	Potato	Medium	Line Nr (37)*(1.00)	1.95	0.2	0.78	1
C42G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.67	0.2	0.78	1
C42G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.08	0.2	0.78	1
C42G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.69	0.2	0.78	1
C42H	Kikuyu	Low	Line Nr (8)*(1.00)	0.5	0.2	0.78	1
C42H	Lucerne	Low	Line Nr (9)*(1.00)	0.45	0.2	0.78	1
C42H	Potato	Medium	Line Nr (37)*(1.00)	1.95	0.2	0.78	1
C42H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.67	0.2	0.78	1
C42H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.08	0.2	0.78	1
C42H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.69	0.2	0.78	1
C42J	Kikuyu	Low	Line Nr (8)*(1.00)	0.5	0.2	0.78	1
C42J	Lucerne	Low	Line Nr (9)*(1.00)	0.45	0.2	0.78	1
C42J	Potato	Medium	Line Nr (37)*(1.00)	1.95	0.2	0.78	1
C42J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.67	0.2	0.78	1
C42J	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.08	0.2	0.78	1
C42J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.69	0.2	0.78	1
C42K	Kikuyu	Low	Line Nr (8)*(1.00)	0.5	0.2	0.78	1
C42K	Lucerne	Low	Line Nr (9)*(1.00)	0.45	0.2	0.78	1
C42K	Potato	Medium	Line Nr (37)*(1.00)	1.95	0.2	0.78	1
C42K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.67	0.2	0.78	1
C42K	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.08	0.2	0.78	1
C42K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.69	0.2	0.78	1
C42L	Kikuyu	Low	Line Nr (8)*(1.00)	0.5	0.2	0.78	1
C42L	Lucerne	Low	Line Nr (9)*(1.00)	0.45	0.2	0.78	1
C42L	Potato	Medium	Line Nr (37)*(1.00)	1.95	0.2	0.78	1
C42L	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.67	0.2	0.78	1
C42L	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.08	0.2	0.78	1
C42L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.69	0.2	0.78	1
C43A	Kikuyu	Low	Line Nr (8)*(1.00)	0.07	0.1	0.79	1
C43A	Lucerne	Low	Line Nr (9)*(1.00)	0.07	0.1	0.79	1
C43A	Potato	Medium	Line Nr (37)*(1.00)	1.29	0.1	0.79	1
C43A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.62	0.1	0.79	1
C43A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.87	0.1	0.79	1
C43C	Kikuyu	Low	Line Nr (8)*(1.00)	0.07	0.1	0.79	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
C43C	Lucerne	Low	Line Nr (9)*(1.00)	0.07	0.1	0.79	1
C43C	Potato	Medium	Line Nr (37)*(1.00)	1.29	0.1	0.79	1
C43C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.62	0.1	0.79	1
C43C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.87	0.1	0.79	1
C43D	Kikuyu	Low	Line Nr (8)*(1.00)	0.07	0.1	0.79	1
C43D	Lucerne	Low	Line Nr (9)*(1.00)	0.07	0.1	0.79	1
C43D	Potato	Medium	Line Nr (37)*(1.00)	1.29	0.1	0.79	1
C43D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.62	0.1	0.79	1
C43D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.87	0.1	0.79	1
Total irrigation in key area:				**121.93**			
Total irrigation in Sand-Vet catchment				**121.93**			
Irrigation in Rhenoster-Vals catchment							
Rhenoster key area:							
C70D	Kikuyu	Low	Line Nr (8)*(1.00)	1.5	0.2	0.69	1
C70D	Lucerne	Low	Line Nr (9)*(1.00)	2	0.2	0.69	1
C70D	Potato	Medium	Line Nr (37)*(1.00)	1	0.2	0.69	1
C70D	Rye grass	Low	Line Nr (46)*(1.00)	0.6	0.2	0.69	1
C70D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	4.75	0.2	0.69	1
C70D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	3	0.2	0.69	1
C70F	Kikuyu	Low	Line Nr (8)*(1.00)	1.84	0.25	0.69	1
C70F	Lucerne	Low	Line Nr (9)*(1.00)	2.45	0.25	0.69	1
C70F	Potato	Medium	Line Nr (37)*(1.00)	1.22	0.25	0.69	1
C70F	Rye grass	Low	Line Nr (46)*(1.00)	0.73	0.25	0.69	1
C70F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	5.82	0.25	0.69	1
C70F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	3.67	0.25	0.69	1
Total irrigation in key area:				**28.58**			
Vals key area:							
C60G	Lucerne	Low	Line Nr (9)*(1.00)	0.17	0.1	0.75	1
C60G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.02	0.1	0.75	1
C60G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.51	0.1	0.75	1
C60J	Lucerne	Low	Line Nr (9)*(1.00)	0.17	0.1	0.75	1
C60J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.02	0.1	0.75	1
C60J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.51	0.1	0.75	1
Total irrigation in key area:				**3.4**			
Total Irrigation in Rhenoster-Vals catchment				**31.98**			
Total Irrigation in Middle Vaal WMA				**209.7**			

APPENDIX D.2

URBAN AREAS

Urban areas in the Middle Vaal WMA

Quaternary	Urban centre	Urban area km^2	Runoff coefficient for paved areas	Proportion of impervious area
Vaal River key area:				
C24A	Stilfontein TLC	11	0.84	0.125
C24H	Klerksdorp, Orkney TLCs	48	0.84	0.125
C25B	Odendaalsrus TLC	19	0.84	0.125
Total:		**78**		
Vet key area:				
C42J	Welkom, Virginia TLCs	89	0.84	0.125
C43B	Welkom TLC	42	0.84	0.125
Total:		**131**		
Vals key area:				
C60D	Kroonstad TLC	23	0.84	0.125
C60J	Bothaville TLC	20	0.84	0.125
Total:		**43**		
Total urbanised area in WMA:		**252**		

Source of data:

1. Water Research Commission (1994) Surface Water Resources of South Africa : 1990; WRC Report No. 298/2.1/94, Volume II, Appendices, Appendix 5.4

APPENDIX E: WATER REALTED INFRASTRUCTURE

Comprising:

Appendix E.1	Weir details
Appendix E.2	Reservoir details
Appendix E.3	Pumpstation details
Appendix E.4	Watewater treatment works details
Appendix E.5	Boreholes details
Appendix E.6	Pipelines details
Appendix E.7	Canal details

APPENDIX E.1

WEIR DETAILS

Weir name	River name	Position of weir		Full supply gross storage capacity (10^6 m^3)	Full supply surface area (km^2)
		Longitude	Latitude		
Virginia Weir	Sand				
Mooifontein Weir	Vals	26°37'29"	27°24'00"	26°37'29"	
Roodewal Weir	Vals	26°58'11"	27°26'29"	26°58'11"	

APPENDIX E.2

RESERVOIR DETAILS

Name of reservoir	Quaternary catchment	Storage capacity (Ml)
Odensdaalsrus	C25B	Unknown [3]
Wesselbron (5)	C25F	7.2
Marquard (2)	C41A	3.0
Winburg (3)	C41A	2.5
Verkeerdevlei (3)	C41D	0.4
Theunissen (3)	C41G	5.9
Paul Roux (5)	C42A	2.4
Senekal (2)	C42C	10.5
Arlington (2)	C42F	unknown
Ventersburg (3)	C42H	3.0
Hennenman (2)	C42J	123.0
Virginia	C42J	2.1
Bultfontein (4)	C43A	6.4
Welkom	C43B	Supplied by Sedibeng Water
Lindley (2)	C60B	8.2
Kroonstad (12)	C60D	66.7
Steynsrus (2)	C60E	1.7
Bothaville (5)	C60J	12.0
Petrus Steyn (2)	C70A	2.1
Edenville (7)	C70D	1.1
Koppies (3)	C70D	5.7
Viljoenskroon (4)	C70K	17.4

Notes:

1. The bulk storage reservoirs listed in the table below are mainly reinforced concrete.
2. The figure within the bracket indicates the number of reservoirs existing in the town (**source: Water Affairs document: 1st Order Strategy to Develop Community Water Supply & Sanitation**).
3. No information available for urban centres in the North West Province (this provincial information not provided to WRSA consultant).

APPENDIX E.3

PUMPSTATION DETAILS

Name of Pumpstation	**Raw or treated water**	**Peak rated design pumping capacity (m^3/s)**	**Static head (m)**
Allanridge			
Sedibeng Water Balkfontein Inlet and High Pressure (NW – section)	Treated	1.39	
Sedibeng Water Balkfontein Inlet and High Pressure (FS – section)	Treated	2.86	
Beatrix			
De Werf			
Delport		0.20	
Henneman			
Koppie Alleen			
Leeudoringstad			
Midvaal Water Co. Midvaal	Treated	3.47	32
Saaiplaas			
Vaal River			
Wesselbron (Goldfields)			
Virginia			

Note:

1. Static head generally not known.

APPENDIX E.4

WASTEWATER TREATMENT WORKS DETAILS

Name of Wastewater treatment Works	Peak rated design flow capacity (Ml/day)	Treatment process description	Effluent disposal process
Allanridge STWs (2)	3.1	Oxidation ponds	No discharges
Arlington STW	Not known	Oxidation ponds	No discharges
Beatrix mine STW	3.8		For irrigation and a portion to Theronspruit
Bothaville STWs (2)	5.0	Dasveer system	No discharges
Bultfontein STW	1	Oxidation ponds	No discharges
Edenville STW	Not known	Oxidation ponds	Evaporation ponds
Free State Geduld	5		
Heilbron STW	4.1	Activated sludge	Oxidation ponds
Henneman STWs (2)	1.8	Biological / oxidation	Irrigation and a small proportion into the Rietspruit
Hoopstad	0.45	Oxidation ponds	No discharges
Joel Mine STW	1.5		Irrigation and a small proportion into the Theronspruit
Klerksdorp STW	21.9	Activated sludge	Discharge into the Schoonspruit
Kroonstad STW	8.0	Activated sludge & biological seep beds	Discharge into Vals River
Lindley STW	Not known	Not known	No discharges
Marquard STW		Oxidation ponds	No discharges
Odendaalsrus STWs (2)	10	Bio filters & Activated sludge	All effluent re-used by mines
Oryx Mine STW	1.2		Irrigation and into the Bosluisspruit
Paul Roux STWs (2)	Not known	Oxidation ponds	No discharges
Petrus Steyn STW	0.6	Oxidation ponds	No discharges
Senekal STW	3.0	Not known	Discharge into Sand River
Theunissen STWs (3)	4.9	Activated sludge and oxidation ponds	No discharges
Ventersburg STWs (2)	1.7	Oxidation ponds	No discharges
Viljoenskroon STW	3.5	Activated sludge	Swamp
Virginia STWs (2)	46	Activated sludge	Re-use and a proportion into the Sand River
Wesselsbron STW	3.4	Oxidation ponds	No discharges
Winburg STW	0.5	Activated sludge	Discharge into the Winburgspruit
Wolmaranstad STW		Biosphere	Discharge into Makwasiespruit
Witpan STW* (Welkom)	22	Biological	Discharge onto Witpan
Theronia STW* (Welkom)	15	Biological	Discharge onto Flamingo Pan

Name of Wastewater treatment Works	Peak rated design flow capacity (Ml/day)	Treatment process description	Effluent disposal process
Allanridge STWs (2)	3.1	Oxidation ponds	No discharges
Arlington STW	Not known	Oxidation ponds	No discharges
Beatrix mine STW	3.8		For irrigation and a portion to Theronspruit
Bothaville STWs (2)	5.0	Dasveer system	No discharges
Bultfontein STW	1	Oxidation ponds	No discharges
Edenville STW	Not known	Oxidation ponds	Evaporation ponds
Free State Geduld	5		
Heilbron STW	4.1	Activated sludge	Oxidation ponds
Henneman STWs (2)	1.8	Biological / oxidation	Irrigation and a small proportion into the Rietspruit
Hoopstad	0.45	Oxidation ponds	No discharges
Thabang STW* (Welkom)	14	Biological	Discharge into Sand River

Note: Source of information:
Water Affairs document: 1st Order Strategy to Develop Community Water Supply & Sanitation for the Free State Province (not for North West Province).

* WRSA survey of selected TLC's

(2) Number of sewage treatment works.

APPENDIX E.5

BOREHOLES DETAILS

Name (no. of boreholes)	**Quaternary catchment**	**Abstraction ($10^6 m^3$ pa)**
Arlington (2)	C60B	0.07
Bultfontein (7)	C43A	?
Edenville/Ngwathe (27)	C70D	?
Marquard (6)	C41A	0.10
Paul Roux/Fateng Tse Ntso (10)	C42A	?
Petrus Steyn/Mamafubedu (3)	C70A	0.13
Steynsrus (5)	C60E	0.38
Verkeerdevlei (6)	C41D	?
Ventersdorp Eye Subterranean GWCA(1)	C24C, D, E	16.4 (Irrigation) + ? (other rural req.)
Goldfields Wellfield(2) (Wolmaransstad)	C25D	0.0 (1995) 0.3 (1996) 0.78 (1997) 0.77 (1998)

Note: Sources of data:

1. Vaal River Irrigation Study, DWAF report # PC000/00/21599, 1999.
2. Information supplied by Sedibeng Water, AJ Dippenaar (CE), 5/6/1999.
3. All other data from: 1st Order Strategy to Develop Community Water Supply & Sanitation for the Free State Province (not for North West Province).

APPENDIX E.6

PIPELINE DETAILS

Description of pipelines	Position (Latitude, Longitude)	Flow direction	Peak rated design flow capacity (10^6m^3)	Gravity or rising main	Diameter (mm)	Pipe material	Raw or treated water
Sedibeng Water Northern Balkfontein network		To Wolmaranstad etc. in NW Province	44.2 ($1.4m^3/s$)	Pumping	150 to 250	Steel	Treated
Sedibeng Water Southern Balkfontein network		To FS Goldfield, Bothaville etc.	99.5 (2.9)	Pumping	533 to 1200	Steel	Treated
Sedibeng Water Sand River network		To FS Goldfields		Pumping			Treated
Midvaal Water Company				Pumping			Treated

APPENDIX E.7

CANAL DETAILS
(Information not readily available)

Description	For	Canal & Reservoir lining	Length (km)	Diameter	Condition
Vet River, Sand-Vet GWS	Irrigation (Demand driven)	Primary canal: Concrete Secondary canals: ? Reservoirs: Unlined	?	?	Poor
Sand River, Sand-Vet GWS	Irrigation (Demand driven)	Primary canal: Concrete Secondary canals: ? Reservoirs: Unlined	117km	?	Poor
Klerksdorp IB	Irrigation (Demand driven)	Primary canal: Concrete Pipelines: Concrete Reservoirs: Concrete	?	?	Unknown
Schoonspruit GWS	Irrigation (Demand driven)	Primary canal: Concrete Pipelines: Concrete Reservoirs: Concrete	?	?	Unknown
Rhenoster GWS (Koppies Dam)	Irrigation (Demand driven)	Primary canal: Concrete and unlined	2km lined 26km unlined	?	Poor
Rhenoster GWS (Rooipoort Dam)	Irrigation (Demand driven)	Primary canal: unlined	22	?	Poor

Note: Source of data: Vaal River Irrigation Study, DWAF report No: PC000/00/21599, 1999.

APPENDIX F: WATER REQUIREMENTS

Comprising:

Appendix F.1	Ecological status classes
Appendix F.2	Ecological flow requirements
Appendix F.3	Livestock and game details
Appendix F.4	Transfers details
Appendix F.5	Strategic bulk user and other bulk user detail
Appendix F.6	Mine detail
Appendix F.7	Power Station details
Appendix F.8	Urban details
Appendix F.9	Assurance of supply to water users

APPENDIX F.1

ECOLOGICAL STATUS CLASS INDEX

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
C24A	NORTH WEST	Mooirivier/Brakspruit system	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
C24B	GAUTENG	Vaal (main)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C24C	NORTHERN CAPE	Dry Harts (and tributaries)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C24D	NORTHERN CAPE	Skoonspruit (downstream from Ventersdorp)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
C24E	NORTH WEST	Skoonspruit main stem	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C24F	NORTH WEST	Taaibosspruit??	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C24G	NORTH WEST	Skoonspruit (upstream from farm dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C24H	NORTH WEST	Skoonspruit (after confluence with Jagerspruit)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
C24J	NORTH WEST	Vaal (from Okney to confluence with Vals)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C25A	FREE STATE	Klipspruit?	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C25B	GAUTENG	Sandspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C25C	GAUTENG	Vaal (up to Bloemhof)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C25D	FREE STATE	Makwasiespruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C25E	FREE STATE	Bamboesspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C25F	GAUTENG	Bloemhof dam (entire quatenary inundated)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
C41A	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C41B	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C41C	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C41D	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C41E	FREE STATE	Erfenis Dam	INVALID ENTRIES	WRONG ENTRY	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
C41F	FREE STATE	Trib	LOW	CLASS D: LARGE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C41G	FREE STATE	Vet (before confluence with Sand)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
C41H	FREE STATE	Vet (before confluence with Sand)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C41J	FREE STATE	Vet (before confluence with Sand)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C42A	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C42B	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C42C	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C42D	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C42E	FREE STATE	Upper Sand (upstream of Allemanskraal Dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C42F	FREE STATE	Trib. of Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C42G	FREE STATE	Sand?? (after confluence with main channel sand)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C42H	FREE STATE	Trib. of Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C42J	FREE STATE	Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
C42K	FREE STATE	Main channel Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
C42L	FREE STATE	Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C43A	FREE STATE	Sand	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C43B	FREE STATE	Endoreic region	INVALID ENTRIES	WRONG ENTRY	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
C43C	FREE STATE	Vet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C43D	FREE STATE	Vet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C60A	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C60B	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C60C	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C60D	FREE STATE	Vals	MODERATE	CLASS C: MODERATE RISK	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
				ALLOWED		
C60E	FREE STATE	Upper Sand (upstream of dams)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C60F	FREE STATE	Trib	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C60G	FREE STATE	Vals	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C60H	FREE STATE	Trib. of Vals	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C60J	FREE STATE	Vals	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C70A	FREE STATE	Renoster system	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C70B	FREE STATE	Renoster system	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C70C	FREE STATE	Renoster system (upstream from Koppies dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C70D	FREE STATE	Renoster system (downstream from Koppies dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C70E	FREE STATE	Renoster system	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C70F	FREE STATE	Renoster system (downstream from Koppies dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C70G	FREE STATE	Renoster system	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C70H	FREE STATE	Renoster system	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
C70J	FREE STATE	Renoster system (downstream from Koppies dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C70K	FREE STATE	Renoster system (downstream from Koppies dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED

APPENDIX F.2

ECOLOGICAL FLOW REQUIREMENT
(This data is not readily available)

APPENDIX F.3

LIVESTOCK AND GAME DETAILS

Conversion of mature Livestock and Game Populations to Equivalent Large Stock Units (ELSU) (DWAF, Circular 14/98).

Livestock species:	**Number per ELSU**	**Game species:**	**Number per ELSU**
Cattle	0.85	Black Wildebeeste	3.3
Sheep	6.5	Blou Wildebeeste	2.4
Goats	5.8	Blesbuck	5.1
Horses	1	Buffalo	1
Donkeys / mules	1.1	Eland	1
Pigs	4	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.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
Middle Vaal WMA:		
Vaal River area:		
Vaal River key area:		
C24A	22,944	45
C24B	14,575	45
C24H	15,186	45
C24J	46,796	45
C25A	17,057	45
C25B	35,562	45
C25C	28,847	45
Total:	**180,967**	
ELSU 1995 req. (million cubic meters/a):		**2.97**
Johan Neser key area:		
C24C	28,409	45
C24D	12,041	45
C24E	30,560	45
C24F	48,266	45
C24G	18,134	45
Total:	**137,409**	
ELSU 1995 req. (million cubic meters/a):		**2.26**
Bloemhof key area:		
C25D	24,022	45
C25E	30,802	45
C25F	82,034	45
Total:	**136,858**	
ELSU 1995 req. (million cubic meters/a):		**2.25**
ELSUs - Vaal River area:	**455,234**	
ELSUs req. - Vaal River area (mcm/a):		**7.48**
Sand-Vet area:		
Erefenis Dam key area:		
C41A	35,493	45
C41B	32,604	45
C41C	30,793	45
C41D	28,044	45
C41E	9,838	45
Total:	**136,772**	
ELSU 1995 req. (million cubic meters/a):		**2.25**
Allemanskraal Dam key area:		
C42A	20,944	45
C42B	21,586	45
C42C	22,585	45
C42D	19,667	45
C42E	22,545	45
Total:	**107,327**	
ELSU 1995 req. (million cubic meters/a):		**1.76**
Vet key area:		
C41F	20,994	45
C41G	5,466	45
C41H	27,485	45
C41J	10,275	45
C42F	19,593	45

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
C42G	14,060	45
C42H	9,462	45
C42J	20,243	45
C42K	12,753	45
C42L	9,153	45
C43A	29,826	45
C43B	11,050	45
C43C	45,446	45
C43D	86,966	45
Total:	**322,772**	
ELSU 1995 req. (million cubic meters/a):		**5.31**
ELSUs - Sand-Vet area:	**566,871**	
ELSUs req. - Sand-Vet area (mcm/a):		**9.32**
Rhenoster-Vals area:		
Vals key area:		
C60A	25,980	45
C60B	29,789	45
C60C	28,230	45
C60D	12,276	45
C60E	19,332	45
C60F	13,219	45
C60G	15,650	45
C60H	24,398	45
C60J	23,911	45
Total:	**192,785**	
ELSU 1995 req. (million cubic meters/a):		**3.17**
Rhenoster key area:		
C70A	26,705	45
C70B	41,792	45
C70C	52,805	45
C70D	27,941	45
C70E	25,798	45
C70F	24,200	45
C70G	22,659	45
C70H	5,214	45
C70J	16,353	45
C70K	26,959	45
Total:	**270,426**	
ELSU 1995 req. (million cubic meters/a):		**4.44**
ELSUs - Rhenoster-Vals area:	**463,211**	
ELSUs req. - Rhenoster-Vals area (mcm/a):		**7.61**
ELSUs - Free State Province:	**1,164,885**	
ELSUs - North West Province:	**320,431**	
Total ELSUs - Middle Vaal WMA:	**1,485,316**	
Total ELSUs Req. - Middle Vaal WMA:		**24.41**

LIVESTOCK AND GAME DATA FOR MAGISTERIAL DISTRICTS FOR MIDDLE VAAL WMA

Figures from 1990 Food Survey Report by Department of Agric (Glen) & CSS survey of 1988 (where necessary)

		(DOA)	(DOA)	(DOA)	(CSS)	(CSS)	(DOA)	(CSS)	(CSS)	(Unadjusted)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(DOA)	(unadjusted)
PROVINCE	DISTRICT	CATTLE	SHEEP	GOATS	GOATS	PIGS	Horses, mules & donkeys	HORSES	MULES/ DONKEYS	LIVESTOCK	Gemsbok	Kudu	Spring-buck	Blesbuck	Black Wilde-beeste	Blue Wildebeeste	Eland	Impala	Waterbuck	Zebra	Hartebees	GAME
FREE STATE	Bothaville	50404	57999	4000	1443	0	0	376	0	112779												0
FREE STATE	Brandfort	95094	322036	904	11670	375	0	416	26	429617			500	1500								2000
FREE STATE	Bultfontein	34841	93074	430	1088	450	0	204	15	129672												0
FREE STATE	Excelsior	31696	66539	0	5200	2455	0	234	0	106124			200	1100								1300
FREE STATE	Heilbron	165886	232972	0	0	427	0	357	29	399671												0
FREE STATE	Hennenman	9190	21315	2500	2448	594	0	41	0	33640												0
FREE STATE	Hoopstad	213951	32108	1700	3433	757	0	375	21	250645												0
FREE STATE	Koppies	50636	86717	134	0	0	738	89	8	138225												0
FREE STATE	Kroonstad	51915	115569	2310	3423	0	600	604	36	171507			220	350								570
FREE STATE	Lindley	54291	113349	1875	2575	0	1300	323	48	171515			200	600								800
FREE STATE	Marquard	29068	69428	3883	3002	1272	0	138	0	103789												0
FREE STATE	Odendaalsrus	5663	16000	0	5196	1515	0	42	0	28416												0
FREE STATE	Senekal	63310	156202	12660	10681	462	0	603	20	233257												0
FREE STATE	Theunissen	23000	46000	2000	3653	433	0	129	34	73249			380	760								1140
FREE STATE	Ventersburg	20811	42928	975	4227	104	0	170	0	68240			2300	1300								3600
FREE STATE	Viljoenskroon	47180	44825	2898	429	814	0	98	49	95864												0
FREE STATE	Virginia	4500	6800	500	5196	0	0	18	0	16514												0
FREE STATE	Vredefort	31512	45125	2598	430	150	0	41	0	79426												0
FREE STATE	Welkom	3074	7590	138	5196	0	0	33	0	15893												0
FREE STATE	Wesselsbron	21206	55771	810	254	525	0	168	15	78495												0
FREE STATE	Winburg	38000	121300	2300	4781	552	0	163	12	164808			450	900								1350
NORTH WEST	Bloemhof	27119	28502	2229	1402	400	0	184	41	58475												0
NORTH WEST	Coligny	27100	35100	360	0	666	0	127	31	63384												0
NORTH WEST	Klerksdorp	44492	47565	3798	0	9438	1434	291	26	106727												0
NORTH WEST	Lichtenburg	83190	96690	1500	680	5463	0	288	63	187194												0
NORTH WEST	Ventersdorp	89928	46195	1042	0	14612	0	151	40	151968												0
NORTH WEST	Wolmaranstad	70429	87801	1700	5128	9820	0	341	52	173571												0
	TOTAL:	1387486	2095500	53244	81535	51284	4072	6004	566	3642665	0	0	4250	6510	0	0	0	0	0	0	0	10760

NOTE: Data = 0 or blank means either no animals present or no data found

* Magisterial district straddles catchment / WMA divide

APPENDIX F.4

TRANSFER DETAILS

Inter-Basin Transfers

From quat	To quat	From sector	To sector	Description	Maximum Capacity (Million cubic metres per annum)	1995 (Million cubic metres per annum)
EXPORTS OUT WMA:						
C41G	C52G	SRD	SSU	Brandfort TLC: from Erefenis Dam [Vet river GWS]	2.3	2.3
Total:					**2.3**	**2.3**
IMPORTS INTO WMA:						
C22F	C70C	SRD	SSU	Heilbron TLC: from Vaal Dam [Rand Water has taken over bulk supply in 1998 via Sasolburg]	0.9	0.9
Total:					**0.9**	**0.9**
TRANSFERS WITHIN WMA						
TRANSFERS FROM VAAL KEY AREA TO U/S BLOEMHOF KEY AREA						
C25C	C25F	SRD	SSU	Wesselbron TLC: Sedibeng water transfer from Vaal River	0.8	0.8
C25C	C25D	SRD	SSU	Wolmaranstad and Makwassies TLCs: Sedibeng water transfer from Vaal River	1.3	1.3
Total:					**2.1**	**2.1**
TRANSFERS FROM VAAL KEY AREA TO VET KEY AREA						
C25C	C42H	SRD	SSU	Ventersburg TLC: Sedibeng Water transfer from Vaal River [Balkfontein].	0.3	0.3
C25C	C42J	SRD	SSU	Welkom, Virginia & Hennenman TLCs: Sedibeng Water transfer from Vaal River [Balkfontein].	24.6	24.6
C25C	C42J	SRD	SSM	Harmony, President Steyn, Bambanani & Tshepong GM: Sedibeng Transfer from Vaal River [Balkfontein]	25.2	24.3
C25C	C42K	SRD	SSM	Beatrix, Joel, Oryx GMs and Star Diamond Mine: Sedibeng Water transfer from Vaal River [Bal	3.1	3.1
C25C	C43B	SRD	SSM	St Helena, Anglogold, African Rainbow Minerals GMs and Samada Diamond Mine: Sedibeng Water transfers from Vaal River [Balkfontein].	9.0	9.0
Total:					**62.2**	**61.3**
TRANSFERS FROM VAAL KEY AREA TO VALS KEY AREA						
C25C	C60J	SRD	SSU	Bothaville TLC: Sedibeng Water transfer from Vaal River [Balkfontein]	1.9	1.9
Total:					**1.9**	**1.9**
TRANSFERS WITHIN KEY AREAS:						
TRANSFERS WITHIN VAAL KEY AREA						
C24B	C24A	SRD	SSM	Buffelfontein and Stilfontein GMs: Midvaal Water Company transfer from Vaal River	11.6	11.6
C24B	C24A	SRD	SSU	Stilfontein TLC: Midvaal Water Company transfer from Vaal River	3.6	3.6
C24B	C24H	SRD	SSM	Hartebeesfontein GM: Midvaal Water Company transfer from Vaal River	8.5	8.5
C24B	C24H	SRD	SSU	Klerksdorp TLC: Midvaal Water Company transfer from Vaal River	12.9	12.9
C25C	C25A	SRD	SSU	Leeudoringstad TLC: Sedibeng transfer from Vaal River [Balkfontein]	0.3	0.3
C25C	C25B	SRD	SSM	Avgold GM: Sedibeng Water transfer from Vaal River [Balkfontein]	2.3	2.2
C25C	C25B	SRD	SSU	Odendaalsrus & Allenridge TLCs: Sedibeng Water transfer from Vaal River [Balkfontein]	4.4	4.4
C25C	C25B	SRD	SSO	Sedibeng Water transfers from Vaal River to 'small' consumers, including farmers, rural business's and institutions	0.8	0.8

Total:					**44.4**	**44.3**
TRANSFERS WITHIN ALLEMANSKRAAL KEY AREA						
C42B	C42C	SRD	SSU	Senekal TLC: Transfers from Cyferfontein Dam	0.6	0.6
Total:					**0.6**	**0.6**

Note : From DWAF, Middle Vaal Tables.xls

APPENDIX F.5

STRATEGIC BULK USER AND OTHER BULK USER DETAILS

1995 Strategic bulk user details.

There are no Strategic bulk users in this WMA.

1995 Other bulk user details.

Bulk user	Main activity	Source of water	Bulk requirement ($10^6 m^3$)	River returned to
Midvaal Water Co: Small consumers (all in NW)	Insitutional , rural & agricultural	Vaal @ Midvaal WTW	2.7	No known returns
Sedibeng Water: Small consumers (all in FS)	Insitutional , rural & agricultural	Vaal @ Balkfontien WTW	0.8	No known returns

APPENDIX F.6

MINE DETAILS

Prov.	Mine	Location	Source of water	Bulk requirement $10^6 m^3$	Mine pumpage $10^6 m^3$	Destination river of mine effluent or groundwater decanted.
NW	Buffelsfontein Gold Mine	Near Stilfontein	Vaal R. [Midvaal]	11.4	9.1	Koekemoerspruit
NW	Stilfontein Gold Mine	Stilfontein	Vaal R. [Midvaal]	0.2	7.3	Koekemoerspruit
NW	Vaal Reefs Gold Mine	Buffelsfontein / Orkney area	Vaal R. [direct]	4.5	0	Not known
NW	Vaal Reefs Gold Mine	Buffelsfontein / Orkney area	Vaal R. [Midvaal]	16.0	0	Not known
NW	Hartebeestfontein Gold Mine	Klerksdorp area	Vaal R. [Midvaal]	8.2	0	Oxidation ponds
FS	Avgold Mine (prev. Loraine Gold) Mine [JR Mining]		Vaal R. [Sedibeng]	2.2	0	Not known
FS	Harmony Gold Mines (Erfdeel, Unisel, Saaiplaas)	Virginia	Vaal R. [Sedibeng]	15.4	0	?seepage into system possible
FS	President Steyn [prev. Freegold South]	Virginia	Vaal R. [Sedibeng]	5.0	0	Not known
FS	Bambanani [prev. part of Pres. Steyn]	Virginia	Vaal R. [Sedibeng]	2.8	0	Not known
FS	Tshepong [previously Freegold]	Virginia	Vaal R. [Sedibeng]	0.5	0	Not known
FS	Beatrix Gold Mine [Gencor]	S of Virginia	Vaal R. [Sedibeng]	1.5	**1.2***	Theronspruit
FS	Joel Gold Mine [JCI]	S of Virginia	Vaal R. [Sedibeng]	0.9	***Part of 1.2**	Theronspruit
FS	Oryx Gold Mine [Gencor]	S of Virginia	Vaal R. [Sedibeng]	0.5	***Part of 1.2**	Bosluisspruit
FS	Star Diamonds	S of Virginia	Vaal R. [Sedibeng]	0.1	0	Not known
FS	St Helena Gold Mines	Welkom	Vaal R. [Sedibeng]	2.1	0	Not known
FS	Anglogold (prev. Freegold North)	Welkom	Vaal R. [Sedibeng]	2.1	0	Not known
FS	Samada Diamond Mine	Welkom	Vaal R. [Sedibeng]	0.02	0	Not known
FS	African Rainbow Minerals (prev. Western Holdings)	Welkom	Vaal R. [Sedibeng]	4.5	0	Not known
Total mining water requirement: North West Province			**Vaal River**	**40.4**	**16.4**	**Koekemoerspruit**
Total mining water requirement: Free State Province			**Vaal River**	**37.6**	**1.2**	**?Seepage in FS Goldfields area into Bosluisspruit & Theronspruit**

Sources of data:

- VRSAU reports for Middle Vaal
- WRC report for Sand Vet
- Bulk water data from Midvaal Water Company (pers. Comm)
- Bulk water data and Sedibeng Water (pers. Comm).

APPENDIX F.7

POWER STATIONS DETAILS

(Eskom operational and mothballed stations and municipal stations)

Operational Eskom Power Stations

No operational power stations in this WMA.

Mothballed power stations (coal)

Description	Quatenary
Vierfontein	C24A
Maintenance requirement	

Power stations (coal) operated by local councils

There are none in this WMA.

APPENDIX F.8

URBAN USER DETAILS AND TRENDS

(Trend analysis)
(Per capita usage per residential category for urban areas)
(Consumption factors for urban areas)

TRENDS IN WATER USE IN THE MIDDLE VAAL WMA

It is essential to examine trends in the various water use sectors. This is particularly important to the urban water use sector as this sector has been most dynamic in recent years. The vast majority of TLC's analysed in developing these trends were in the Upper Vaal WMA but there were still a significant number of TLC's analysed in the Middle Vaal WMA. The following trends are therefore of significance to both the Upper Vaal WMA and the Middle Vaal WMA. Table F.8.1 indicates historic trends in water allocation amongst the various water use sectors.

TABLE F.8.1: HISTORIC TREND AND MOST RECENT PERCENTAGE DISTRIBUTION OF WATER AMONGST THE FOREMOST WATER USE SECTORS.

YEAR	ECOLOGY AND FORESTRY	AGRICULTURE	URBAN SECTOR	REMARKS
1975	-	75	25	Ecology sector not recognised
1985	10	65	25	
1995	20	50	30	

Note: Urban sector represents the residential, public, commercial, industrial and mining categories.

The actual contributions from the data capture process on the water use of numerous TLCs in the study area enabled only limited analysis of specific variables. The variables that were well surveyed, indicate certain trends and are as follows:

- type and size of dwelling and land size/income structure
- composition of area serviced
- water supply standards
- water losses

Residential land and residential house sizes are declining as illustrated in Table F.8.2, consequently the domestic water use for indoor and outdoor purposes is also declining.

TABLE F.8.2: TRENDS IN URBAN RESIDENTIAL HOUSE AND LAND SIZES.

YEAR	RESIDENTIAL LAND (M^2)	RESIDENTIAL HOUSE SIZE (M^2)	REMARKS
1980	1275	190	House with water and sewer connection
1985	1050	150	do. Do
1990	950	175	do. Do
1995	900 (estimate)	150 (estimate)	Housing developed under RDP criteria

NOTE: Source of information: Housing Trust (1993)

The large water services providers are currently using the following unit water use values shown in Table F.8.3, in the development of water services infrastructure.

TABLE F.8.3: DESIGN UNIT WATER VALUES USED FOR THE INFRASTRUCTURE DEVELOPMENT.

USER'S INCOME LEVEL	UNIT RANGE (KL/STAND/DAY)	UNIT RANGE (KL/HECTARE/DAY)	AVERAGE VALUES FROM DMS SURVEY (KL/UNIT/DAY)
Upper income	1.150 – 2.150	-	1.55 (erf >500m^2)
Middle income	0.650 – 1.150	-	0.75 (erf >500m^2)
Low income	0.400 – 0.600	-	1.25 (high density)
Wet. Industries		40 – 65	
Dry industries		30 – 40	19.0 (light industry)

Source of information: TLC guidelines for development of municipal infrastructure.

From the survey carried out on major TLC's situated in the study area, it has been determined that there are seven distinct water services categories to be dealt with. Table F.8.4 illustrates 1995 distribution patterns according to seven water services categories.

TABLE F.8.4: TYPICAL WATER SERVICES SITUATION IN THE STUDY AREA IN 1995.

CATEGORIES OF DOMESTIC USAGE	DWELLING AND WATER SUPPLY CATEGORY	TYPE OF SANITATION SERVICES	PERCENTAGE BREAKDOWN (%)
1,2,3,4	In-house connection	Full water and waterborne sewerage	27
5	Yard taps (metered and unmetered) Communal standpipes	Water connection only	31
6	Backyard shacks	No water connection, communal tap	16
7	Informal/inadequate	None	26

The current management functions of the TLCs and MTCs are stated in the general Proclamation No. 35, 1995 under Section 8(20) read with Section 10(1) of the Local Government Transition Act, 1993 (Act No. 209 of 1993). This Act determines bulk supply of water as one of the powers and duties of the town and metropolitan councils.

The water and sanitation departments of each council are to provide a continuous and reliable supply of bulk water of specified quality for distribution in order to meet the needs of communities.

Summary on urban water use trends

These trends are of lesser significance in the Middle Vaal, which is less developed and less reliant on transfers than the Upper Vaal WMA.

The growth for urban water supplies in the provinces increased between 1985 and 1995 about one and half times as shown in Table F.8.5. However, the general short-term trend experienced in very recent years, indicate very low or negative growth for water in some locations. This is most likely on account of a significant decline in mining activities in this WMA. Table F.8.5 gives the trends of source of water supply over a 10-year period from 1985 to 1995.

TABLE F.8.5: TRENDS IN WATER SUPPLIES FROM VARIOUS SOURCES IN 1995.

SOURCE OF WATER	WATER SUPPLIES 1985 (10^6m^3/ANNUM)	WATER SUPPLIES 1995 (10^6m^3/ANNUM)	INCREASE OVER 10 YEARS (%)	REMARKS
Local surface and Groundwater	28.6	44.0	154	
Bulk external supply	44.8	63.8	142	
Bulk and local water sources	4.9	7.8	159	RDP systems
Total for all supplies	78.3	115.6	148	

Note : Source of information – Barta, 1999.

The typical characteristics of urban/peri-urban water services situation in this WMA is related to an absence of strong rural water use component. Rural water services information in this WMA areas is not readily available.

A significant water services development in this WMA is taking place primarily in the former constituent townships. These townships are now integrated under TLCs and MTCs jurisdiction.

The constraints influencing this WMA's urban/metropolitan water services trends are primarily of the natural, socio-economic and institutional nature. The technical and to some extent environmental restraints also play an important but somewhat secondary role. The water services development and management in this WMA is subjected primarily to the constraints as follows:

- stochastic distribution of precipitation,
- evaporation exceeding precipitation due to highly variable temperature
- patterns (i.e. peak demand variability in water supply)
- high population growth rate (some 2,4% p.a.) and unabated population influx of rural population,
- competition for financial resources between established and growing new communities,
- culture of non-payment for services rendering to a slow-down in maintenance and expansion of existing water services infrastructure,
- direct and indirect subsidisation of least contributing communities,
- ongoing restructuring of local government management structures causing serious discontinuity in development of needed services,
- a pure monopoly of potable water supply of a single water services provider taking over of the entire market demand,
- a fragmentation in management of metropolitan water supply and wastewater
- reclamation causing a lack of interest in a conjunctive management actions,
- a crisis management approach to water services development in an absence of an overall metropolitan master plan,
- a huge demand for electrical energy due to large volumes of water pumped over long distances and excessive pumping heads,
- inadequate methods used in determining of metropolitan demand for water and capacity expansion and timing,
- the demand management principles overlooked in sizing of new capacity,

- inconsistent technology transfer by the metropolitan authorities,
- non-methodological financial management by the metropolitan stakeholders in absence of asset management practices,
- unattended urban hydrology problems with regard to contaminated urban runoff and excessive pumpage of mineralised mining waters.

Most of the above listed constraints contribute directly or indirectly to the present trends in management and development of water services in this WMA. It is anticipated that by means of new water legislation on the background of a wider Local Government Transition Act specifying implementation of the Integrated Development Planning (IDP) principles, many above mentioned constraints will eventually be eliminated.

APPENDIX F.9

ASSURANCE OF SUPPLY TO USERS IN WMA

(data on assurance supplied by DWAF and used in WSAM to determine 1:50 yr assurance quantites)

MIDDLE VAAL WMA									
			Per captia consumption per residential category						
Quaternary	Transitional Council	Cat1_SS	Cat2_SS	Cat3_SS	Cat4_SS	Cat5_SS	Cat6_SS	Cat7_SS	Direct : Indirect
Vaal key area:									
C24A	STILFONTEIN / KHUMA	246	246	123	69	8	5	69	58 % : 42 %
C24B	ORKNEY/KANANA	130	130	65	37	4	2	37	58 % : 42 %
C24B	VIERFONTEIN	361	361	180	102	11	6	102	72 % : 28 %
C24B	VAAL REEFS	320	320	160	90	10	6	90	72 % : 28 %
C24H	HARTBEESFONTEIN / TIGANE	320	320	160	90	10	6	90	72 % : 28 %
C24H	KLERKSDORP / JOUBERTON	208	208	104	58	6	4	58	58 % : 42 %
C25A	LEEUDORINGSTAD / KGAKALA	124	124	62	35	4	2	35	72 % : 28 %
C25B	ODENDAALSRUS / KUTLWANONG	91	91	47	28	2	1	28	72 % : 28 %
C25B	ALLANRIDGE / NYAKALONG	239	239	120	66	6	4	66	72 % : 28 %
C25C	WITPOORT / RULAGANYANG	320	320	160	90	10	6	90	72 % : 28 %
Pattern of usage:		236	236	118	67	7	4	67	
Johan Neser key area:									
C24E	VENTERSDORP / TSHING	369	369	185	104	12	7	104	40 % : 60 %
C24F	COLIGNY/THLABOLOGANG	168	168	84	47	5	3	47	72 % : 28 %
Pattern of usage:		269	269	135	76	9	5	76	
u/s Bloemhof key area:									
C25D	MAKWASSIE / LEBALENG	137	137	68	38	4	3	38	72 % : 28 %
C25D	WOLMARANSSTAD / TSWELELANG	199	199	99	56	6	4	56	58 % : 42 %
C25F	WESSELSBRON / MONYAKENG	149	149	74	42	5	3	42	58 % : 42 %
Pattern of usage:		162	162	80	45	5	3	45	
Erefenis key area:									
C41A	MARQUARD / MOEMANENG	268	268	134	75	8	5	75	72 % : 28 %
C41A	WINBURG / MAKELEKETLA	408	408	204	115	13	8	115	72 % : 28 %
C41C	EXCELSIOR / MAHLATSWETSA	320	320	160	90	10	6	90	72 % : 28 %
C41D	VERKEERDEVLEI / TSHEPONG	320	320	160	90	10	6	90	72 % : 28 %
Pattern of usage:		329	329	165	93	10	6	93	
Allemanskraal key area:									
C42A	PAUL ROUX / FATENG-TSE-NTSHO / MOTLOMO	239	239	119	67	7	4	67	72 % : 28 %
C42C	SENEKAL / MATWABENG	215	215	108	61	7	4	61	58 % : 42 %
Pattern of usage:		227	227	114	64	7	4	64	
Vet key area:									
C41G	THEUNISSEN / MASILO	320	320	160	90	10	6	90	72 % : 28 %
C42H	VENTERSBURG / MNAMAHABANE	134	134	67	38	4	3	38	72 % : 28 %
C42J	VIRGINIA / MELODING	234	234	117	66	7	4	66	58 % : 42 %
C42J	HENNENMAN / PHOMOLONG	187	187	93	52	6	3	52	58 % : 42 %
C42J	WELKOM	231	231	116	65	7	4	65	58 % : 42 %
C43A	BULTFONTEIN	332	332	166	93	10	6	93	72 % : 28 %

MIDDLE VAAL WMA									
			Per captia consumption per residential category						
Quaternary	Transitional Council	Cat1_SS	Cat2_SS	Cat3_SS	Cat4_SS	Cat5_SS	Cat6_SS	Cat7_SS	Direct : Indirect
C43C	HOOPSTAD / TIKWANA	320	320	160	90	10	6	90	72 % : 28 %
Pattern of usage:		251	251	126	71	8	5	71	
Vals key area:									
C60B	ARLINGTON / LERATSWANA	105	105	53	30	3	2	30	72 % : 28 %
C60B	LINDLEY / NTHA	153	153	76	43	5	3	43	72 % : 28 %
C60D	KROONSTAD / MAOKENG	377	377	189	106	12	7	106	58 % : 42 %
C60E	STEYNSRUS / MATLWANTLWANG	320	320	160	90	10	6	90	72 % : 28 %
C60J	BOTHAVILLE / KGOTSONG	256	256	128	72	8	5	72	72 % : 28 %
Pattern of usage:		242	242	121	68	8	5	68	
Rhenoster key area:									
C70A	PETRUS STEYN / MAMAFUEDU	150	150	75	42	5	3	42	72 % : 28 %
C70C	HEILBRON / PHIRITONA	197	197	99	56	6	4	56	58 % : 42 %
C70D	EDENVILLE / NQWATHE	320	320	160	90	10	6	90	72 % : 28 %
C70F	KOPPIES / KWAKWATSI	386	386	193	109	12	7	109	72 % : 28 %
C70K	VILJOENSKROON / RAMMULOTSI	266	266	133	75	8	5	75	72 % : 28 %
Pattern of usage:		264	264	132	74	8	5	74	
Pattern of usage for Middle Vaal WMA:		247	247	124	70	8	5	70	
Default pattern of usage [Markdata]:		320	320	160	90	10	6	90	
		77%	77%	77%	77%	77%	77%	77%	

Middle Vaal WMA: Urban consumption parameters

	Direct consumption - Residential categories							Indirect cons.	
Quaternary	fUL1i	fUL2i	fUL3i	fUL4i	fUL5i	fUL6i	fUL7i	fULIi	Urban centre, source of potable water and comments
Vaal key area:									
C24A	**0.25**	**0.1**	**0.15**	**0.5**	**1**	**1**	**0.1**	**0.24**	**Stilfontein TLC (Midvaal) - returns to Koekmoerspruit; decreased consumption by 20% to 40 %.**
C24B	**0.65**	**0.4**	**0.55**	**1**	**1**	**1**	**1**	**0.515**	**Orkney (Midvaal); Vaal Reefs Village (Midvaal) & Vierfontein village (no known returns) - returns to Schoonspruit; adjusted coefficients up 20 % to 50 % to reflect combined consumption patterns.**
C24H	**0.25**	**0.1**	**0.15**	**0.5**	**1**	**1**	**0.1**	**0.24**	**Klerksdorp TLC (Midvaal Water Co.) & Hartbeesfontein TLC (no known returns) - returns to Schoonspruit; reduce consumption of residential categories by 20 % to 40 %.**
C25A	1	1	1	1	1	1	1	1	Leeudoringstad TLC (Sedibeng Water) - no known returns (oxidation dams)
C25B	1	1	1	1	1	1	1	1	Odendaalsrus & Allenridge TLCs (Sedibeng Water); returns are re-used locally or to to nearby vlei.
C25C	1	1	1	1	1	1	1	1	Witpoort TLC (Vaal River) - no known returns
Note:	**Klerksdorp and Stilfontein returns could include returns from gold mines in the area.**								
Johan Neser key area:									
C24E	1	1	1	1	1	1	1	1	Ventersdorp TLC (Schoonspruit & boreholes) - no known returns (oxidation dams).
C24F	1	1	1	1	1	1	1	1	Coligny TLS (Municipal Dam & boreholes) - no known returns
Note:	**No known returns in this area.**								
u/s Bloemhof key area:									
C25D	**0.5**	**0.25**	**0.4**	**1**	**1**	**1**	**0.5**	**0.392**	**Wolmaranstad & Makwassie TLCs (Sedibeng Water) - returns to Makwassiespruit by Wolmaranstad only; increased consumption by 5 % to 20 % to reflect combined pattern.**
C25F	1	1	1	1	1	1	1	1	Wesselbron TLC (Sedibeng Water) - no known returns.
Note:	**Consumption parameters increased to reflect combined urban consumption pattern.**								
Erefenis key area:									
C41A	**0.85**	**0.6**	**0.75**	**1**	**1**	**1**	**1**	**0.84**	**Winburg (returns to Winburgspruit) & Marquard (no known returns); Increased consumption by 40 % to account for combined consumption pattern.**
C41C	1	1	1	1	1	1	1	1	Exelsior TLC (Lehanaspruit & boreholes) - no known returns (oxidation dams).
C41D	1	1	1	1	1	1	1	1	Verkeerdevlei TLC (boreholes) - no known returns (oxidation dams).
Note:	**Consumption parameters increased to reflect combined urban consumption pattern.**								
Allemanskraal key area:									
C42A	1	1	1	1	1	1	1	1	Paul Roux TLC (boreholes) - no known returns (oxidation dams).
C42C	0.45	0.2	0.35	0.8	1	1	0.5	0.336	Senekal TLC (Cyferfontein & De Put Dams) - returns to Sandspruit.
Note:	**No major adjustments**								
Vet key area:									
C41G	1	1	1	1	1	1	1	1	Theunissen TLC (Sand-Vet GWS) - no known returns (oxidation dams).
C42H	1	1	1	1	1	1	1	1	Ventersburg TLC (Sedibeng Water) - no known returns (oxidation dams).
C42J	**0.75**	**0.5**	**0.65**	**1**	**1**	**1**	**1**	**0.73**	**Welkom; Virginia & Henneman TLCs (Sedibeng Water) - some returns by Welkom & Virginia to Sand River; Henneman to Rietspruit (negligble); - Increased consumption by 20% 50 % to to reflect combined pattern & because most returns are to Witpan & Flamingo Pans.**
C43A	1	1	1	1	1	1	1	1	Bultfontein TLC (Sand-Vet GWS & boreholes) - no known returns (oxidation dams).

Middle Vaal WMA: Urban consumption parameters

	Direct consumption - Residential categories							Indirect cons.	
Quaternary	fUL1i	fUL2i	fUL3i	fUL4i	fUL5i	fUL6i	fUL7i	fULIi	Urban centre, source of potable water and comments
C43C	1	1	1	1	1	1	1	1	Hoopstad TLC - no known returns (re-use for irrigation)
Note:	**Consumption parameters increased for Welkom etc because not all sewage returned to system.**								
Vals key area:									
C60B	1	1	1	1	1	1	1	1	Lindley (Piekniekdraai Dam) & Arlington (Transnet Dam & boreholes) TLCs - no known returns (oxidation dam).
C60D	0.45	0.2	0.35	0.8	1	1	0.5	0.336	Kroonstad TLC (Serfontein Dam) - returns to Vals River.
C60E	1	1	1	1	1	1	1	1	Steynsrus TLC (dam and boreholes) - no known returns
C60J	0.45	0.2	0.35	0.8	1	1	0.5	0.468	Bothaville TLC (Sedibeng Water) - returns to Vals River.
Note:	**No major adjustments**								
Rhenoster key area:									
C70A	1	1	1	1	1	1	1	1	Petrus Steyn TLC (Middelpunt Dam & boreholes) - no known returns (re-used locally for irrigation)
C70C	0.45	0.2	0.35	0.8	1	1	0.5	0.336	Heilbron TLC (Vaal Dam) - returns to Elandspruit.
C70D	1	1	1	1	1	1	1	1	Edenville TLC (boreholes) - no known returns.
C70F	0.45	0.2	0.35	0.8	1	1	0.5	0.469	Koppies TLC (Rhenoster River) - returns to Rhenoster R.
C70K	1	1	1	1	1	1	1	1	Viljoenskroon TLC (Vaal River) - no known returns (effluent to swamp)
Note:	**No major adjustments**								

APPENDIX G: WATER RESOURCES

Comprising:

Appendix G.1	Details of postulated dam storages
Appendix G.2	Sediment load per quaternary catchment
Appendix G.3	Groundwater Resources of South Africa
Appendix G.4	Potential vulnerability of surface water and groundwater to microbial contamination.
Appendix G.5	Water quality database

APPENDIX G.1

DETAILS OF POSTULATED DAM STORAGES

Quat. No	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m3)		
	(mm)	(S - mm)	zone	$(10^6 m^3)$	(%MAR)	$(10^6 m^3)$	Capacity	Farm	Total
Vaal key area:									
C24A	584	1750	H	17.67	250	44.17	0.00	4.66	4.66
C24B	562	1750	H	9.63	250	24.08	0.00	1.03	1.03
C24H	576	1820	K	8.80	300	26.40	0.00	4.29	4.29
C24J	552	1800	K	14.20	300	42.60	0.00	1.91	1.91
C25A	542	1850	K	8.22	300	24.66	0.00	0.37	0.37
C25B	509	1750	K	8.45	300	25.35	0.00	3.49	3.49
C25C	522	1825	K	9.63	300	28.89	0.00	2.24	2.24
Total:	**550**	**1792**		**76.60**		**216.15**	**0.00**	**17.99**	**17.99**
Johan Neser key area:									
C24C	587	1750	A	27.90	100	27.90	0.00	0.13	0.13
C24D	584	1725	H	8.20	250	20.50	7.36	0.38	7.74
C24E	560	1800	H	11.80	250	29.50	1.24	3.25	4.49
C24F	577	1830	H	21.30	250	53.25	0.00	4.51	4.51
C24G	581	1820	H	18.30	250	45.75	5.82	3.51	9.33
Total:	**578**	**1785**		**87.50**		**176.90**	**14.42**	**11.78**	**26.20**
U/s Bloemhof key area:									
C25D	525	1860	K	9.68	300	29.05	0.00	2.67	2.67
C25E	510	1900	K	8.17	300	24.50	0.00	1.90	1.90
C25F	481	1850	K	7.15	300	21.45	0.00	0.27	0.27
Total:	**505**	**1870**		**25.00**		**75.00**	**0.00**	**4.84**	**4.84**
Erfenis key area:									
C41A	598	1480	G	42.27	200	84.54	0.00	6.57	6.57
C41B	598	1500	G	39.27	200	78.54	0.00	6.45	6.45
C41C	595	1530	G	41.91	200	83.81	0.00	11.76	11.76
C41D	549	1560	G	33.86	200	67.72	0.00	5.09	5.09
C41E	519	1580	G	9.49	200	18.98	212.34	2.00	214.34
Total:	**572**	**1530**		**166.80**		**333.59**	**212.34**	**31.87**	**244.21**
Allemanskraal key area:									
C42A	633	1440	E	23.20	200	46.40	0.00	1.01	1.01
C42B	582	1460	E	17.69	200	35.38	0.00	6.02	6.02
C42C	626	1450	E	25.25	200	50.50	0.00	3.17	3.17
C42D	556	1500	E	13.36	200	26.72	0.00	3.21	3.21
C42E	565	1480	E	16.20	200	32.40	180.00	3.52	183.52
Total:	**592**	**7330**		**95.70**		**191.40**	**180.00**	**16.93**	**196.93**
Vet key area:									
C41F	496	1600	G	12.83	200	25.65	0.00	6.25	6.25
C41G	516	1600	G	6.67	200	13.35	0.00	0.13	0.13
C41H	500	1680	G	19.62	200	39.23	0.00	3.20	3.20
C41J	495	1700	G	11.88	200	23.77	0.00	0.96	0.96
C42F	567	1540	E	21.07	200	42.15	0.00	2.86	2.86
C42G	549	1560	E	14.10	200	28.21	0.00	2.14	2.14
C42H	540	1590	E	10.52	200	21.05	0.00	2.15	2.15
C42J	530	1600	E	24.57	200	49.14	0.00	7.30	7.30
C42K	521	1600	E	15.22	200	30.44	0.00	2.64	2.64
C42L	506	1680	E	11.11	200	22.22	0.00	1.25	1.25

Quat. No	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m3)		
	(mm)	(S - mm)	zone	(10^6m^3)	(%MAR)	(10^6m^3)	Capacity	Farm	Total
C43A	483	1780	K	3.00	300	9.00	0.00	0.22	0.22
C43B	495	1730	K	0.00	300	0.00	0.00	0.00	0.00
C43C	470	1830	K	4.50	300	13.50	0.00	0.43	0.43
C43D	465	1850	K	4.10	300	12.30	0.00	0.64	0.64
Total:	**510**	**1667**		**159.19**		**330.01**	**0.00**	**30.17**	**30.17**
Vals key area:									
C60A	625	1450	E	31.12	200	62.23	0.00	1.83	1.83
C60B	610	1480	E	32.61	200	65.22	0.00	2.64	2.64
C60C	571	1550	E	24.47	200	48.95	0.00	2.48	2.48
C60D	550	1600	E	12.90	200	25.80	0.00	8.79	8.79
C60E	557	1500	E	14.06	200	28.12	0.00	3.29	3.29
C60F	556	1580	E	14.34	200	28.68	0.00	5.22	5.22
C60G	537	1620	E	14.20	200	28.40	0.00	10.05	10.05
C60H	513	1650	K	5.90	300	17.70	0.00	11.18	11.18
C60J	548	1700	K	5.50	300	16.50	0.00	5.57	5.57
Total:				**155.10**		**321.60**	0.00	**51.05**	**51.05**
Rhenoster key area:									
C70A	627	1500	E	18.48	200	36.97	0.00	2.37	2.37
C70B	612	1550	E	17.43	200	34.85	0.00	1.49	1.49
C70C	615	1600	E	23.19	200	46.38	41.20	3.93	45.13
C70D	586	1600	E	12.40	200	24.80	0.00	1.47	1.47
C70E	578	1630	H	11.70	250	29.25	0.00	3.14	3.14
C70F	574	1620	H	9.20	250	23.00	0.00	6.68	6.68
C70G	577	1600	E	15.30	200	30.60	0.00	6.33	6.33
C70H	568	1650	H	3.80	250	9.50	0.00	2.14	2.14
C70J	575	1670	H	8.40	250	21.00	0.00	1.57	1.57
C70K	565	1690	H	6.90	250	17.25	0.00	5.25	5.25
Total:				**126.80**		**273.60**	**41.20**	**34.37**	**75.57**
TOTAL FOR WMA:				**3915.28**		**1918.25**	**447.95**	**199.00**	**646.95**

APPENDIX G.2

SEDIMENT LOAD PER QUATERNARY CATCHMENT

Quat. number	Gross area (km^2)	Net area (km^2)	Sediment region	Erodibilty index	Sediment ($t/km^2/a$)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
Vaal key area:								
C24A	839	839	3	7	153.34	128652	0.129	0.730
C24B	530	530	3	7	153.34	81270	0.081	0.845
C24H	840	840	3	7	153.34	128806	0.129	1.467
C24J	2110	1681	3	7	153.34	257765	0.258	1.819
C25A	864	864	3	7	153.34	132486	0.133	1.615
C25B	1888	1206	3	7	153.34	184928	0.185	2.193
C25C	1210	1210	3	7	153.34	185541	0.186	1.931
Total:	**8281**	**7170**			**1073.38**	**1099448**	**1.101**	**1.514**
Johan Neser key area:								
C24C	1350	1350	3	6	153.34	207009	0.207	0.743
C24D	364	364	3	7	153.34	55816	0.056	0.682
C24E	925	664	3	7	153.34	101818	0.102	0.865
C24F	2020	1180	3	7	153.34	180941	0.181	0.851
C24G	985	985	3	7	153.34	151040	0.151	0.827
Total:	**5644**	**4543**			**766.70**	**696624**	**0.697**	**0.794**
U/s Bloemhof key area:								
C25D	1203	1203	3	7	153.34	184468	0.185	1.909
C25E	1537	1184	3	7	153.34	181555	0.182	2.227
C25F	2219	1388	3	7	153.34	212836	0.213	2.983
Total:	**4959**	**3775**			**460.02**	**578859**	**0.580**	**2.373**
Erfenis key area:								
C41A	1078	1078	3	9	82	88396	0.089	0.210
C41B	1005	1005	3	9	82	82410	0.083	0.210
C41C	1095	1095	3	9	82	89790	0.090	0.215
C41D	1155	1155	3	10	82	94710	0.095	0.280
C41E	391	391	3	9	82	32062	0.032	0.338
Total:	**4724**	**4724**			**410**	**387368**	**0.389**	**0.251**
Allemanskraal key area:								
C42A	695	695	3	9	82	56990	0.057	0.246
C42B	727	727	3	9	82	59614	0.060	0.338
C42C	793	793	3	9	82	65026	0.065	0.258
C42D	663	663	3	7	153.34	101664	0.102	0.762
C42E	750	750	3	9	82	61500	0.062	0.380
Total:	**3628**	**3628**			**481.34**	**344794**	**0.346**	**0.397**
Vet key area:								
C41F	555	555	3	7	153.34	85104	0.085	0.665
C41G	272	272	3	9	82	22304	0.022	0.335
C41H	887	887	3	10	82	72734	0.073	0.372
C41J	556	556	3	7	153.34	85257	0.085	0.719
C42F	734	734	3	7	153.34	112552	0.113	0.535
C42G	555	555	3	7	153.34	85104	0.085	0.605
C42H	445	445	3	7	153.34	68236	0.068	0.650
C42J	1014	1014	3	7	153.34	155487	0.156	0.634
C42K	668	668	3	7	153.34	102431	0.103	0.674
C42L	511	511	3	7	153.34	78357	0.079	0.707
C43A	1491	523	3	7	153.34	80197	0.080	2.679
C43B	723	0	3	7	153.34	0	0.000	0.000
C43C	913	499	3	7	153.34	76517	0.077	1.704
C43D	1476	1020	3	7	153.34	156407	0.157	3.822

Quat. number	Gross area (km^2)	Net area (km^2)	Sediment region	Erodibilty index	Sediment ($t/km^2/a$)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
Total:	**10800**	**8239**			**2004.08**	**1180687**	**1.183**	**1.007**
Vals key area:								
C60A	860	860	3	8	153.34	131872	0.132	0.425
C60B	1022	1022	3	7	153.34	156713	0.157	0.482
C60C	1048	1048	3	7	153.34	160700	0.161	0.658
C60D	645	645	3	7	153.34	98904	0.099	0.768
C60E	664	664	3	9	82	54448	0.055	0.388
C60F	659	659	3	7	153.34	101051	0.101	0.706
C60G	782	782	3	7	153.34	119912	0.120	0.846
C60H	1232	257	3	7	153.34	39408	0.039	0.669
C60J	959	828	3	7	153.34	126966	0.127	2.313
Total:	**7871**	**6765**				**989975**	**0.992**	**0.640**
Rhenoster key area:								
C70A	613	613	3	7	153.34	93997	0.094	0.510
C70B	660	660	3	7	153.34	101204	0.101	0.582
C70C	887	887	3	7	153.34	136013	0.136	0.588
C70D	675	675	3	7	153.34	103505	0.104	0.836
C70E	693	693	3	7	153.34	106265	0.106	0.910
C70F	564	564	3	7	153.34	86484	0.087	0.942
C70G	901	901	3	8	153.34	138159	0.138	0.905
C70H	251	251	3	7	153.34	38488	0.039	1.015
C70J	521	521	3	7	153.34	79890	0.080	0.953
C70K	891	392	3	7	153.34	60109	0.060	0.873
Total:	**6656**	**6157**				**944114**	**0.946**	**0.746**
WMA TOTAL	**52 563**	**45 724**				**622 1867**	**6.235**	**0.698**

APPENDIX G.3

GROUNDWATER RESOURCES OF SOUTH AFRICA

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 ℓ/s	0,7
1,5 – 3,0 ℓ/s	0,6
0,7 – 1,5 ℓ/s	0,5
0,3 – 0,7 ℓ/s	0,4
<0,3 ℓ/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,

- negligible where corrected baseflow factor is = 0
- low where the corrected baseflow factors is ≤ 0,3
- moderate where the corrected baseflow factor is ≤ 0,8
- 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 ℓ/capita/day.

- Livestock use

  The number of equivalent large livestock units per quaternary catchment was taken from the WSAM and multiplied by 45 ℓ/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 (Baron and Seward, 2000).

The following scenario's 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 (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 (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

Colour Code	Description	TDS Range (mg/l)
Blue	Ideal water quality	<260
Green	Good water quality	260 – 600
Yellow	Marginal water quality	601 – 1 800
Red	Poor water quality	1 801 – 3 400
Purple	Completely unacceptable water quality	>3 400

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 91 000 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 (3 750 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 19 100 x $10^6 m^3/a$ and varies from less than 0,5 mm/a in quaternary catchment D82J to more than 352 mm/a in quaternary catchment W12J.

Borehole yields vary considerably. The highest boreholes yields (up to 100 ℓ/s) have been found in the Malmani Dolomites. Other high borehole yielding (> 10 ℓ/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 ℓ/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 10 100 x $10^6 m^3$/a and varies from less than 0,2 mm/a in quaternary catchment D82G to more than 211 mm/a in quaternary catchment W12J.

The ground water use, excluding mines and industries, has been estimated to be some 1 040 x $10^6 m^3$/a 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 > 20 000 mg/ℓ. The higher rainfall eastern parts have the best water quality, TDS < 100 mg/ℓ. 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.

APPENDIX G.4

POTENTIAL VULNERABILITY OF SURFACE WATER AND GROUNDWATER TO MICROBIAL CONTAMINATION

WATER RESOURCES SITUATION ASSESSMENTS

DEPARTMENT: WATER AFFAIRS & FORESTRY
DIRECTORATE: WATER RESOURCE PLANNING

POTENTIAL VULNERABILITY OF SURFACE WATER & GROUNDWATER TO MICROBIAL CONTAMINATION

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SUMMARY

This report forms part of the Water Resources Situation Assessments undertaken for the Department of Water Affairs and Forestry. Information is provided on the potential microbial contamination of surface water and groundwater resources in South Africa.

For surface water, initial mapping information was taken from the National Microbiological Monitoring Program where priority contaminated areas were identified and mapped. As part of this project, it was necessary to produce a surface contamination map for the whole country. A national surface faecal contamination map was produced using population density and sanitation type available from DWAF databases. A three category rating system was used (low, medium and high) to describe the surface faecal contamination. This information was delineated on a quaternary catchment basis for the whole country.

For groundwater, the first step involved the development of a groundwater vulnerability map using the depth to groundwater, soil media and impact of the vadose zone media. A three category rating system was used (least, moderate, most) to describe the ease with which groundwater could be contaminated from a source on the surface. The second step involved using the surface contamination and aquifer vulnerability maps to derive a groundwater contamination map. The derived map shows the degree of faecal contamination that could be expected of the groundwater for all areas in South Africa.

Conclusions and recommendations

- Maps were produced that provide an overall assessment of potential microbial contamination of the surface water and groundwater resources of South Africa.

- Spatial resolution of the maps is based on a quaternary catchment scale. It is recommended that these maps are not used to derive more detailed spatial information.

- Once sufficient microbial data are available, it is recommended that the numerical methods, and their associated assumptions, be checked, and the maps replotted where necessary.

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ACKNOWLEDGEMENT

The support of Mr Julian Conrad of Environmentek, CSIR for providing the GIS DRASTIC coverages. His help is fully acknowledged and appreciated.

GLOSSARY

Aquifer	Strata, or a group of interconnected strata, comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes
Contamination	Introduction into the environment of an anthropogenic substance
DRASTIC	Numerical method that describes groundwater characteristics, using: water depth, recharge, aquifer media, soil media, topography, impact on vadose zone, and conductivity
Faecal	Material that contains bodily waste matter derived from ingested food and secretions from the intestines, of all warm-blooded animals including humans
Fitness for use	Assessment of the quality of water based on the chemical, physical and biological requirements of users
Groundwater	Subsurface water occupying voids within a geological stratum
Microbial	Microscopic organism that is disease causing
Ratio	Mathematical relationship defined by dividing one number by another number
Rating	Classification according to order, or grade
Vadose zone	Part of the geological stratum above the saturated zone where voids contain both air and water
Vulnerability	In the context of this report, it is the capability of surface water or groundwater resources to become contaminated

1. INTRODUCTION

The purpose of the Water Resources Situation Assessments is to prepare an overview of the water resources in South Africa. This will take account of the availability and requirements for water, as well as deal with issues such as water quality. The country has been divided into nineteen water management areas. Eight separate studies are being carried out within catchment boundaries that roughly approximate provincial borders. Once these studies have been completed, all information will also be synthesized into a single report for the whole country.

This report describes the method used to prepare a series of maps that show the microbial rating of surface water and groundwater resources in South Africa. Maps are produced at a quaternary catchment scale. It is intended that the appropriate portions of the maps be incorporated into each of the Water Management Area reports.

The microbial information provided in this report is intended for planning purposes, and is not suitable for detailed water quality assessment. The maps provide a comparative rating of the faecal contamination status of the surface water and groundwater resources in South Africa.

This report contains five sections:

- Section One: Introduction
- Section Two: Mapping of surface contamination
- Section Three: Mapping Groundwater Resources
- Section Four: Conclusions and Recommendations
- Section Five: References

2. MAPPING SURFACE WATER RESOURCES

2.1 Background

The water resources of South Africa have come under increasing influence from faecal contamination as a result of increased urban development and lack of appropriate sanitation. Due to increased use of contaminated water for domestic consumption, people are at serious risk of contracting water-borne disease (e.g. gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis). The Department of Water Affairs and Forestry (DWAF) is the custodian of the national water resources and should ensure *fitness for use* of the water resources. Thus, the Department has developed a monitoring system to provide the necessary management information to assess and control the health hazard in selected areas. This project is called the National Microbiological Monitoring Programme (NMMP).

As part of the NMMP, a screening exercise was carried out to determine the number of catchments that experience faecal contamination. A short-list of tertiary catchment areas was compiled. Data from the database of the Directorate: Water Services Planning of DWAF was used to prioritize catchments to assess the overall health hazard (see Figure 1).

Ratings for land use activity were assigned using the method developed by Goodmin & Wright (1991), IWQS (1996), and Murray (1999). Ratings for land and water use were combined to establish an overall rating. Water use was considered to have a higher effect than the land use so that a 60:40 weighting was used (see Equation 1).

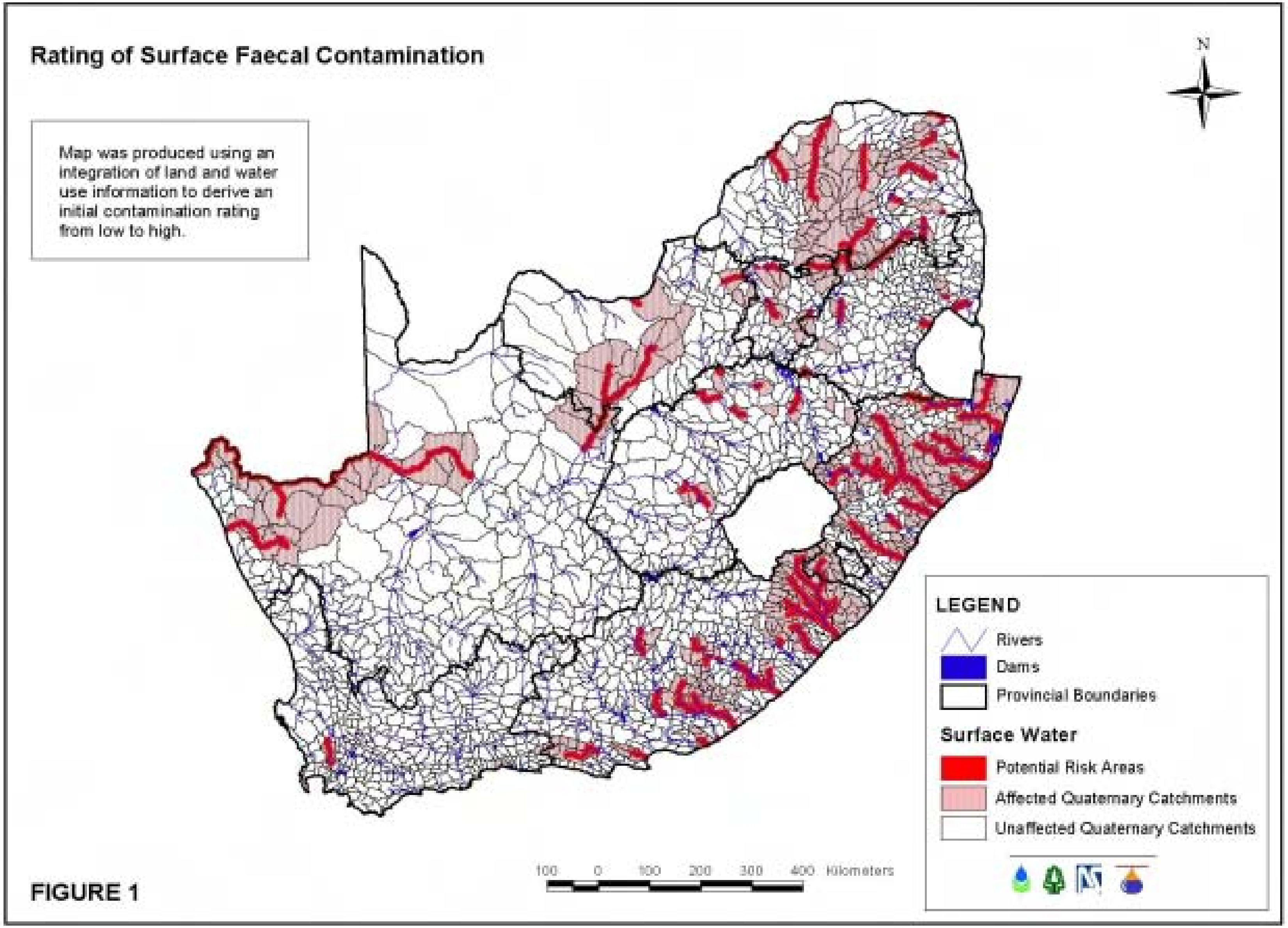
$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

Where OR = Area Rating (no units)
TLU = Total land use rating for area (no units)
TWU = Total water use rating for area (no units)

Each area was assigned a rating to indicate low (1), medium (2) or high (3) potential risk to users in the catchment area. The following values were used to designate each class:

Low	OR = 0 to 1000	
Medium	OR = 1001 to100 000	
High	OR > 100 000	.......(2)

Figure 1 shows the surface faecal contamination map for priority rated catchments in South Africa.



Rating of Surface Faecal Contamination

FIGURE 1

2.2 Surface faecal contamination

Figure 2 shows the potential surface faecal contamination map, developed using average population density (for a quaternary) and degree of sanitation (Venter, 1998). The land use rating is given by:

$$LU = SA + PD \quad \text{........ (3)}$$

Where LU = Land use rating per settlement (no units)
SA = No/poor sanitation rating (no units)
PD = Population Density rating (no units)

Land use rankings for quaternary catchments were determined by calculating the total ratings of all settlements within a particular quaternary catchment, given by:

$$TLU = (LU_n) \quad \text{........ (4)}$$

Where TLU = Total land use rating per quaternary catchment
LU_n = Land use rating for n settlements, per quaternary

Each quaternary catchment was allocated a low (1), medium (2) and high (3) priority rating used to map the information using GIS. Classes were designated by the following values:

Low = $TLU < 1000$
Medium = $1000 < TLU < 3000$
High = $TLU > 3000$ .... (5)

2.3 Results: GIS Surface Water Mapping

Figure 1 was plotted on GIS by firstly assembling the national coverages for the quaternary catchments, rivers and dams. The data described above were processed using the following method:

The quaternary catchments were shaded according to whether they were considered potential risk areas or not (refer to Equations 1 & 2).

Within the quaternaries at risk, the rivers were buffered and shaded red to indicate the risk to potential surface water users.

Figure 2, the potential surface faecal contamination map, was produced as follows:

The ratings (TLU) were distributed into intervals (refer to Equations 5 and 6).

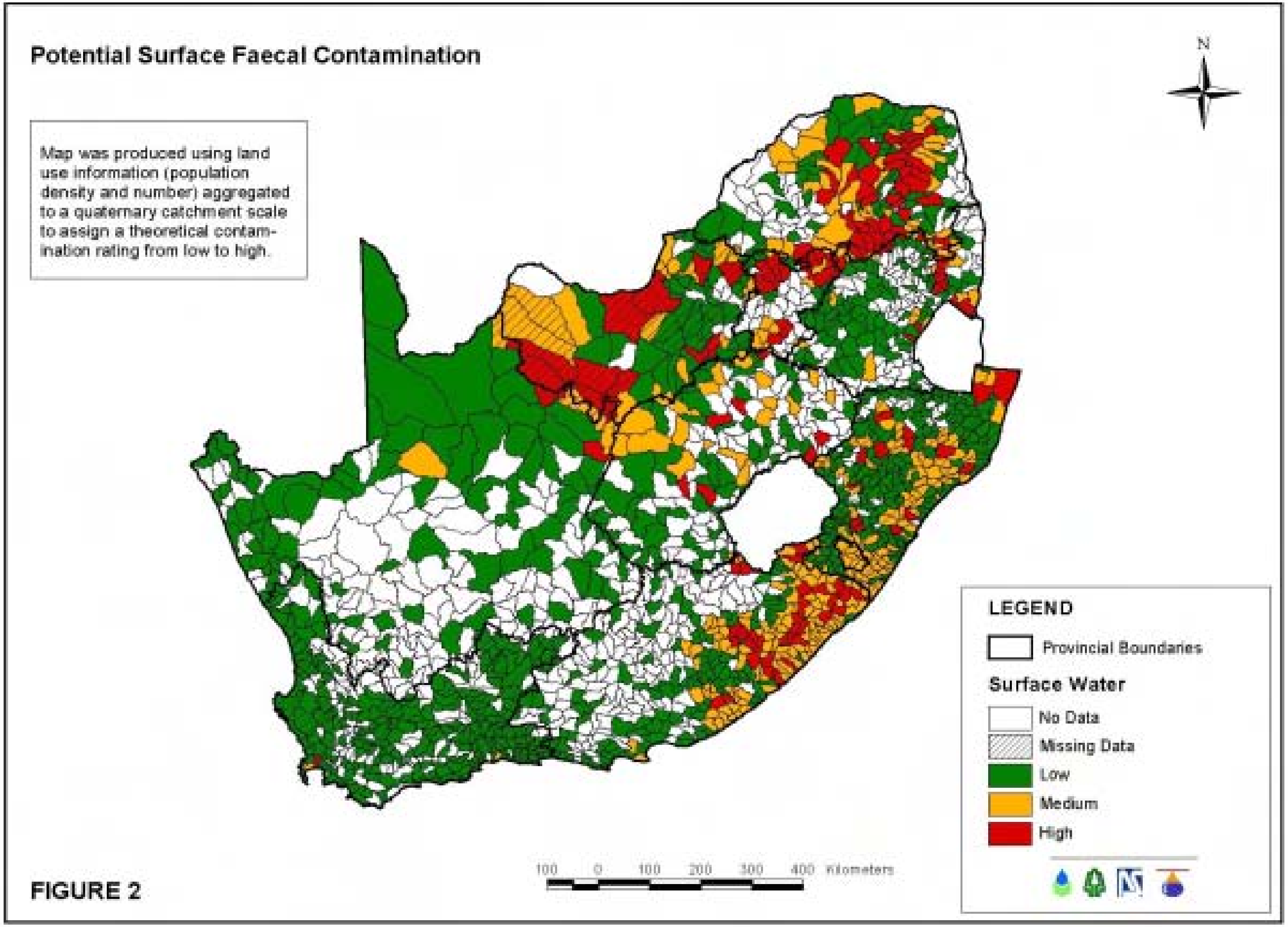

Potential Surface Faecal Contamination
N
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
100 0 100 200 300 400 Kilometers

FIGURE 2

The quaternary catchments were then shaded according to these rating intervals indicating areas of Low, Medium or High Risk, see below.

Low	Green	TLU < 1000	
Medium	Yellow	1000 < TLU < 3000	
High	Red	TLU > 3000	.... (6)

Quaternary catchments with no data were unshaded.

Quaternary catchments containing missing data were hatched.

3. MAPPING GROUNDWATER RESOURCES

3.1 Background

Groundwater is an important national water resource that plays an important role in meeting water requirements in remote areas. This is particularly true in areas where rainfall is low and surface water resources are scarce.

Microbial contamination of groundwater increases in high population density areas and areas with inadequate sanitation. Approximately three quarters of the population of South Africa do not have access to adequate sanitation.

Considerable work has already been carried out to map the groundwater resources in South Africa. Examples include: the national Groundwater Resources of the Republic of South Africa map produced by Vegter (1995) for the Water Research Commission (WRC), regional 1: 500 000 scale hydrogeological maps produced by DWAF, the national groundwater vulnerability map prepared by Reynders & Lynch (1993) and the aquifer classification map of Parsons & Conrad (1998). Figure 3 shows the vulnerability map used by Parsons & Conrad (1998). The existing work, particularly the vulnerability map (Figure 3), has therefore been used as a basis for assessing the potential of microbial contamination of groundwater systems.

3.2 Method

It is recognised that certain aquifers are more vulnerable to contamination than others. The DRASTIC method (Aller *et al.*, 1985) is a well-known and studied method of assessing aquifer vulnerability to contamination. Reynders & Lynch (1993) and Lynch *et al*. (1994, 1997) prepared a national scale aquifer vulnerability map using DRASTIC that was revised by Parsons & Conrad (1998) using additional data (see Figure 3).

DRASTIC is a weighting, and rating, technique that considers seven factors when estimating the groundwater vulnerability. Factors are geologically and geohydrologically based. Controls relating to the magnitude or severity of the pollution source are not considered. DRASTIC factors are shown in Table 1.

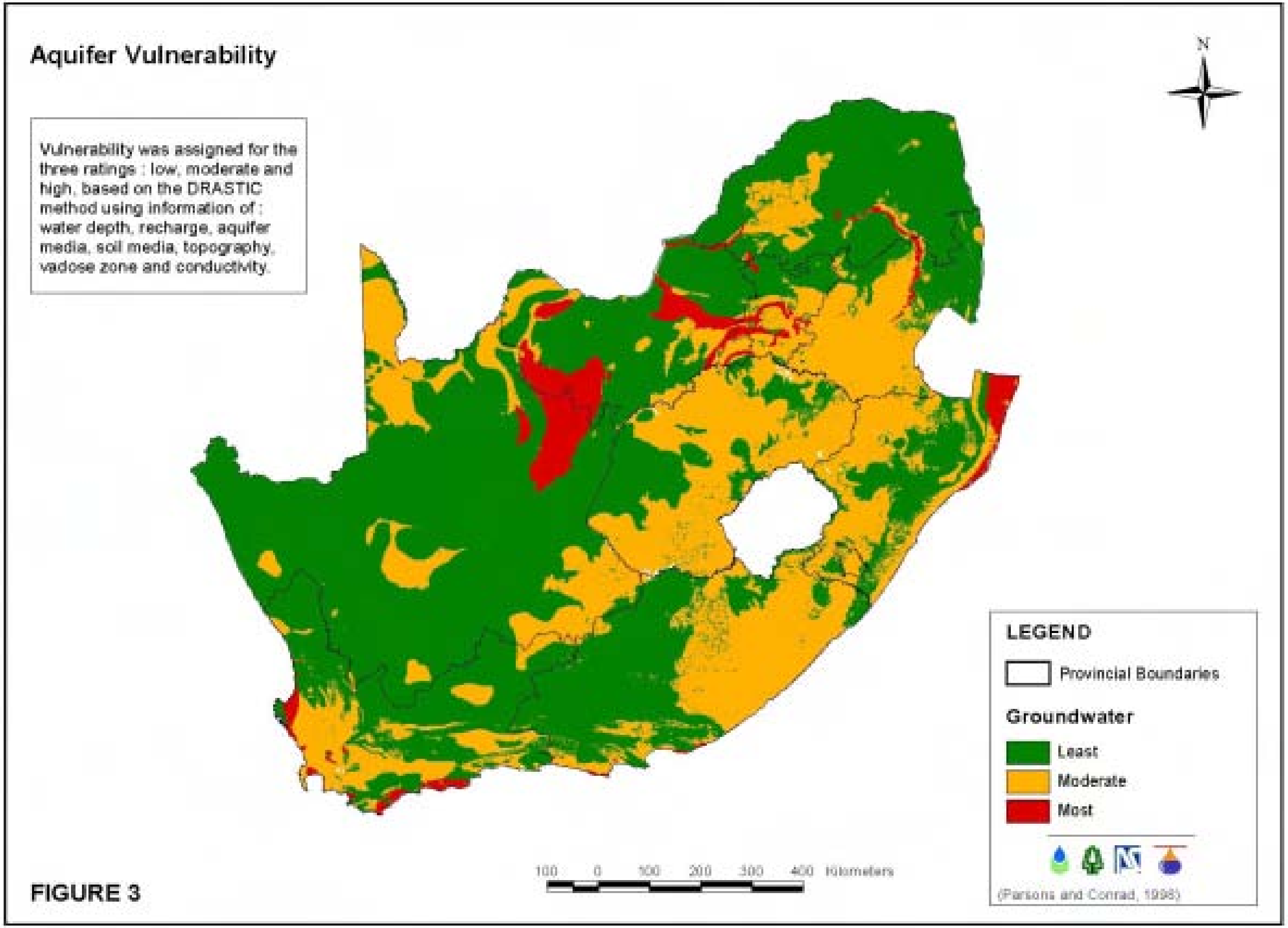

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
LEGEND
Provincial Boundaries
Groundwater
Least
Moderate
Most
100 0 100 200 300 400 Kilometers
(Parsons and Conrad, 1998)

FIGURE 3

TABLE 1: FACTORS USED BY DRASTIC

D	Depth to water
R	(net) Recharge
A	Aquifer media
S	Soil media
T	Topography (slope)
I	Impact of the vadose zone media
C	Conductivity (hydraulic) of the aquifer

Each factor was weighted according to its relative importance (Aller *et al.*, 1985). Using a set of tables, a rating is assigned based on prevailing conditions. A relative DRASTIC index (I) is derived using the following formula, with higher index values showing greater groundwater vulnerability:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad ..... (7)$$

where: I = index rating
$_R$ is the rating for each factor, and
$_W$ is the weighting for each factor.

DRASTIC was also developed to assess the vulnerability to pesticide contamination (Aller *et al.*, 1985). In this case, those factors that play an important role in defining vulnerability to pesticide contamination are assigned higher weights.

In the case of microbial contamination, other factors are more important in terms of aquifer vulnerability to microbial contamination. Travel time in the vadose zone is recognised as an important control in this regard (Xu & Braune, 1995; Wright, 1995; DWAF, 1997). It was hence decided to assess aquifer vulnerability to microbial contamination in terms of D, S and I (i.e. all factors that relate to the vadose zone). [1]

The weighting and rating technique used by DRASTIC was followed in the current study, adopting the weights used by the pesticide DRASTIC. Using the following formula, the highest possible index value is 140 and the lowest value is 14,

$$\text{Index} = 5\ D_R + 5\ S_R + 4\ I_R \qquad .... (8)$$

It must be noted that (1) the value of the index is relative, (2) the factors used in the index were considered by the team to have the greatest influence in assessing the potential for microbial contamination at the surface entering underlying aquifers.

[1] A similar approach was used by Xu & Braune (1995) where they used the factors D, A and S, and used the weightings assigned by DRASTIC and not Pesticide DRASTIC.

3.3 Aquifer vulnerability map

Three DRASTIC groundwater coverages were used to produce an indication of vulnerability of groundwater contamination, namely, depth to groundwater, soil media and vadose.

Each grid element on the DRASTIC coverages was allocated a rating, that was multiplied by a weighting factor (Depth = 5, Soil = 5, Vadose = 4) to produce a score. These three coverages were intersected and their scores added to produce a relative index for each point on the resulting coverage. An additional assumption was applied that assigned a low vulnerability to all areas with a Depth score of less than or equal to 2. This was used to account for deep infiltration of groundwater (over 35 metres) where long residence time and filtration will reduce the degree of contamination.

The relative index (RI) obtained for each grid allowed for grouping into high, medium and low categories. However, setting the intervals for the three categories proved difficult because of sensitivity to the interval chosen. A large percentage of indices fell in the interval of 60 to 80. It was thus decided to use the interval of 70 to 85 to allow for equal distribution between high, medium and low vulnerability areas (see Figure 4), namely:

Low	Green	RI < 70	
Medium	Yellow	70 < RI < 85	
High	Red	RI > 85	.... (9)

To illustrate the sensitivity to the interval chosen the map was replotted using two further intervals of 60-90 and 65-90 (see Figure 5).

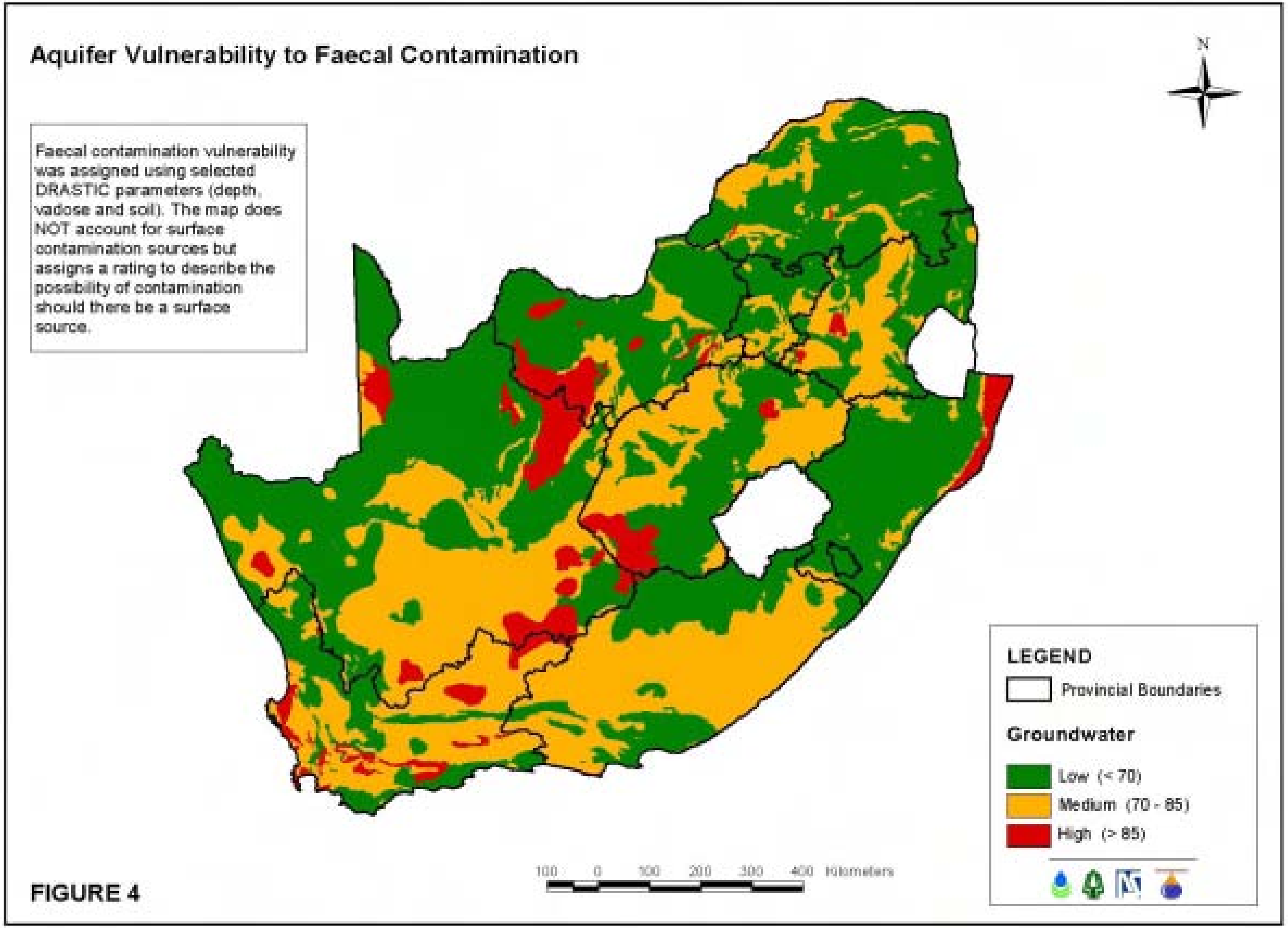
Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider D, S and I. Comparison of Figures 3 and 4 shows remarkable similarity and confirms that the vulnerability *per se* is largely controlled by the three factors (D, S and I), which promotes confidence in the resultant microbial contamination vulnerability map.

A limitation of the study is the inability to validate results obtained. Little information is available regarding groundwater microbial contamination. Monitoring data, from selected areas, should be collected to assess the validity of the vulnerability assessment presented in this report.

3.4 Groundwater faecal contamination

Figure 2 (*Potential Surface Faecal Contamination)* and Figure 4 (*Aquifer vulnerability to Faecal Contamination)* maps were intersected to produce a combined *Risk of Faecal Contamination of Aquifers* map on a quaternary basis, see Figure 6.

A total rating score was calculated for each quaternary (e.g. two medium risk areas and one high risk area gives 2 + 2 + 3). This total was then divided by the total number of different risk areas present in each quaternary to produce an average risk value. Each quaternary catchment was shaded according to this average risk value.


Aquifer Vulnerability to Faecal Contamination
N
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers
FIGURE 4

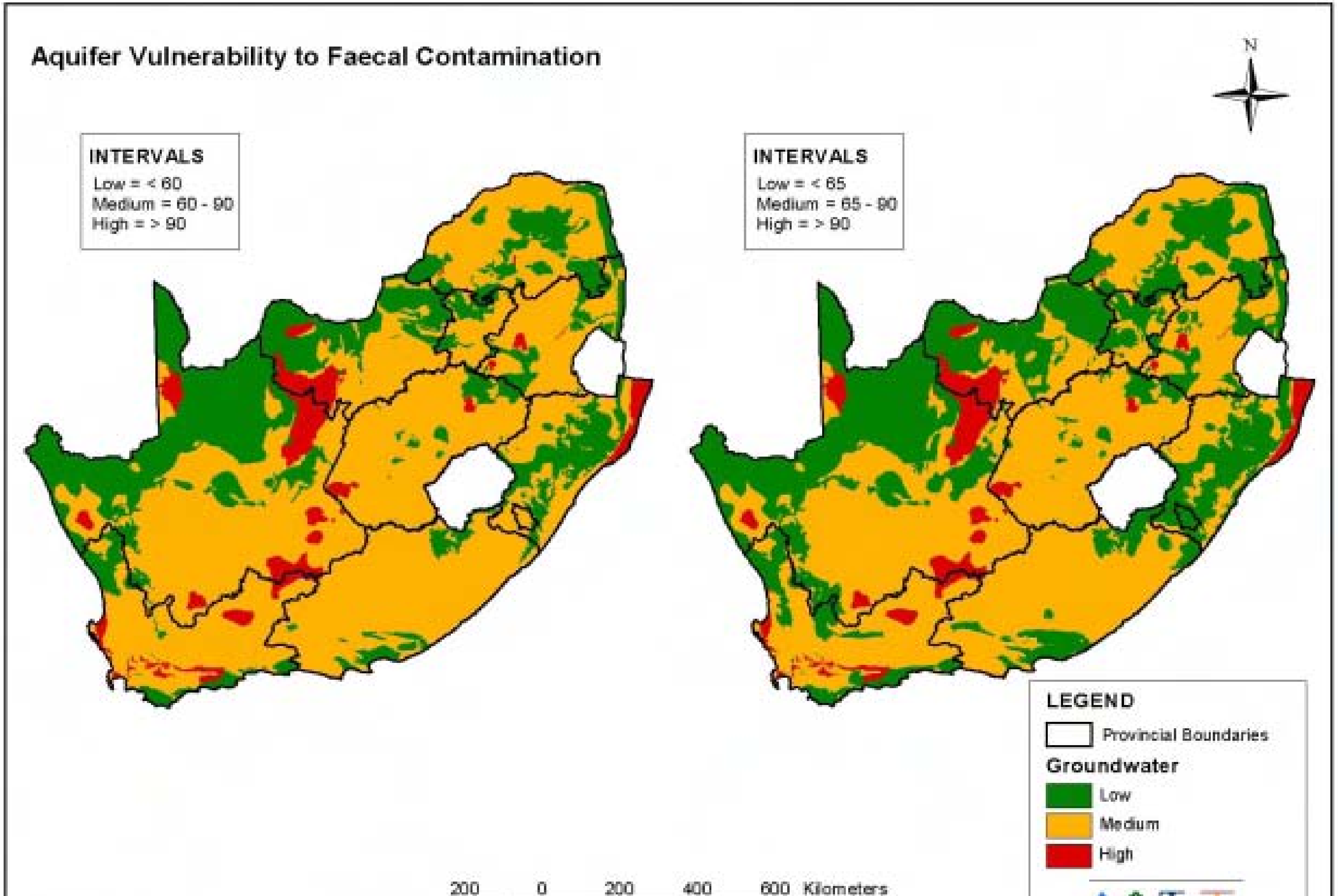
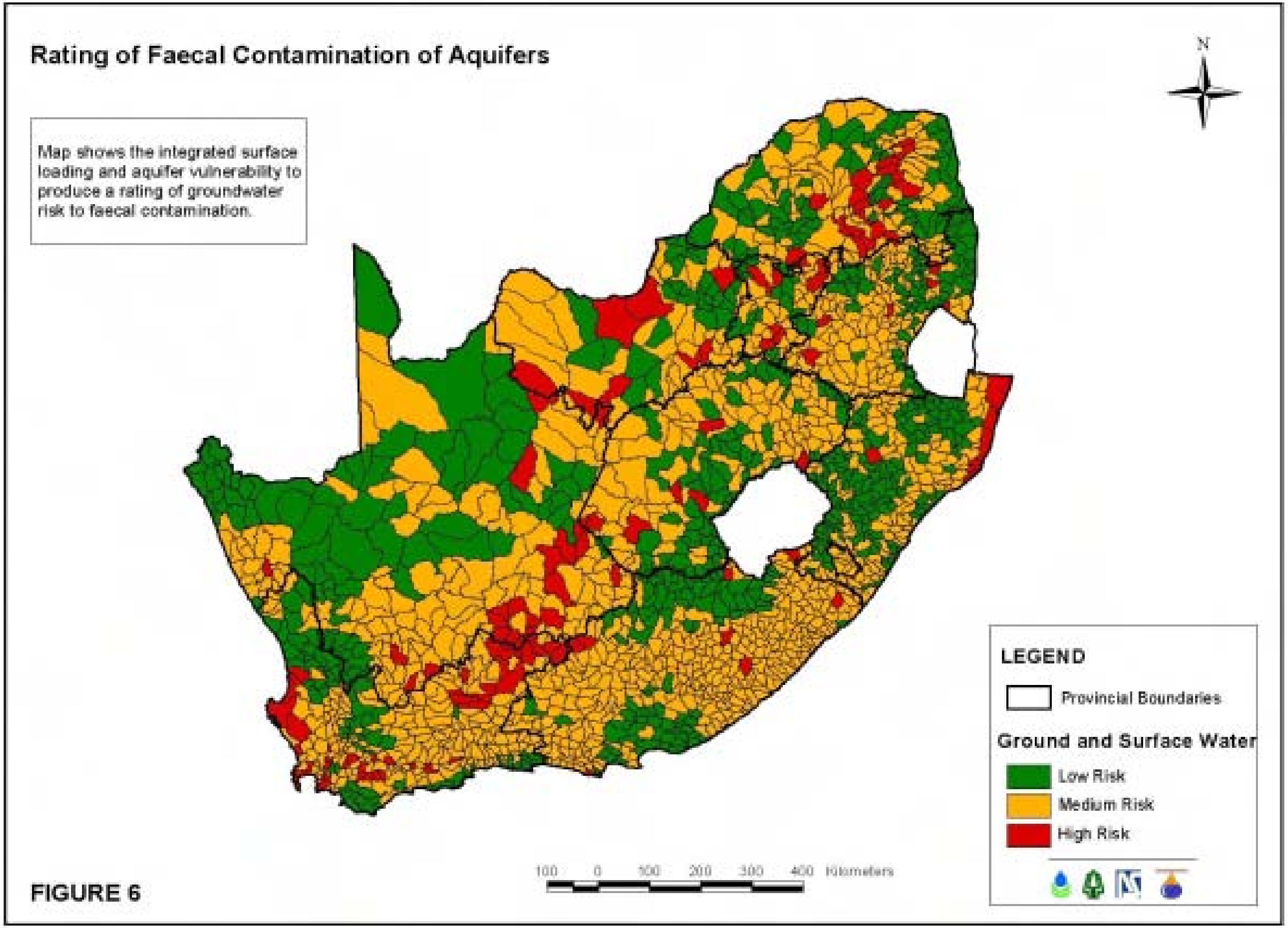

Aquifer Vulnerability to Faecal Contamination
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
N
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers

FIGURE 5


Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk
100 0 100 200 300 400 Kilometers
FIGURE 6

4. CONCLUSIONS & RECOMMENDATIONS

- A series of maps (and their associated GIS coverages) have been produced to show the potential microbial contamination of surface water and groundwater resources in South Africa.

- Maps are produced on a quaternary catchment scale. Where more detailed spatial information is required, alternative methods should be used.

- Once sufficient microbial data are available, it is recommended that the numerical methods are calibrated, and the maps replotted.

- The surface water and groundwater maps should be used in the assessments of water quality for each water management area.

5. REFERENCES

Aller, L., Bennet, T., Lehr, J.H. and Petty, R.J. (1987). DRASTIC - a standardised system for evaluating groundwater pollution potential using hydrogeologic settings; United States Environmental Protection Agency Report EPA/600/2-87/035.

DWAF (1997). A protocol to manage the potential of groundwater contamination from on site sanitation; Edition 1, National Sanitation and Co-ordination Office and Directorate of Geohydrology, Department of Water Affairs and Forestry, Pretoria.

Goodmin. P and Wright, G. (1991). *Decision analysis for management judgement.* John Wiley & Sons Ltd., Chichester, UK. Pp 7 B 36.

Institute for Water Quality Studies, (1996). *A National Microbiological Monitoring Programme to assess faecal Pollution of South African Surface Water Resources: Conceptual Monitoring Design*. Report to Department of Water Affairs and Forestry, PRETORIA, pp 71

Murray, K. (1998). *National Microbial Monitoring Programme Implementation Manual Version 2 (for discussion purposes).* Draft Report to WRC. pp 92.

Lynch, S.D., Reynders, A.G. and Schulze, R.E. (1994). Preparing input data for a national scale groundwater vulnerability map of South Africa; Water SA, Vol. 20 No. 3, pp 239 - 246.

Lynch, S.D., Reynders, A.G. and Schulze, R.E. (1997). A DRASTIC approach to groundwater vulnerability in South Africa; SA Jour. Sci., Vol. 93, pp 56 - 60.

Parsons, R.P. and Conrad, J.E. (1998). Explanatory notes for the aquifer classification map of South Africa; Report prepared for the Water Research Commission, Department of Water Affairs and Forestry and the SA Oil Industry Environment Committee by Parsons & Associates Specialist Groundwater Consultants [cc] and the CSIR (Environmentek).

Reynders, A.G. and Lynch, S.D. (1993). Compilation of a national groundwater vulnerability map of South Africa; Conf. Proc. AAfrica Needs Ground Water@ Johannesburg, Sept. 1993, Poster Paper No. 75.

Reynders, A.G. (1997). An investigation of aquifer vulnerability and pollution risk in formulating a ground-water quality protection strategy for South Africa; *unpublished Ph.D thesis in preparation,* University of Orange Free State, Bloemfontein.

Vegter, J.R. (1995). An explanation of a set of national groundwater maps; Report TT 74/95, Water Research Commission, Pretoria.
Venter, F (1998). Personal communication.

Wright, A.H., (1995). Septic tank systems in the South African coastal zone; WRC Report No. 597/1/95, Water Research Commission, Pretoria.

Xu, Y. and Braune, E. (1995). A guideline for groundwater protection for the community water supply and sanitation programme; First Edition, Department of Water Affairs and Forestry, Pretoria.

APPENDIX G.5

WATER QUALITY DATABASE

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:		Other bulk user returns:	
Quaternary catchment	Virgin MAR (10^6m^3) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns (10^6m^3)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users (10^6m^3)	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users (10^6m^3)
Vaal key area:									
C24A	23.28	253	350	2.4	Stilfontein TLC: Koekmoerspruit from STW.	1000	0	1000	0
C24B	12.7	253	365	1.3	Orkney TLC: Schoonspruit from Orkney STW	1000	0	1000	0
C24H	4.49	291	173	7.7	Klerksdorp TLC: Schoonspruit from STW	1000	0	1000	0
C24J	9.02	457	350			1000	0	1000	0
C25A	4.24	422	350	0.0	Leeudoringstad TLC: returns to oxidation dams	1000	0	1000	0
C25B	7.06	422	350	0.0	Odendaalsrus TLC: no returns (re-uses 4500kl/day).	1000	0	1000	0
C25C	4.97	422	350			1000	0	1000	0
Johan Neser key area:									
C24C	12.67	373	350			1000	0	1000	0
C24D	36.04	280	350			1000	0	1000	0
C24E	8.35	175	350	0.0	Venterdorp TLC: No returns	1000	0	1000	0
C24F	20.38	172	350	0.0	Coligny TLC: No returns	1000	0	1000	0
C24G	10.27	161	350			1000	0	1000	0
Bloemhof key area:									
C25D	4.99	422	350	0.3	Wolmaranstad TLC: Makwassiespruit from STW.	1000	0	1000	0
C25E	5.47	422	350			1000	0	1000	0
C25F	6.08	573	350	0.0	Wesselbron TLC: No returns	1000	0	1000	0
Erfenis key area:									
C41A	42.44	105	350	0.1	Winburg TLC: Winburgspruit from STW	1000	0	1000	0
C41B	39.42	105	350			1000	0	1000	0
C41C	42.07	105	350	0.0	Excelsior TLC: No returns (oxidation dams)	1000	0	1000	0
C41D	33.99	105	350	0.0	Verkeerdevlei TLC: No returns (oxidation dams)	1000	0	1000	0
C41E	9.53	105	350			1000	0	1000	0
Allemanskraal key area:									
C42A	23.3	121	350	0.0	Paul Roux TLC: No returns (oxidation dams)	1000	0	1000	0
C42B	17.77	121	350			1000	0	1000	0
C42C	25.36	121	350	0.4	Senekal TLC: Sandspruit from STW	1000	0	1000	0
C42D	13.42	121	350			1000	0	1000	0
C42E	16.27	121	350			1000	0	1000	0
Vet key area:									
C41F	15.18	127	350			1000	0	1000	0
C41G	7.89	127	350	0.0	Theunissen TLC: No returns (oxidation dams)	1000	0	1000	0
C41H	24.82	127	350			1000	0	1000	0
C41J	15.04	127	350			1000	0	1000	0
C42F	18.89	127	350			1000	0	1000	0
C42G	12.64	127	350			1000	0	1000	0

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:		Other bulk user returns:	
Quaternary catchment	Virgin MAR (10^6m^3) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns (10^6m^3)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users (10^6m^3)	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users (10^6m^3)
C42H	9.43	127	350	0.0	Ventersburg TLC: No returns (oxidation dams)	1000	0	1000	0
C42J	20.07	127	256	6.0	Welkom; Virginia & Henneman TLCs: Sand River and to Witpan & Flamingo Pan	1000	0	1000	0
C42K	12.43	127	350			1000	0	1000	0
C42L	9.07	127	350			1000	0	1000	0
C43A	4.69	127	350	0.0	Bultfontein TLC: No returns (oxidation dams)	1000	0	1000	0
C43B	2.58	127	350			1000	0	1000	0
C43C	2.5	127	350	0.0	Hoopstad TLC: No returns; re-used locally for irrigation	1000	0	1000	0
C43D	3.87	793	350			1000	0	1000	0
Vals key area:									
C60A	31.83	135	350			1000	0	1000	0
C60B	33.35	135	350	0.0	Lindley & Arlington TLCs: no returns (oxidation dams)	1000	0	1000	0
C60C	25.04	135	350			1000	0	1000	0
C60D	13.95	202	150	5.6	Kroonstad TLC: Vals River from STW	1000	0	1000	0
C60E	14.76	111	350	0.0	Steynsrus TLC: No returns	1000	0	1000	0
C60F	15.06	111	350			1000	0	1000	0
C60G	15.21	131	350			1000	0	1000	0
C60H	3.84	477	350			1000	0	1000	0
C60J	3.6	354	74	0.8	Bothaville TLC: Vals River from STW	1000	0	1000	0
Rhenoster key area:									
C70A	18.49	148	350	0.0	Petrus Steyn TLC: returns are re-used locally for irrigation.	1000	0	1000	0
C70B	17.43	148	350			1000	0	1000	0
C70C	23.21	148	350	0.4	Heibron TLC: To Elandspruit.	1000	0	1000	0
C70D	10.59	66	350	0.0	Edenville TLC: No returns	1000	0	1000	0
C70E	12.54	71	350			1000	0	1000	0
C70F	9.97	74	350	0.2	Koppies TLC: Rhenoster River from STW.	1000	0	1000	0
C70G	14.25	71	350			1000	0	1000	0
C70H	4.17	78	350			1000	0	1000	0
C70J	9.01	75	350			1000	0	1000	0
C70K	18.67	231	350	0.0	Viljoenskroon TLC: No returns (effluent to swamp)	1000	0	1000	0

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Qauternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users ($10^6 m^3$)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
Vaal key area:								
C24A	1900	1900	16.43	To Koekemoerspruit: From Buffelsfontein & Stilfontein GMs	150	0	0.4	0.67
C24B					150	0	0.4	0.67
C24H					150	0	0.42	0.56
C24J					150	0	0.89	0.5
C25A					150	0	0.37	0.5
C25B					150	0	0.36	0.5
C25C					150	0	0.37	0.5
Johan Neser key area:								
C24C					150	0	0.57	0.93
C24D					150	0	0.57	0.93
C24E					150	0	0.57	0.93
C24F					150	0	0.55	0.93
C24G					150	0	0.47	0.56
Bloemhof key area:								
C25D					150	0	0.37	0.5
C25E					150	0	0.37	0.5
C25F					150	0	0.36	0.5
Erfenis key area:								
C41A					150	0	0.22	0.69
C41B					150	0	0.22	0.69
C41C					150	0	0.22	0.69
C41D					150	0	0.22	0.69
C41E					150	0	0.22	0.69
Allemanskraal key area:								
C42A					150	0	0.22	0.72
C42B					150	0	0.22	0.72
C42C					150	0	0.22	0.72
C42D					150	0	0.22	0.72
C42E					150	0	0.22	0.72
Vet key area:								
C41F					150	0	0.22	0.69
C41G					150	0	0.22	0.69
C41H					150	0	0.22	0.69
C41J					150	0	0.22	0.69
C42F					150	0	0.22	0.72
C42G					150	0	0.22	0.72

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Qauternary catchment	**TDS concentration in groundwater discharge (oTFMi)**	**Increase in TDS as a result of mining water use (oISMi)**	**Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)**	**Remark**	**Increase in TDS as a result of rural water use**	**Return flows rural Bulk users ($10^6 m^3$)**	**Ratio between salt load in return flow to load in water supply (oPSIi)**	**Reservoir spill TDS/supply TDS (oPSPi)**
C42H					**150**	**0**	**0.22**	**0.72**
C42J					**150**	**0**	**0.22**	**0.72**
C42K	**3000**	**1000**	**1.21**	**To Bosluisspruit & Theronspruit: Beatrix; Joel & Oryx GMs**	**150**	**0**	**0.22**	**0.72**
C42L					**150**	**0**	**0.22**	**0.72**
C43A					**150**	**0**	**0.22**	**0.7**
C43B					**150**	**0**	**0.22**	**0.7**
C43C					**150**	**0**	**0.22**	**0.7**
C43D					**150**	**0**	**0.33**	**0.7**
Vals key area:								
C60A					**150**	**0**	**0.45**	**0.63**
C60B					**150**	**0**	**0.45**	**0.63**
C60C					**150**	**0**	**0.45**	**0.63**
C60D					**150**	**0**	**0.45**	**0.63**
C60E					**150**	**0**	**0.34**	**0.63**
C60F					**150**	**0**	**0.34**	**0.63**
C60G					**150**	**0**	**0.35**	**0.63**
C60H					**150**	**0**	**0.29**	**0.63**
C60J					**150**	**0**	**0.2**	**0.63**
Rhenoster key area:								
C70A					**150**	**0**	**0.62**	**0.67**
C70B					**150**	**0**	**0.62**	**0.67**
C70C					**150**	**0**	**0.62**	**0.67**
C70D					**150**	**0**	**0.62**	**0.67**
C70E					**150**	**0**	**0.43**	**0.67**
C70F					**150**	**0**	**0.31**	**0.67**
C70G					**150**	**0**	**0.43**	**0.67**
C70H					**150**	**0**	**0.44**	**0.67**
C70J					**150**	**0**	**0.43**	**0.67**
C70K					**150**	**0**	**0.89**	**0.67**

APPENDIX H

SUPPLEMENTARY INFORMATION

APPENDIX H.1

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	WRSA consultant
Efficiency and losses	WRSA consultant
Evapotraspiration and crop factors	WRP
Storage-draft-frequency curves	WRP

APPENDIX H.2

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
fiIPMi	Irrigation efficiency – Medium category irrigation (factor)	0.75
fiIPHi	Irrigation efficiency – High category irrigation (factor)	0.75
oRTLi	Rural losses (factor)	0.2

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

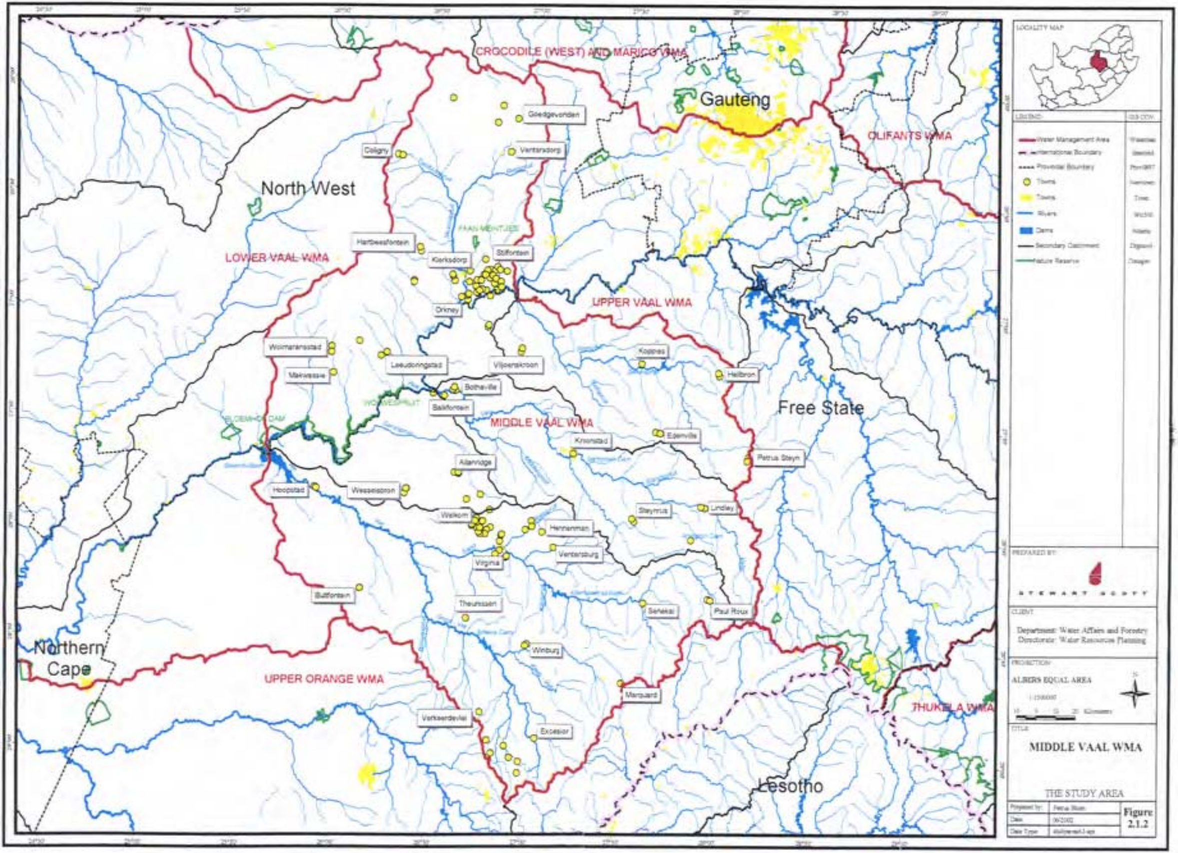
Quat. Number	**Gross area (km2)**	**Net area (km2)**	**Sediment region**	**Erodibility index**	**Sediment (t/km2/a)**	**Sediment yield (t/a)**	**Sediment vol(MCM)**	**Volume (%MAR)**	***Sediment (t/km2/a)***	***Sediment yield (t/a)***	***Sediment vol(MCM)***	***Volume (%MAR)***
D21C	212	212	6	9	335	71020	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

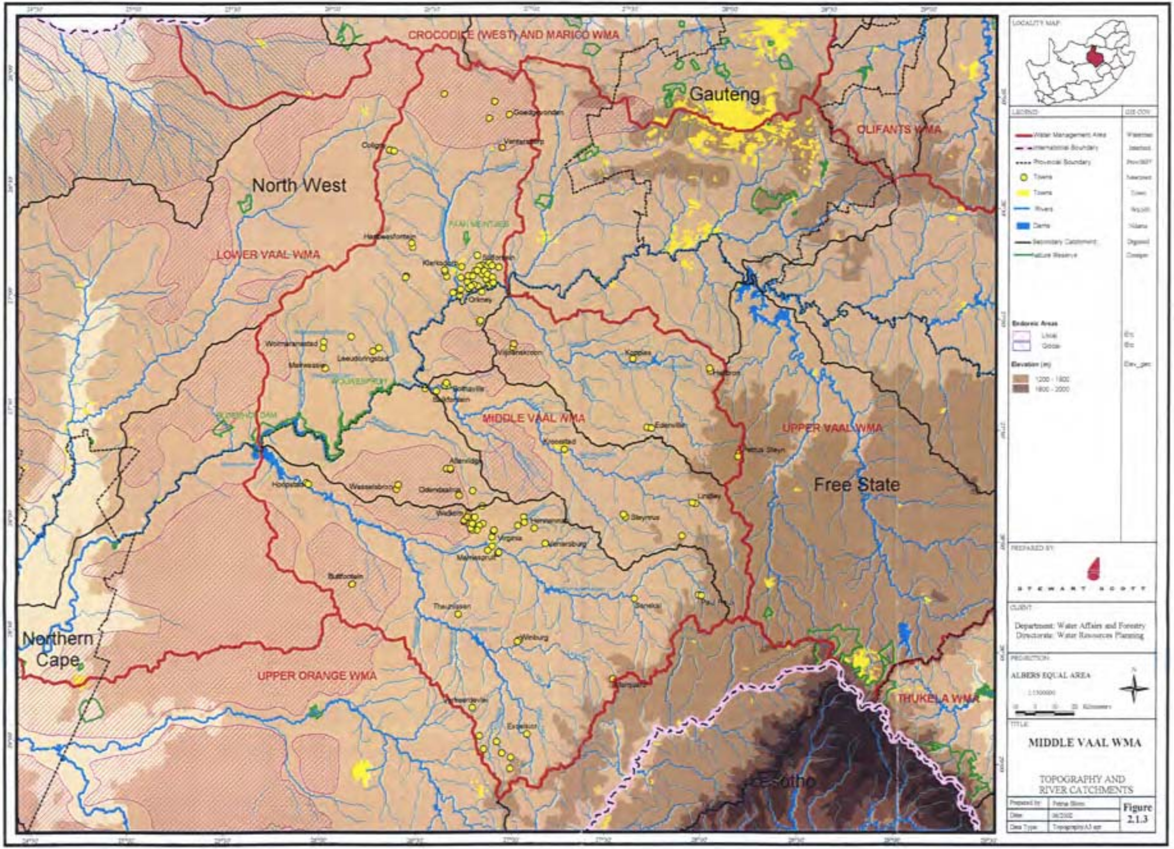
Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
0	**5507**	**5507**				**1627012**	**1.6303**	**0.6465**		**2047654.1**	**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**

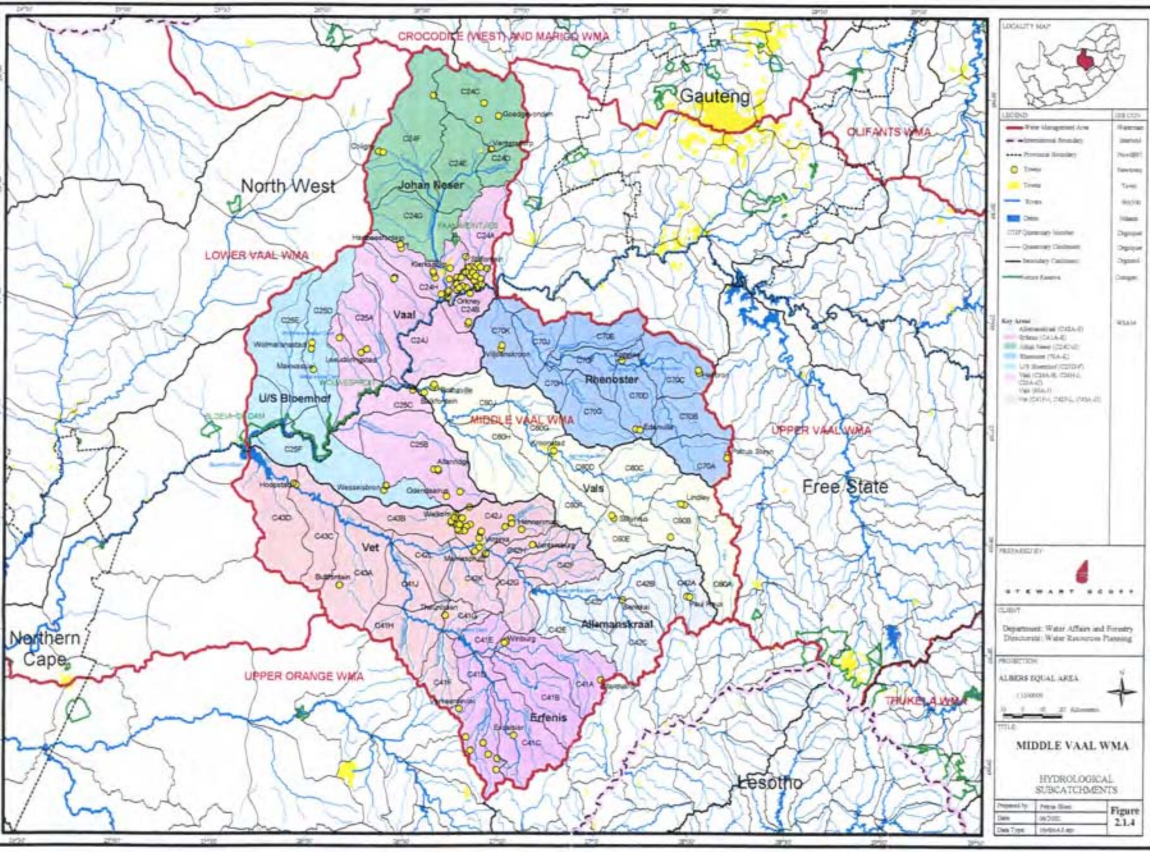
FIGURES


BOTSWANA
NAMIBIA
LIMPOPO
Northern Province
CROCODILE(WEST) AND MARICO
OLIFANTS
Mpumalanga
Gauteng
LOWER VAAL
North West
MIDDLE VAAL
UPPER VAAL
Free State
THUKELA
Kwazulu Natal
LESOTHO
MVOTI TO UMZIMKULU
LOWER ORANGE
Northern Cape
UPPER ORANGE
MZIMVUBU TO KIESKAMMA
Eastern Cape
FISH TO TSITSIKAMMA
GOURITZ
Western Cape
OLIFANTS/DOORN
BERG
Atlantic Ocean
Indian Ocean
Lichtenburg
Coligny
Balfour
Heidelberg
Klerksdorp
Amersfoort
Kuruman
Kroonstad
Christiana
Welkom
Bethlehem
Upington
Alexander Bay
Griekwastad
Douglas
Bloemfontein
Ficksburg
Pofadder
Springbok
Prieska
Fauresmith
De Aar
Victoria West
Richmond
Aliwal North
Sutherland
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Orange-Vaal Watercourse
Water Management Areas within Orange Catchment
Water Management Areas outside Orange Catchment
Main Rivers
Study Area
PREPARED BY
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE:
MIDDLE VAAL WMA
ORANGE RIVER WATERCOURSE
Prepared by: Petrus Bloem
Date: 06/2002
Figure 2.1.1

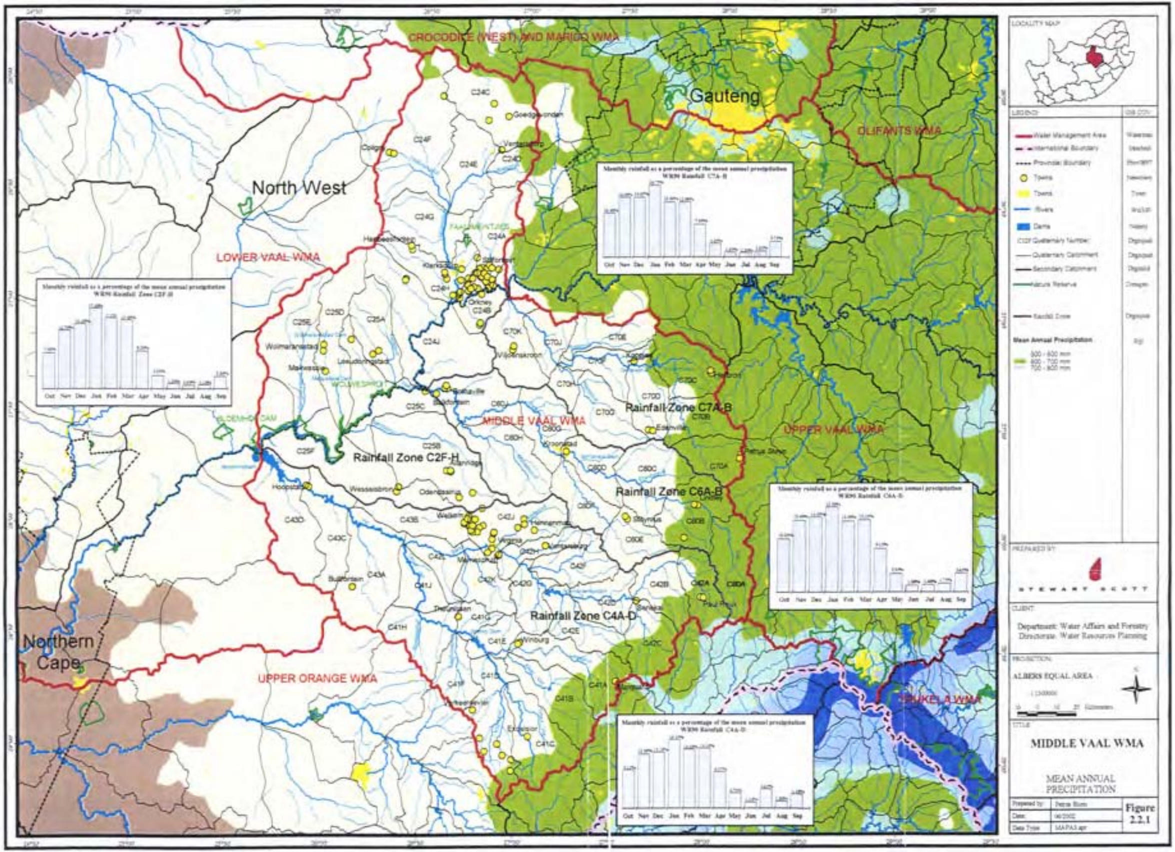

CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
UPPER VAAL WMA
MIDDLE VAAL WMA
Free State
UPPER ORANGE WMA
THUKELA WMA
Northern Cape
Lesotho
Goedgevonden
Coligny
Ventersdorp
Hartbeesfontein
Klerksdorp
Stilfontein
Orkney
Wolmaransstad
Makwassie
Leeudoringstad
Viljoenskroon
Koppies
Heilbron
Bothaville
Balkfontein
Kroonstad
Edenville
Petrus Steyn
Allanridge
Hoopstad
Wesselsbron
Welkom
Hennenman
Steynrus
Lindley
Ventersburg
Virginia
Bultfontein
Theunissen
Senekal
Paul Roux
Winburg
Marquard
Verkeerdevlei
Excelsior
LOCALITY MAP
LEGEND
PREPARED BY:
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
THE STUDY AREA
Figure 2.1.2



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Goedgevonden
Coligny
Ventersdorp
Klerksdorp
Orkney
Wolmaransstad
Leeudoringstad
Makwassie
Viljoenskroon
Koppies
Heilbron
Bothaville
Edenville
Kroonstad
Petrus Steyn
Allanridge
Hoopstad
Wesselsbron
Odendaalsrus
Welkom
Hennenman
Steynsrus
Lindley
Virginia
Ventersburg
Bultfontein
Theunissen
Senekal
Paul Roux
Winburg
Marquard
Excelsior
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Secondary Catchment
Nature Reserve
Endoreic Areas
Local
Global
Elevation (m)
1200 - 1800
1800 - 2000
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
TOPOGRAPHY AND RIVER CATCHMENTS
Figure 2.1.3



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
Johan Neser
LOWER VAAL WMA
Vaal
U/S Bloemhof
MIDDLE VAAL WMA
Rhenoster
UPPER VAAL WMA
Vals
Free State
Vet
Allemanskraal
Erfenis
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
C24C
C24F
C24E
C24D
C24G
C24A
C24H
C24B
C24J
C25A
C25D
C25E
C25C
C25B
C25F
C70K
C70J
C70E
C70H
C70C
C70D
C70G
C70B
C70A
C60J
C60G
C60H
C60D
C60C
C60F
C60B
C60E
C60A
C43D
C43C
C43B
C43A
C42J
C42E
C42H
C42F
C42K
C42G
C42B
C42A
C42D
C42E
C42C
C41J
C41G
C41H
C41E
C41F
C41D
C41A
C41B
C41C
Klerksdorp
Orkney
Viljoenskroon
Kroonstad
Edenville
Petrus Steyn
Lindley
Wesselsbron
Hoopstad
Welkom
Virginia
Winburg
Excelsior
ALBERS EQUAL AREA
MIDDLE VAAL WMA
HYDROLOGICAL SUBCATCHMENTS
Figure 2.1.4



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Northern Cape
Rainfall Zone C2F-H
Rainfall Zone C7A-B
Rainfall Zone C6A-B
Rainfall Zone C4A-D
Monthly rainfall as a percentage of the mean annual precipitation
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
LOCALITY MAP
LEGEND
Mean Annual Precipitation
PREPARED BY
STEWART SCOTT
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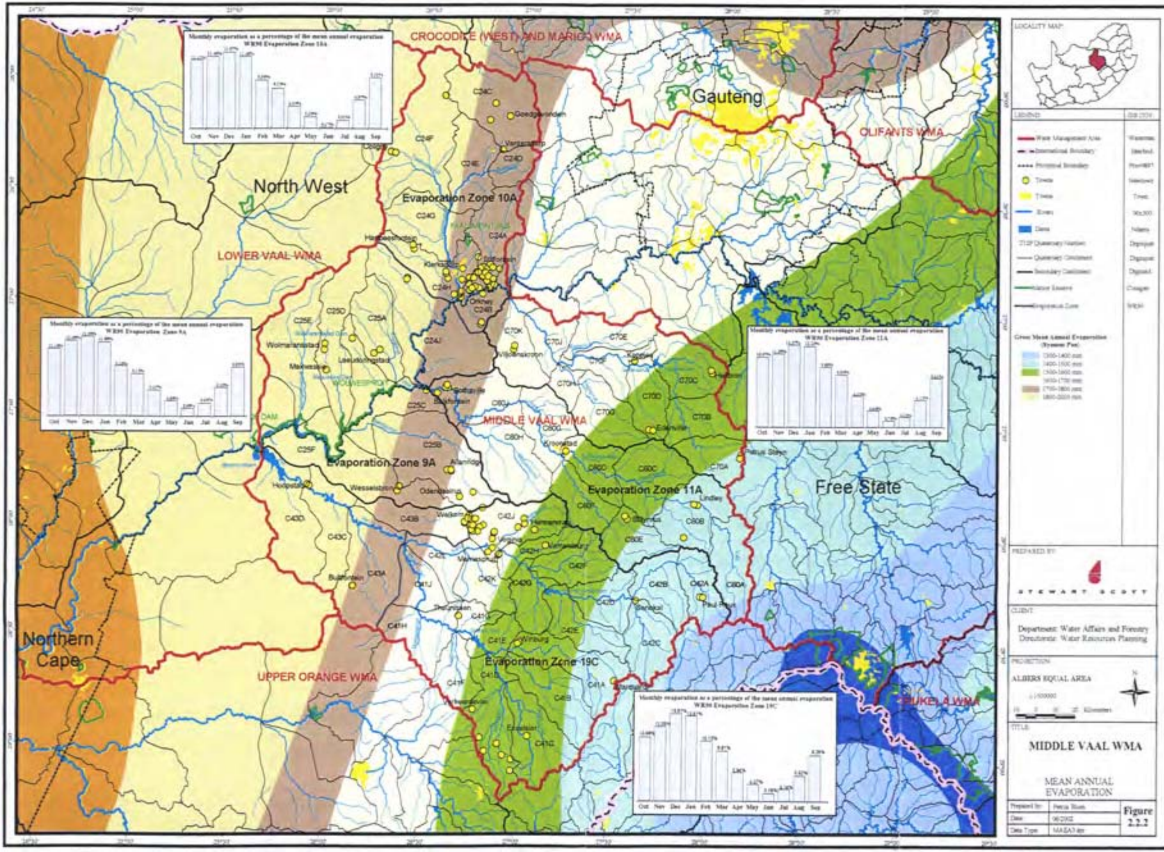
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
MEAN ANNUAL PRECIPITATION
Figure 2.2.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER ORANGE WMA
Free State
Northern Cape
THUKELA WMA
Evaporation Zone 10A
Evaporation Zone 9A
Evaporation Zone 11A
Evaporation Zone 19C
Monthly evaporation as a percentage of the mean annual evaporation
WR90 Evaporation Zone 10A
Monthly evaporation as a percentage of the mean annual evaporation
WR90 Evaporation Zone 9A
Monthly evaporation as a percentage of the mean annual evaporation
WR90 Evaporation Zone 11A
Monthly evaporation as a percentage of the mean annual evaporation
WR90 Evaporation Zone 19C
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
LOCALITY MAP
LEGEND
PREPARED BY
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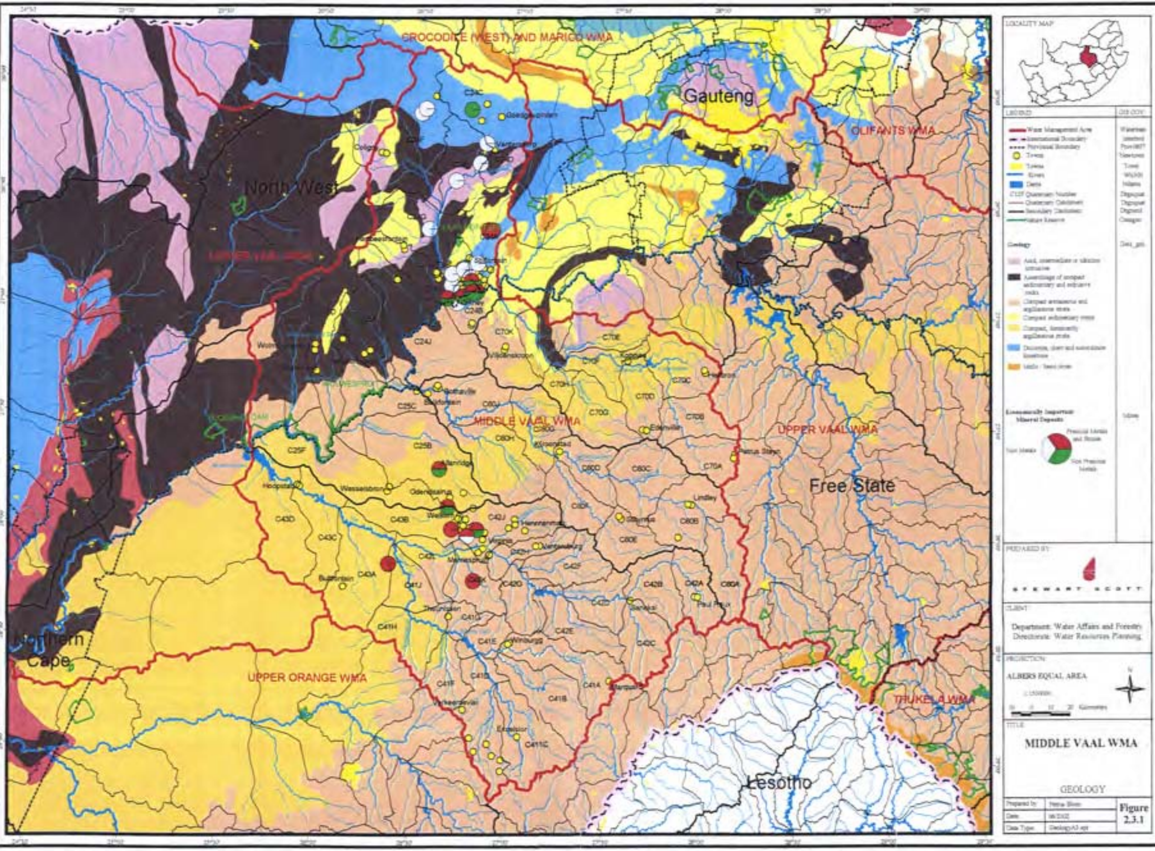
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
MEAN ANNUAL EVAPORATION
Figure 2.2.2



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Geology
Economically Important Mineral Deposits
PREPARED BY
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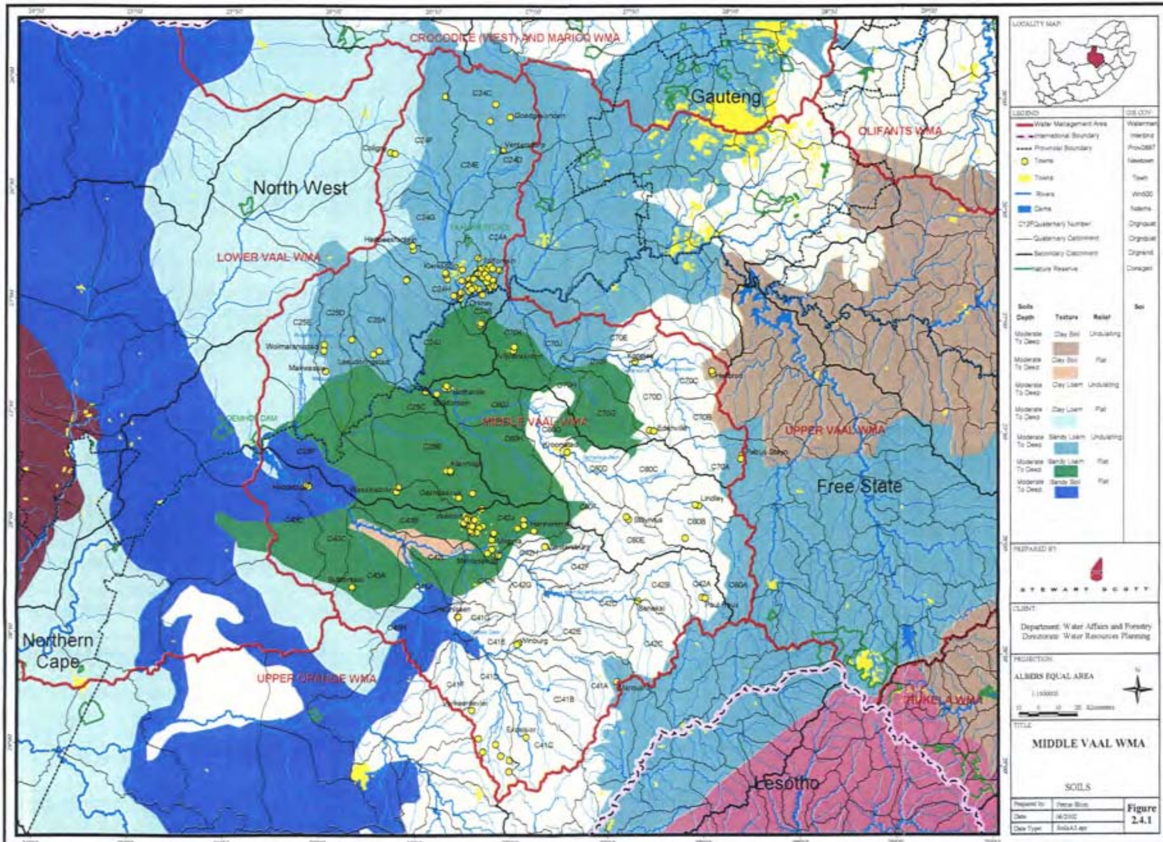
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
GEOLOGY
Figure 2.3.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Soils
Depth
Texture
Relief
Moderate To Deep
Clay Soil
Undulating
Flat
Clay Loam
Sandy Loam
Sandy Soil
PREPARED BY:
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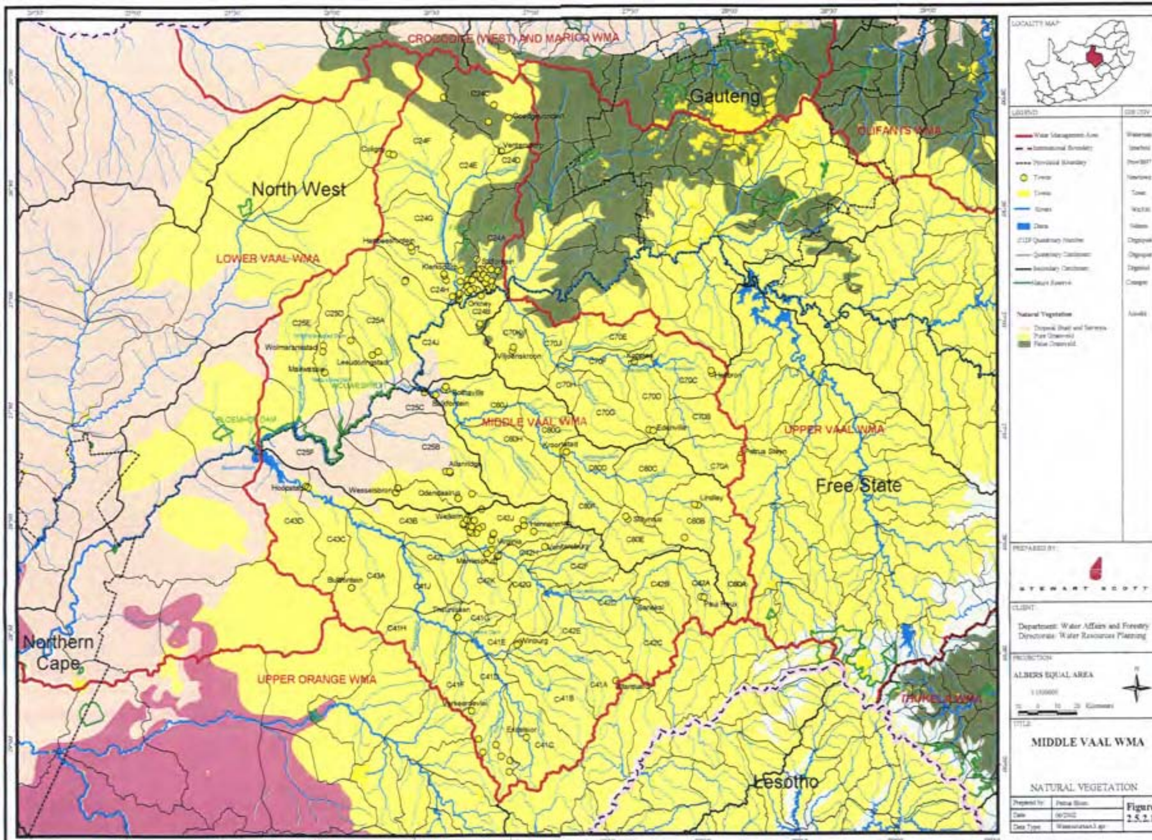
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
SOILS
Figure 2.4.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
Lesotho
LOCALITY MAP
LEGEND
Natural Vegetation
PREPARED BY:
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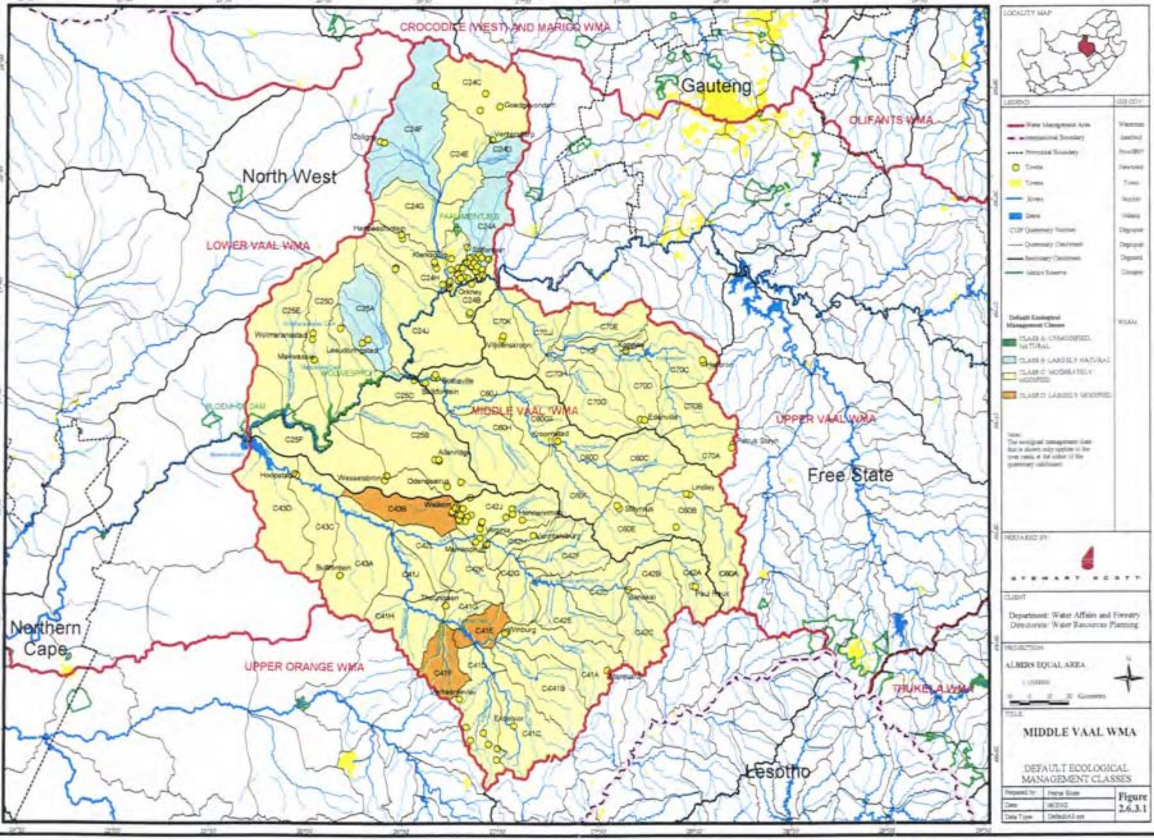
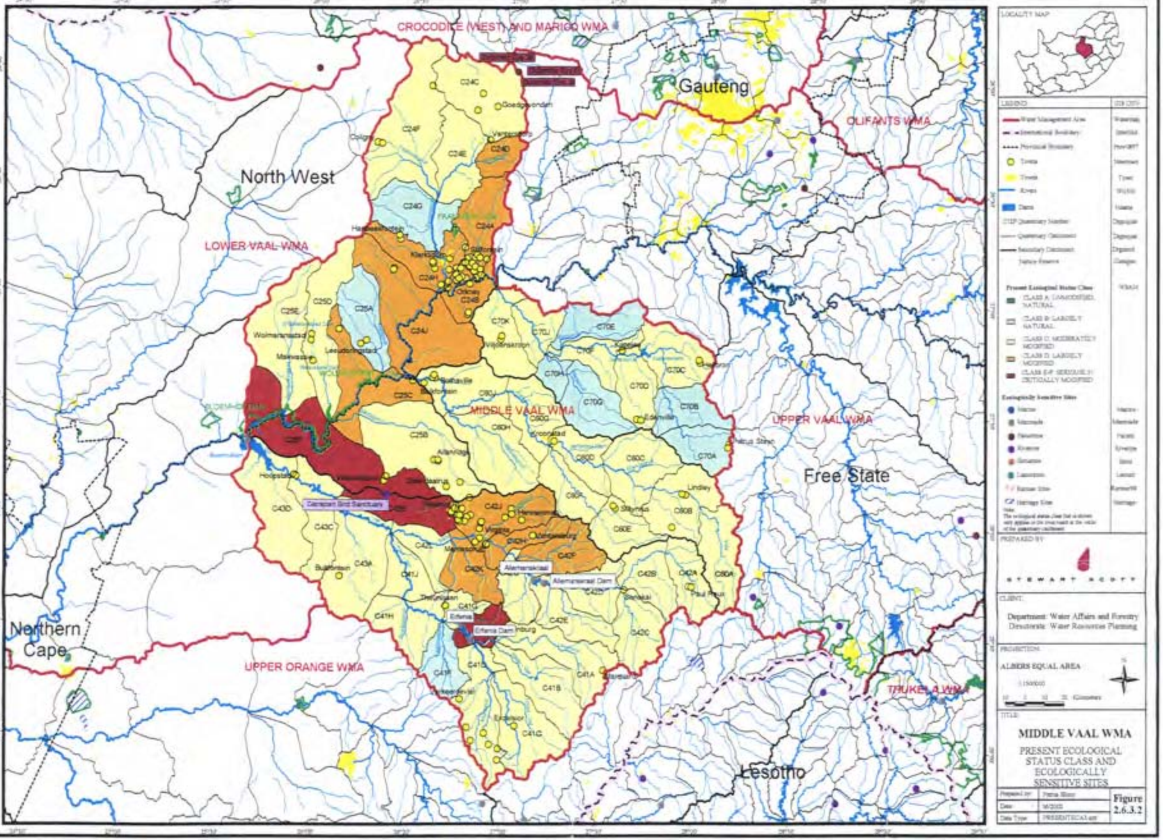
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
NATURAL VEGETATION
Figure 2.5.2.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Default Ecological Management Classes
CLASS A: UNMODIFIED, NATURAL
CLASS B: LARGELY NATURAL
CLASS C: MODERATELY MODIFIED
CLASS D: LARGELY MODIFIED
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Figure 2.6.3.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
Lesotho
LOCALITY MAP
LEGEND
Present Ecological Status Class
CLASS A: UNMODIFIED, NATURAL
CLASS B: LARGELY NATURAL
CLASS C: MODERATELY MODIFIED
CLASS D: LARGELY MODIFIED
CLASS E/F: SERIOUSLY/CRITICALLY MODIFIED
Ecologically Sensitive Sites
PREPARED BY
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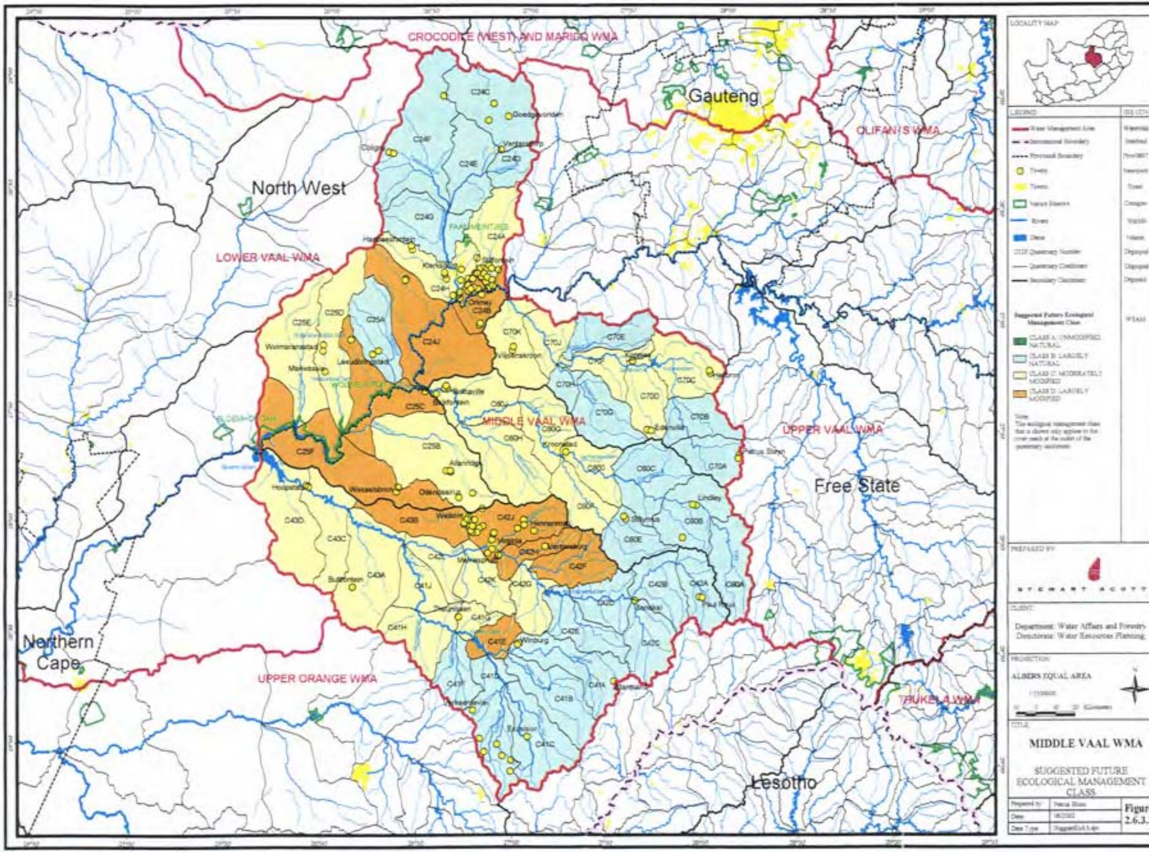
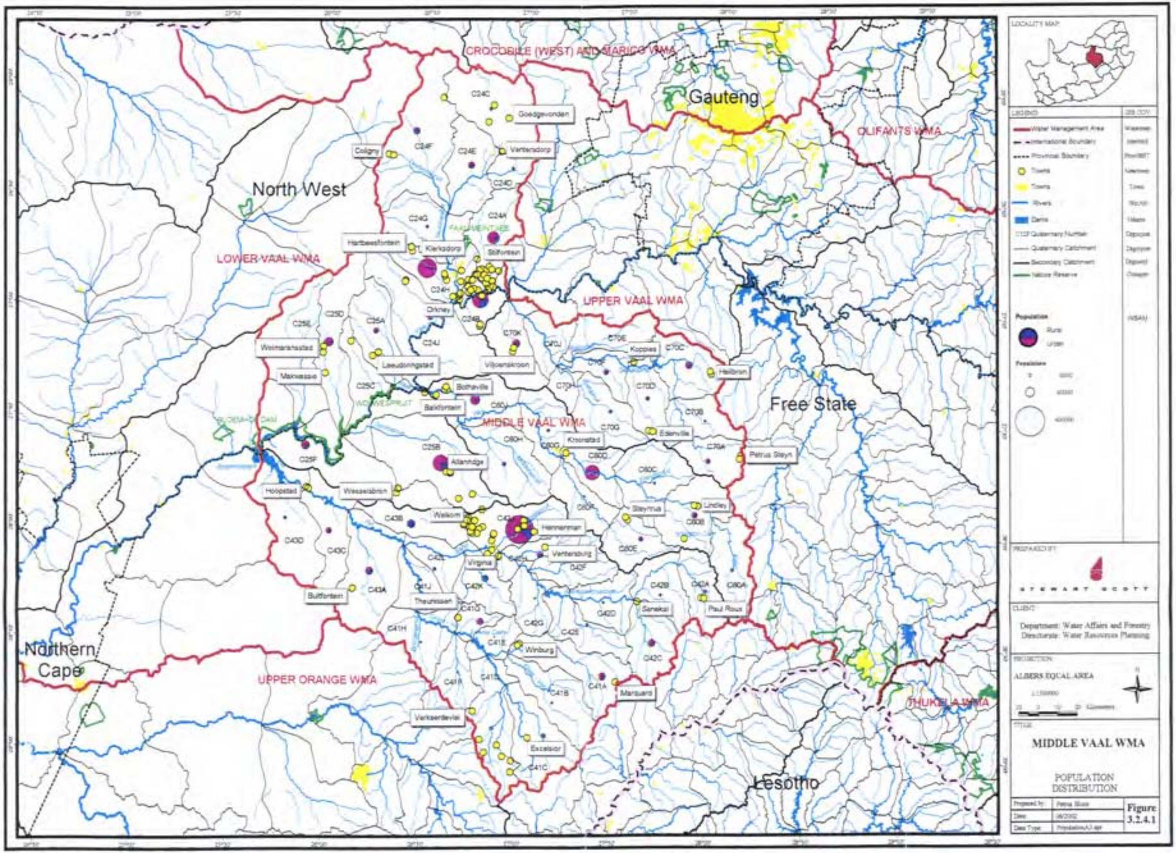
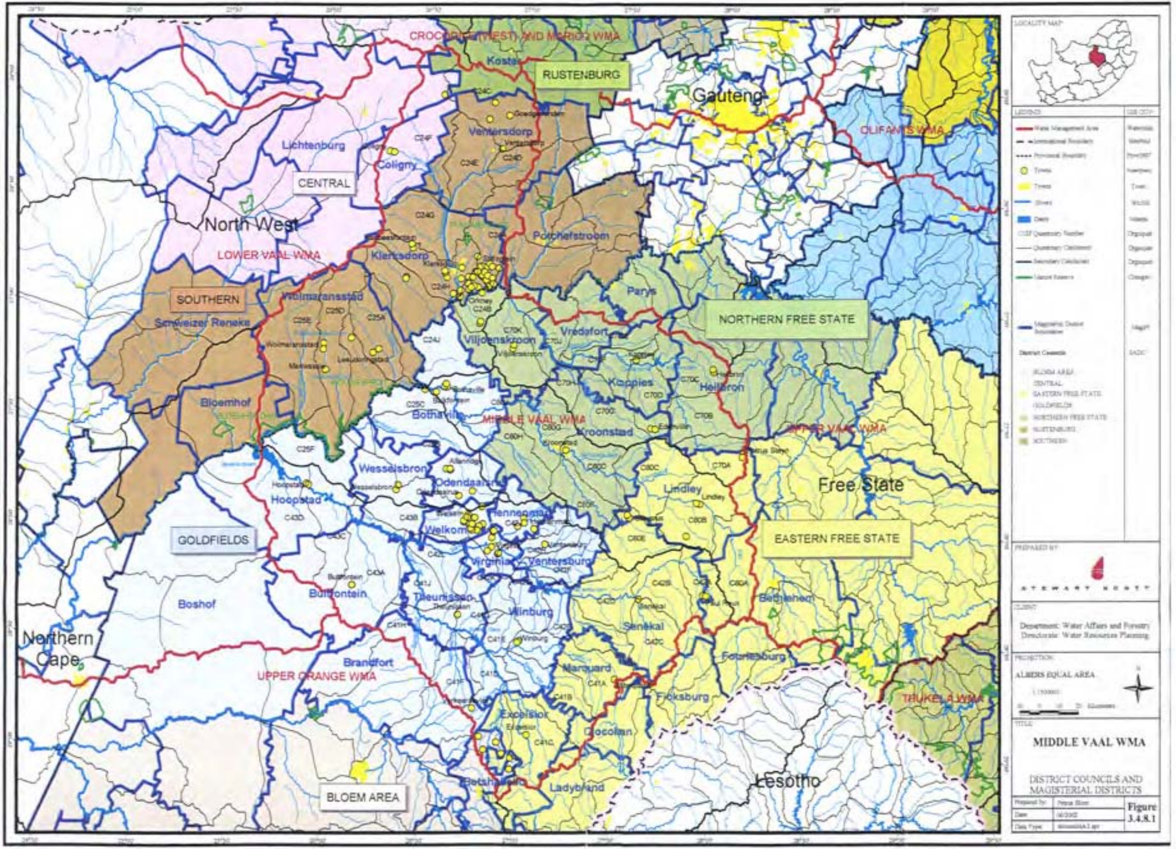
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES
Figure 2.6.3.2

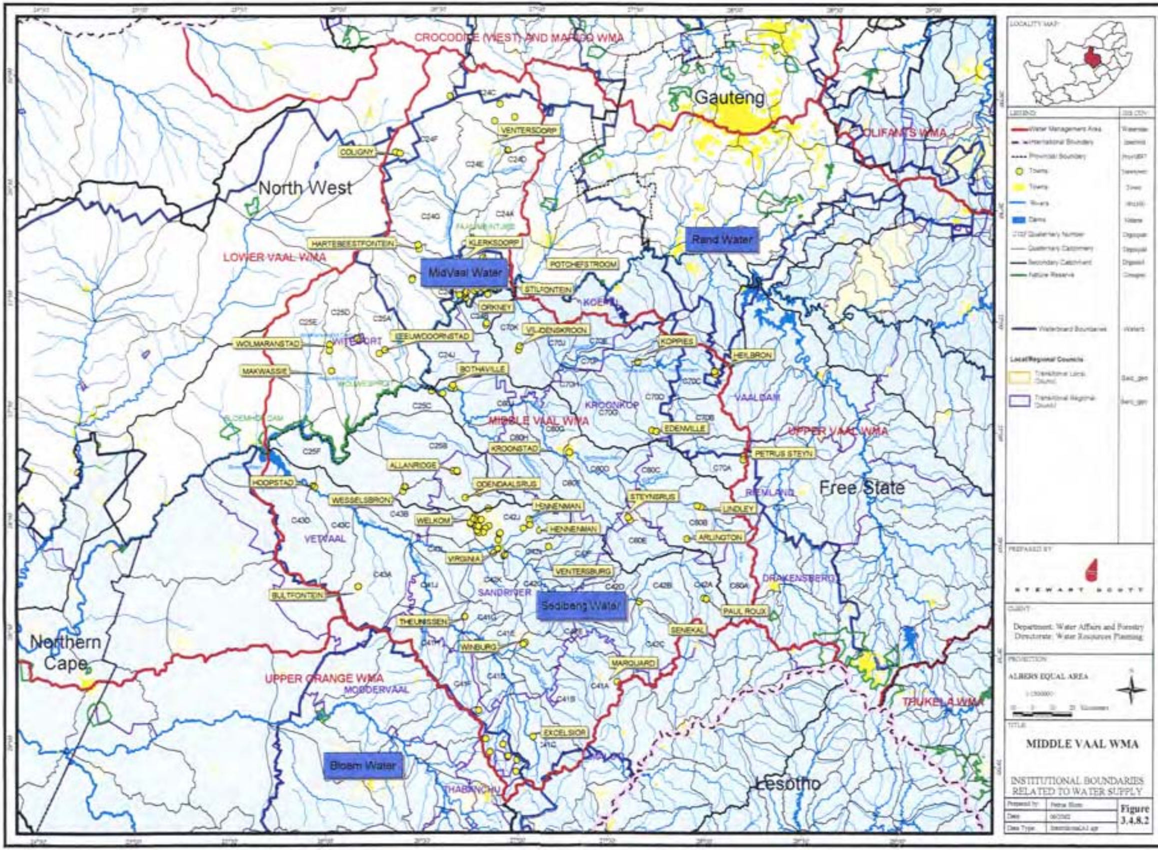


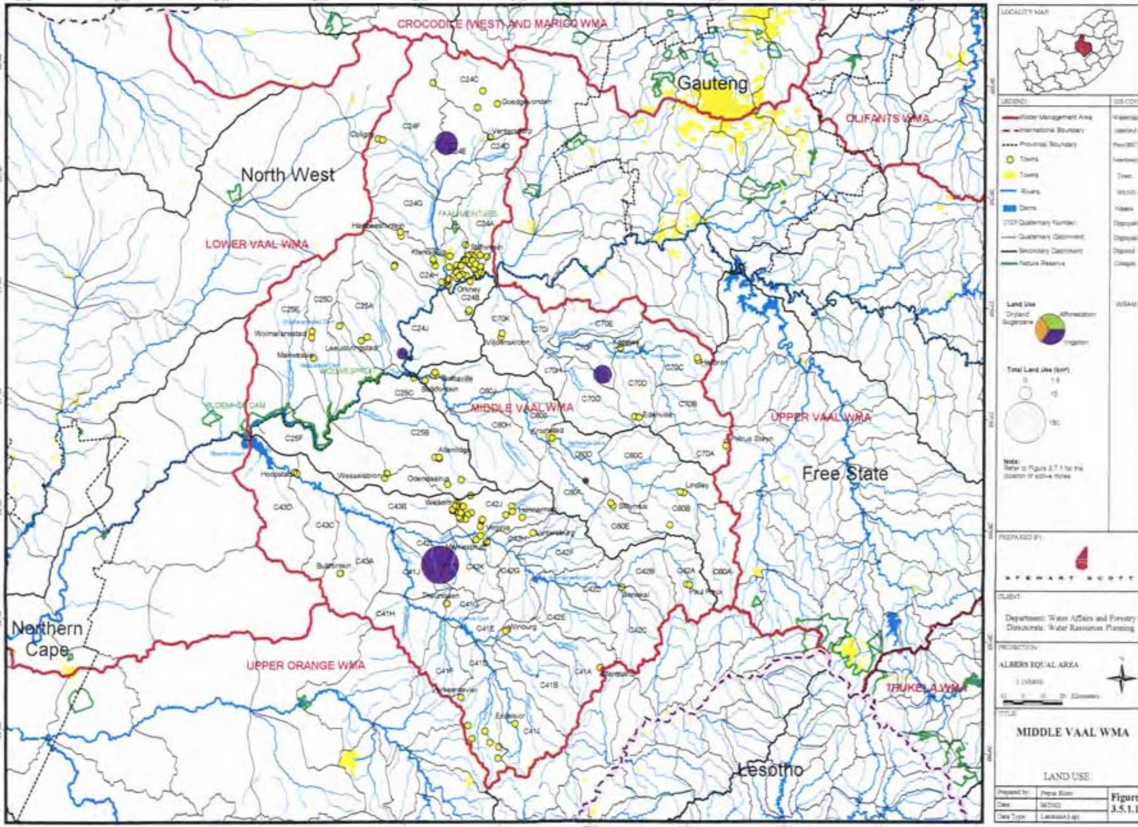
CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Klerksdorp
Orkney
Wolmaransstad
Kroonstad
Welkom
Virginia
Hennenman
Ventersburg
Winburg
Lindley
Petrus Steyn
Edenville
Heilbron
Hoopstad
Wesselsbron
Odendaalsrus
Allanridge
Bultfontein
Theunissen
Senekal
Paul Roux
Brandfort
Excelsior
Suggested Future Ecological Management Class
CLASS A: UNMODIFIED NATURAL
CLASS B: LARGELY NATURAL
CLASS C: MODERATELY MODIFIED
CLASS D: LARGELY MODIFIED
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASS
Figure 2.6.3.3


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
UPPER VAAL WMA
MIDDLE VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Goedgevonden
Coligny
Ventersdorp
Hartbeesfontein
Klerksdorp
Stilfontein
Orkney
Wolmaransstad
Makwassie
Leeudoringstad
Viljoenskroon
Bothaville
Balkfontein
Koppies
Heilbron
Edenville
Kroonstad
Petrus Steyn
Allanridge
Hoopstad
Wesselsbron
Welkom
Hennenman
Steynrus
Lindley
Ventersburg
Virginia
Bultfontein
Theunissen
Senekal
Paul Roux
Winburg
Marquard
Verkeerdevlei
Excelsior
C24C
C24F
C24E
C24D
C24G
C24A
C24H
C24B
C24J
C25E
C25D
C25A
C25C
C25B
C25F
C70K
C70J
C70E
C70C
C70F
C70H
C70D
C70B
C70G
C70A
C60J
C60H
C60G
C60D
C60C
C60F
C60B
C60E
C60A
C43B
C43D
C43C
C43A
C42L
C42H
C42F
C42K
C42J
C42B
C42A
C42D
C42G
C42E
C42C
C41J
C41G
C41H
C41E
C41F
C41D
C41B
C41A
C41C
LOCALITY MAP
LEGEND
Population
Rural
Urban
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
POPULATION DISTRIBUTION
Prepared by:
Date:
Data Type:
Figure 3.2.4.1

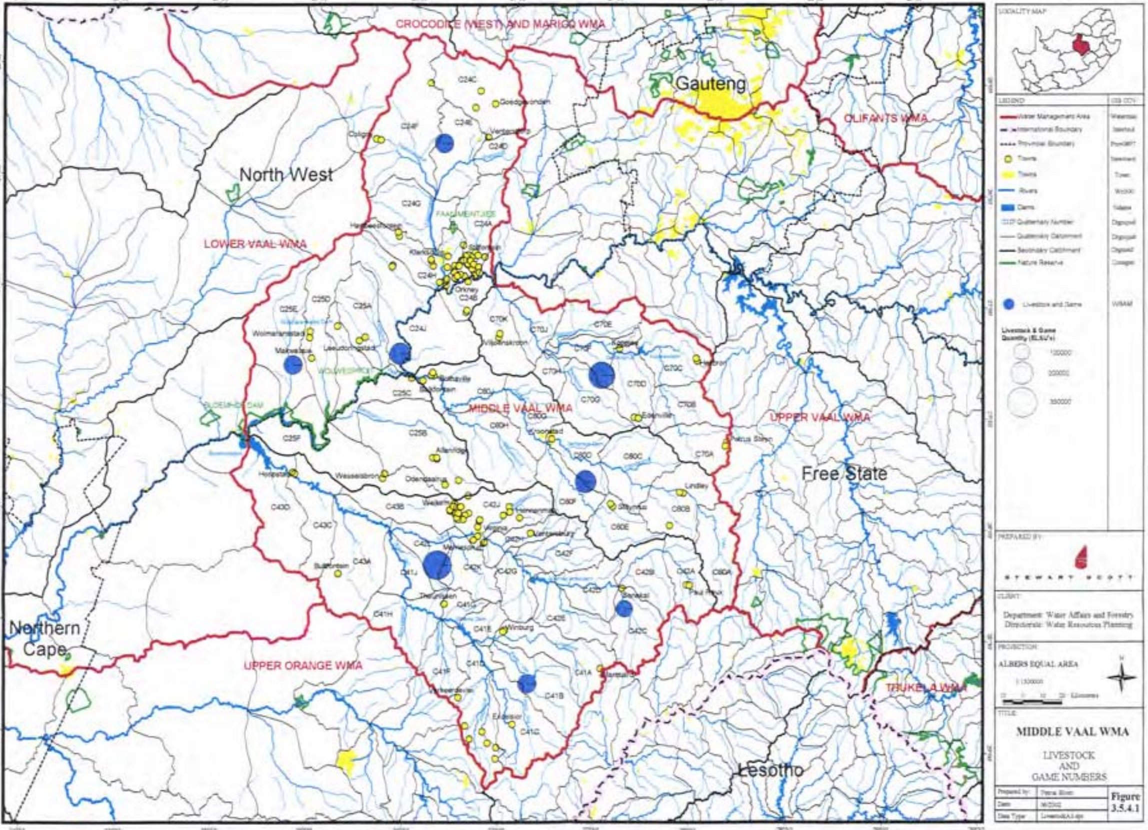


LOCALITY MAP
LEGEND
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS
Figure 3.4.8.1
RUSTENBURG
CENTRAL
SOUTHERN
NORTHERN FREE STATE
GOLDFIELDS
EASTERN FREE STATE
BLOEM AREA
Gauteng
North West
Free State
Northern Cape
Lesotho
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
OLIFANTS WMA
THUKELA WMA
Lichtenburg
Coligny
Ventersdorp
Potchefstroom
Klerksdorp
Wolmaransstad
Schweizer Reneke
Bloemhof
Viljoenskroon
Vredefort
Parys
Koppies
Heilbron
Kroonstad
Bothaville
Wesselsbron
Odendaalsrus
Hoopstad
Welkom
Virginia
Ventersburg
Lindley
Bultfontein
Boshof
Theunissen
Winburg
Senekal
Bethlehem
Brandfort
Marquard
Ficksburg
Fouriesburg
Excelsior
Clocolan
Ladybrand

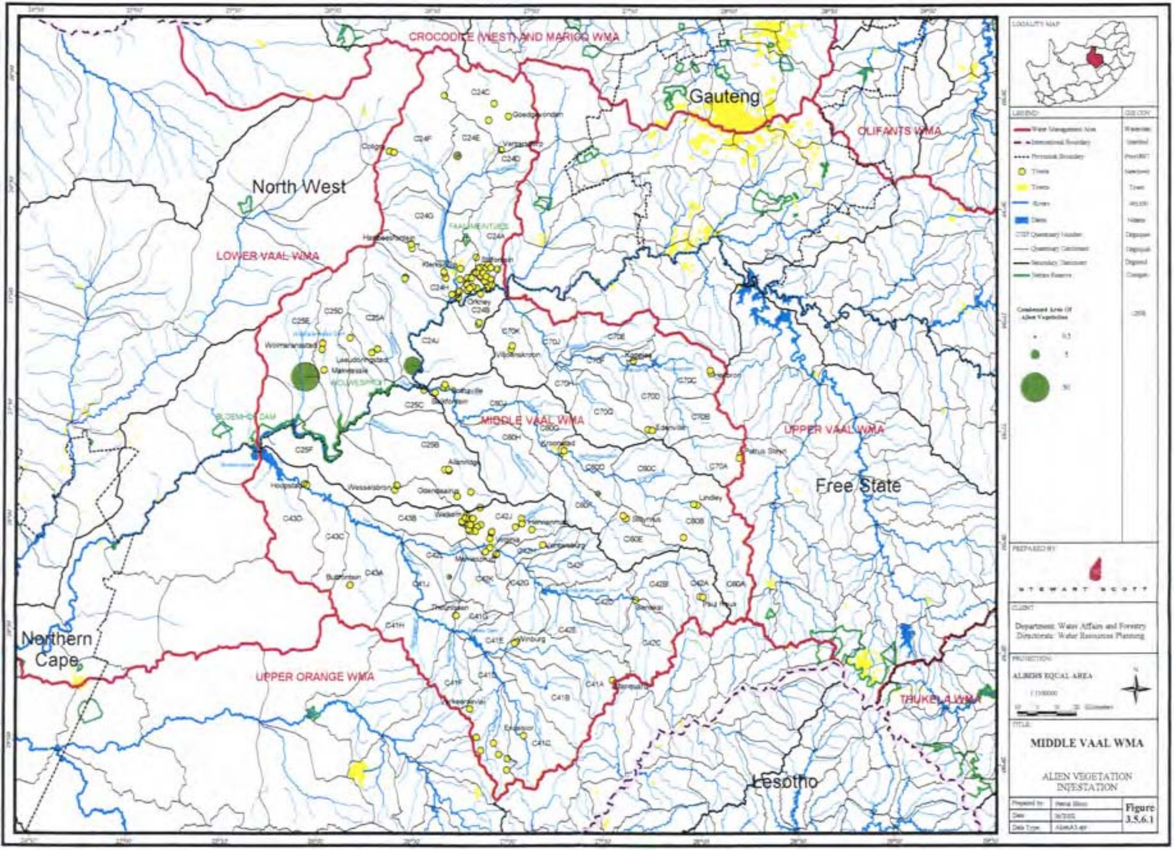

CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Free State
Northern Cape
Lesotho
MidVaal Water
Rand Water
Sedibeng Water
Bloem Water
VENTERSDORP
COLIGNY
HARTEBEESTFONTEIN
KLERKSDORP
POTCHEFSTROOM
STILFONTEIN
ORKNEY
VILJOENSKROON
KOPPIES
HEILBRON
WOLMARANSTAD
LEEUWDOORNSTAD
MAKWASSIE
BOTHAVILLE
KROONSTAD
EDENVILLE
PETRUS STEYN
ALLANRIDGE
HOOPSTAD
ODENDAALSRUS
WESSELSBRON
HENNENMAN
STEYNSRUS
LINDLEY
WELKOM
ARLINGTON
VIRGINIA
VENTERSBURG
BULTFONTEIN
PAUL ROUX
THEUNISSEN
SENEKAL
WINBURG
MARQUARD
EXCELSIOR
THABANCHU
KROONKOP
VAALDAM
RIEMLAND
VETVAAL
SANDRIVER
DRAKENSBERG
MODDERVAAL
BLOEMHOF DAM
STEWART SCOTT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
MIDDLE VAAL WMA
INSTITUTIONAL BOUNDARIES
RELATED TO WATER SUPPLY
Figure
3.4.8.2



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Land Use
Dryland
Sugarcane
Afforestation
Irrigation
Total Land Use (km²)
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
LAND USE
Figure 3.5.1.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Number
Quaternary Catchment
Secondary Catchment
Nature Reserve
Livestock and Game
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
LIVESTOCK
AND
GAME NUMBERS
Figure
3.5.4.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Kroonstad
Welkom
Virginia
Winburg
Hoopstad
Bothaville
Orkney
Klerksdorp
Heilbron
Lindley
Senekal
Paul Roux
Ventersburg
Wesselsbron
Allanridge
Theunissen
Excelsior
Edenville
Petrus Steyn
Steynsrus
Bultfontein
Wolmaransstad
Leeudoringstad
Makwassie
Coligny
Viljoenskroon
Koppies
Hennenman
BLOEMHOF DAM
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Condensed Area Of Alien Vegetation
0.5
5
50
PREPARED BY
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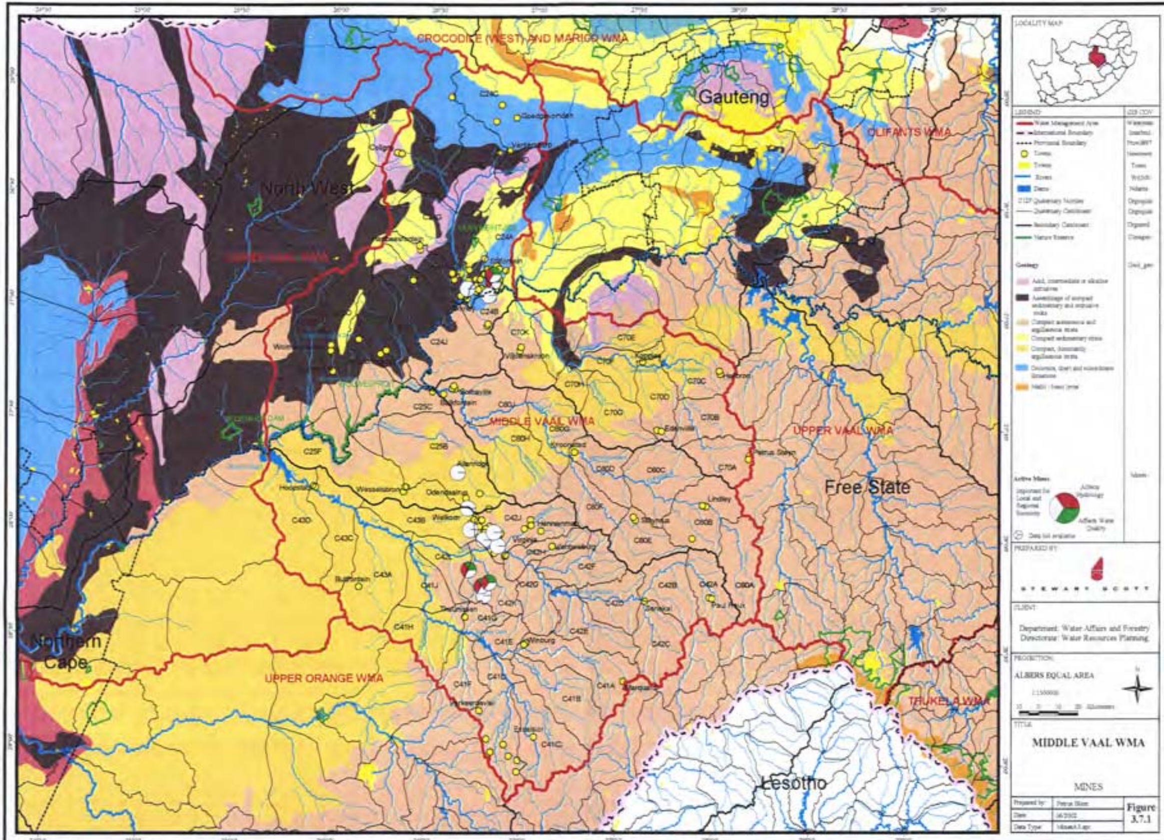
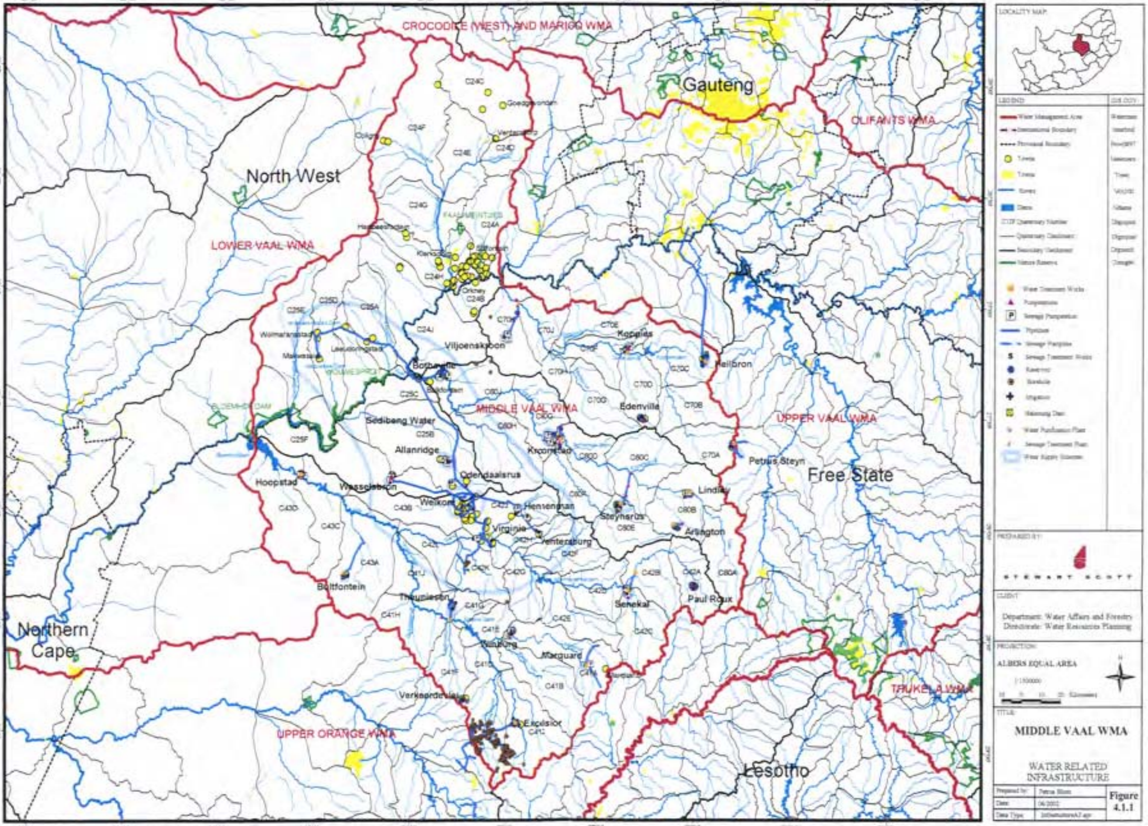
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
MIDDLE VAAL WMA
ALIEN VEGETATION INFESTATION
Prepared by
Date
Data Type
Figure 3.5.6.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
C24C
Coedgevonden
Ventersdorp
C24A
C24B
C24J
C70K
C70E
Viljoenskroon
Kroonstad
Hoopstad
Wesselsbron
Odendaalsrus
Welkom
Hennenman
Virginia
Bultfontein
Theunissen
Winburg
Marquard
Senekal
Paul Roux
Lindley
Steynsrus
Edenville
Petrus Steyn
Heilbron
Koppies
Bothaville
C25F
C25B
C25C
C43D
C43C
C43B
C43A
C41J
C41H
C41G
C41F
C41E
C41D
C41C
C41B
C41A
C42J
C42H
C42G
C42F
C42E
C42D
C42C
C42B
C42A
C42K
C60A
C60B
C60C
C60D
C60E
C60F
C60G
C60H
C60J
C70A
C70B
C70C
C70D
C70F
C70G
C70H
Active Mines
Important for Local and Regional Economy
Affects Hydrology
Affects Water Quality
Data not available
Geology
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
MINES
Prepared by:
Date
Data Type
Figure 3.7.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Orkney
Viljoenskroon
Bothaville
Koppies
Heilbron
Edenville
Kroonstad
Sedibeng Water
Allanridge
Odendaalsrus
Hoopstad
Wesselsbron
Welkom
Hennenman
Virginia
Ventersburg
Steynsrus
Lindley
Arlington
Petrus Steyn
Boltfontein
Theunissen
Senekal
Paul Roux
Marquard
Verkeerdevlei
Excelsior
Wolmaransstad
Makwassie
Leeudoringstad
LOCALITY MAP
LEGEND
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
WATER RELATED INFRASTRUCTURE
Figure 4.1.1

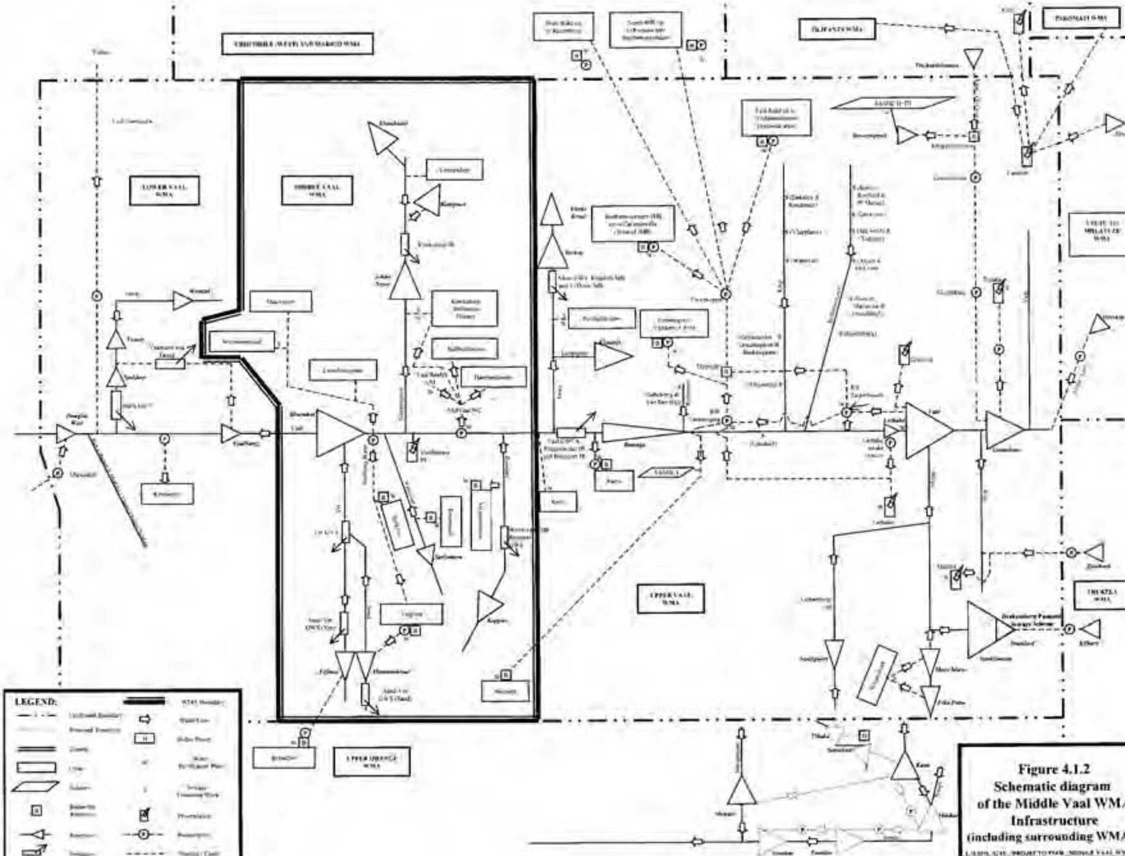
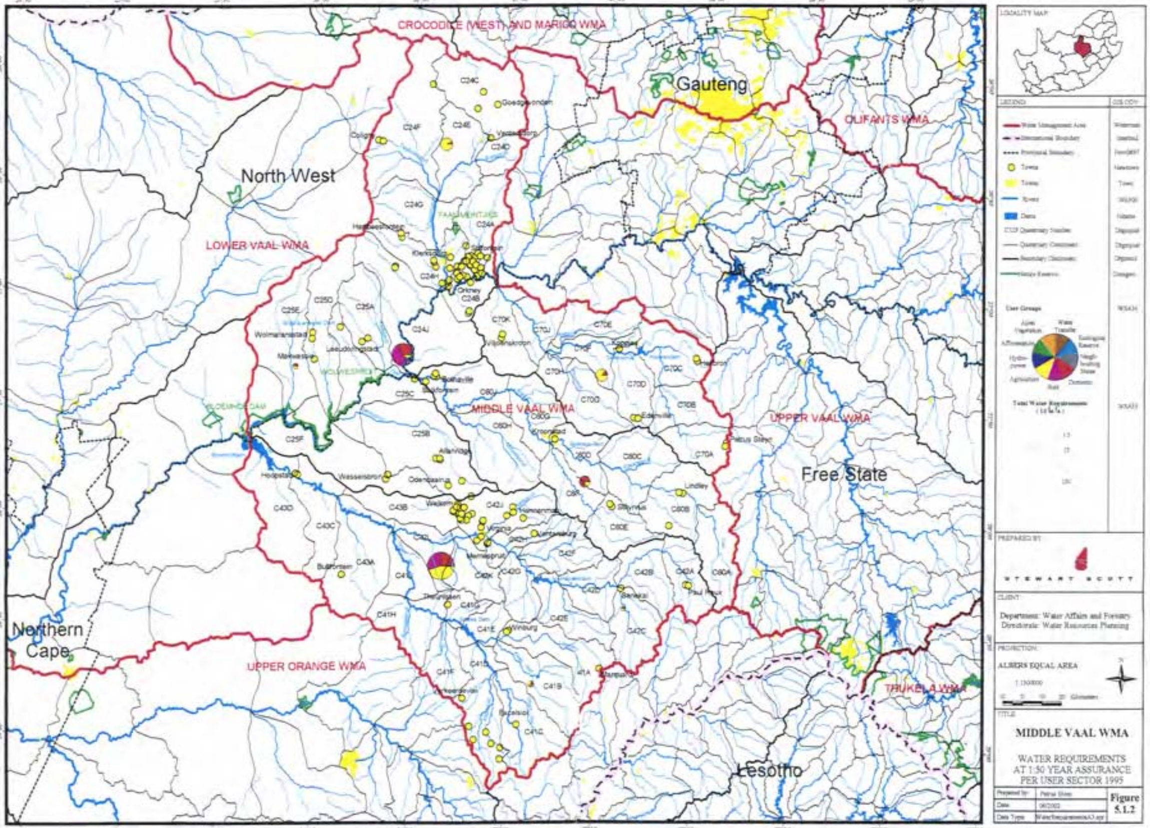


Figure 4.1.2
Schematic diagram of the Middle Vaal WMA Infrastructure (including surrounding WMA's)



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Orkney
Klerksdorp
Wolmaransstad
Bothaville
Kroonstad
Welkom
Virginia
Hoopstad
Wesselsbron
Odendaalsrus
Theunissen
Winburg
Lindley
Petrus Steyn
Edenville
Paul Roux
Senekal
Marquard
Excelsior
Heilbron
Coligny
Ventersdorp
Allanridge
Hennenman
Ventersburg
Brandfort
Viljoenskroon
Bultfontein
LEGEND
User Groups
Total Water Requirements
PREPARED BY:
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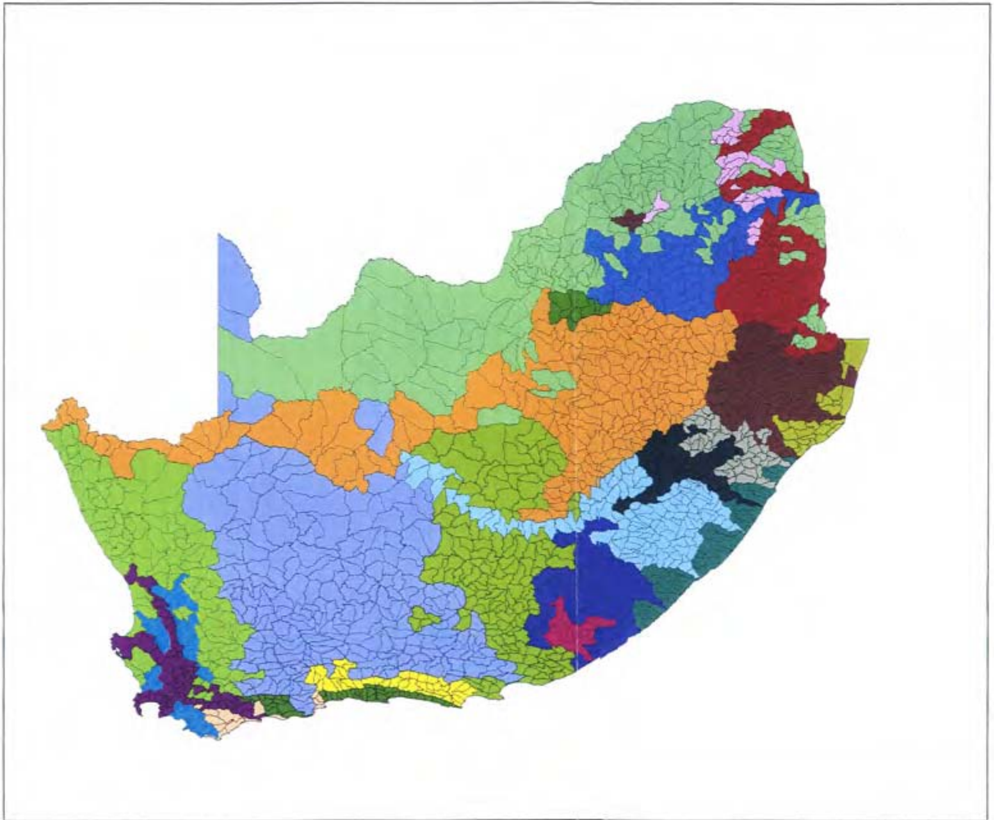
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
WATER REQUIREMENTS
AT 1:50 YEAR ASSURANCE
PER USER SECTOR 1995
Figure 5.1.2



PREPARED BY:

STEWART SCOTT

CLIENT:

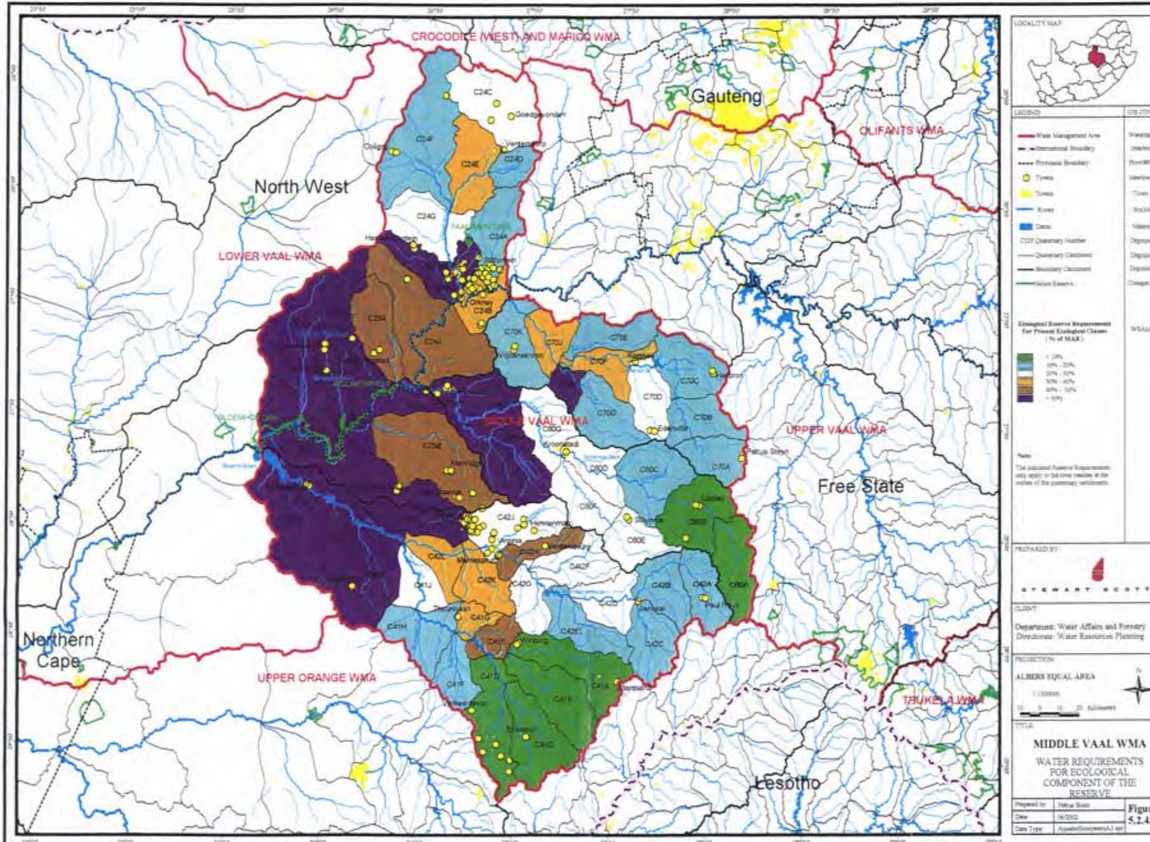
Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

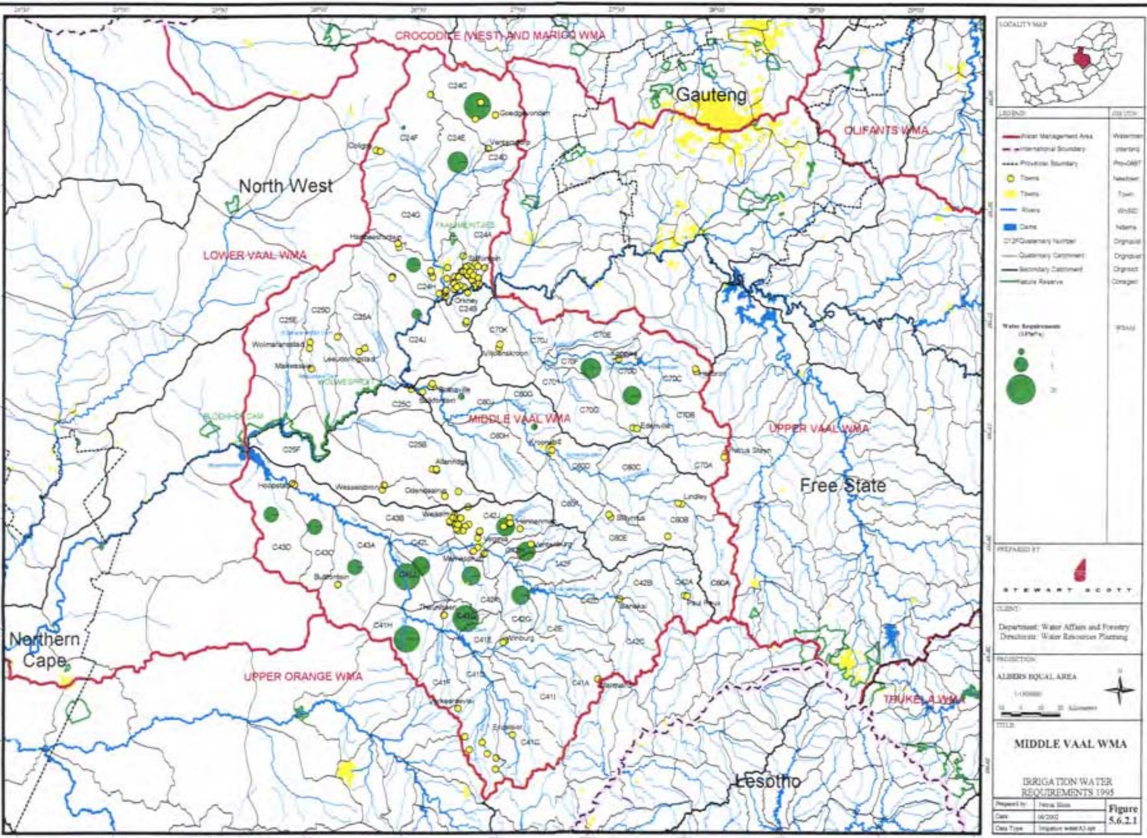
TITLE:

DESKTOP RESERVE
PARAMETER REGIONS

Prepared by:	Petrus Blum	Figure 5.2.1.1
Date:	11/2001	
Data Type:	DesktopA3.apr	



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
Lesotho
LOCALITY MAP
LEGEND
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Figure 5.2.4.1



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Orkney
Hoopstad
Wesselsbron
Odendaalsrus
Virginia
Winburg
Kroonstad
Edenville
Lindley
Petrus Steyn
Senekal
Paul Roux
Wolmaransstad
Leeudoringstad
Allanridge
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Water Requirements
PREPARED BY
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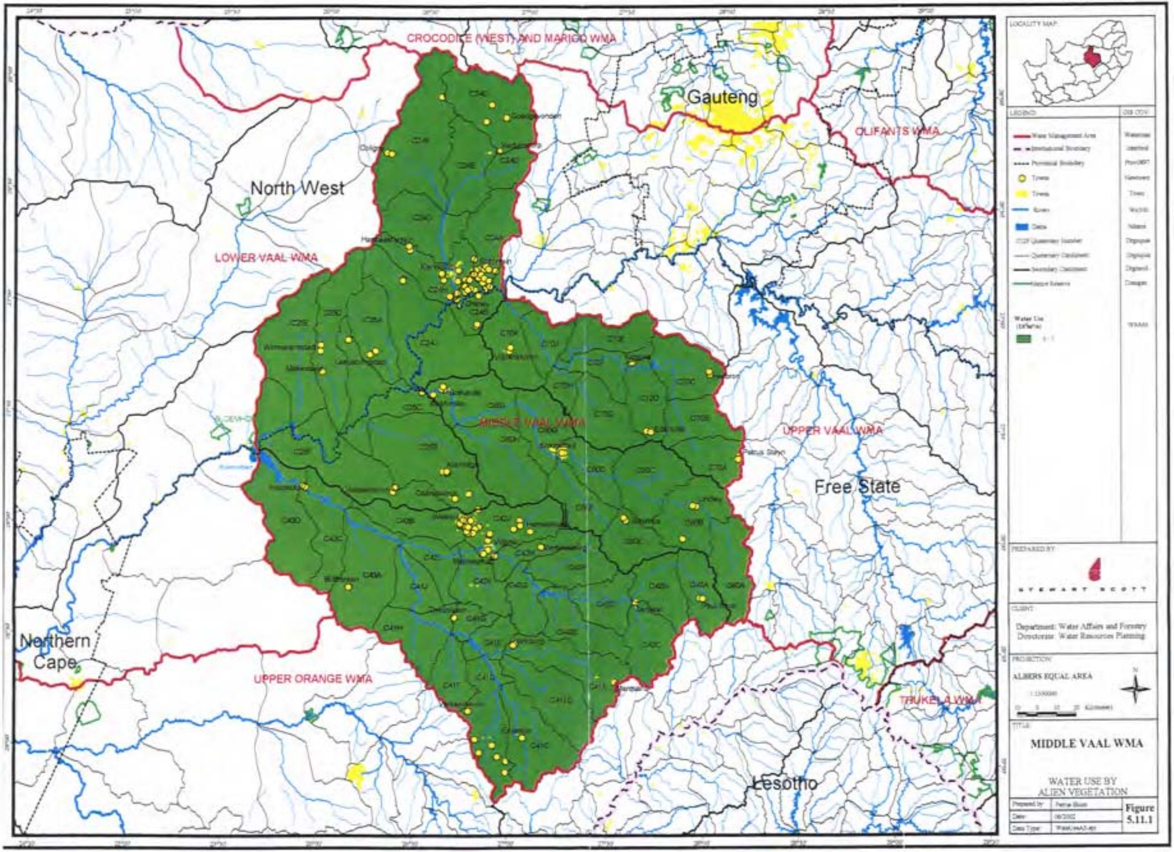
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
IRRIGATION WATER REQUIREMENTS 1995
Figure 5.6.2.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
PREPARED BY
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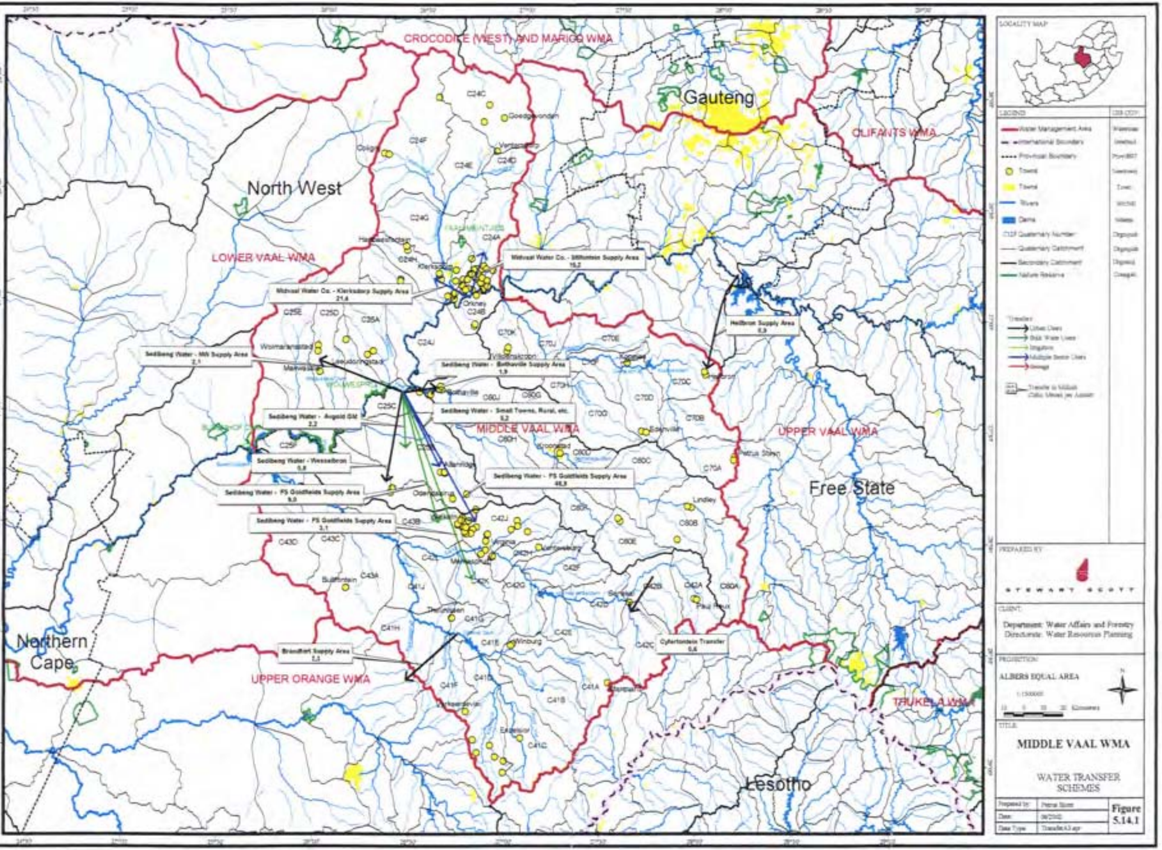
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
WATER USE BY
ALIEN VEGETATION
Figure
5.11.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Midvaal Water Co. - Klerksdorp Supply Area
21,4
Midvaal Water Co. - Stilfontein Supply Area
15,2
Heilbron Supply Area
0,9
Sedibeng Water - NW Supply Area
2,1
Sedibeng Water - Bothaville Supply Area
1,9
Sedibeng Water - Augold GM
2,2
Sedibeng Water - Small Towns, Rural, etc.
5,2
Sedibeng Water - Wesselsbron
5,8
Sedibeng Water - FS Goldfields Supply Area
46,9
Sedibeng Water - FS Goldfields Supply Area
9,0
Sedibeng Water - FS Goldfields Supply Area
3,1
Brandfort Supply Area
2,1
Cyferfontein Transfer
0,6
Klerksdorp
Orkney
Wolmaransstad
Leeudoringstad
Makwassie
Bothaville
Kroonstad
Allanridge
Odendaalsrus
Welkom
Virginia
Theunissen
Winburg
Senekal
Paul Roux
Petrus Steyn
Lindley
Edenville
Heilbron
Koppies
Viljoenskroon
Bultfontein
Excelsior
Goedgevonden
Coligny
C24A
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C25D
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C25F
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C70B
C70C
C70D
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C42G
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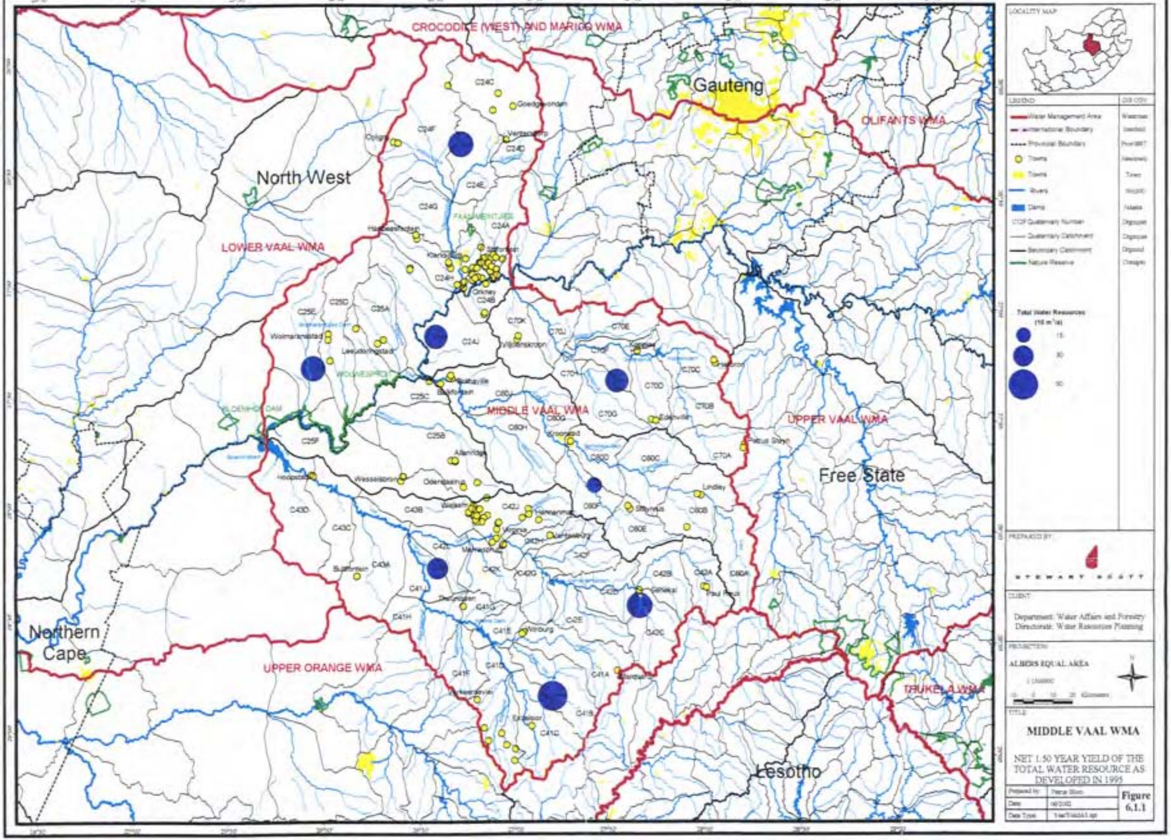
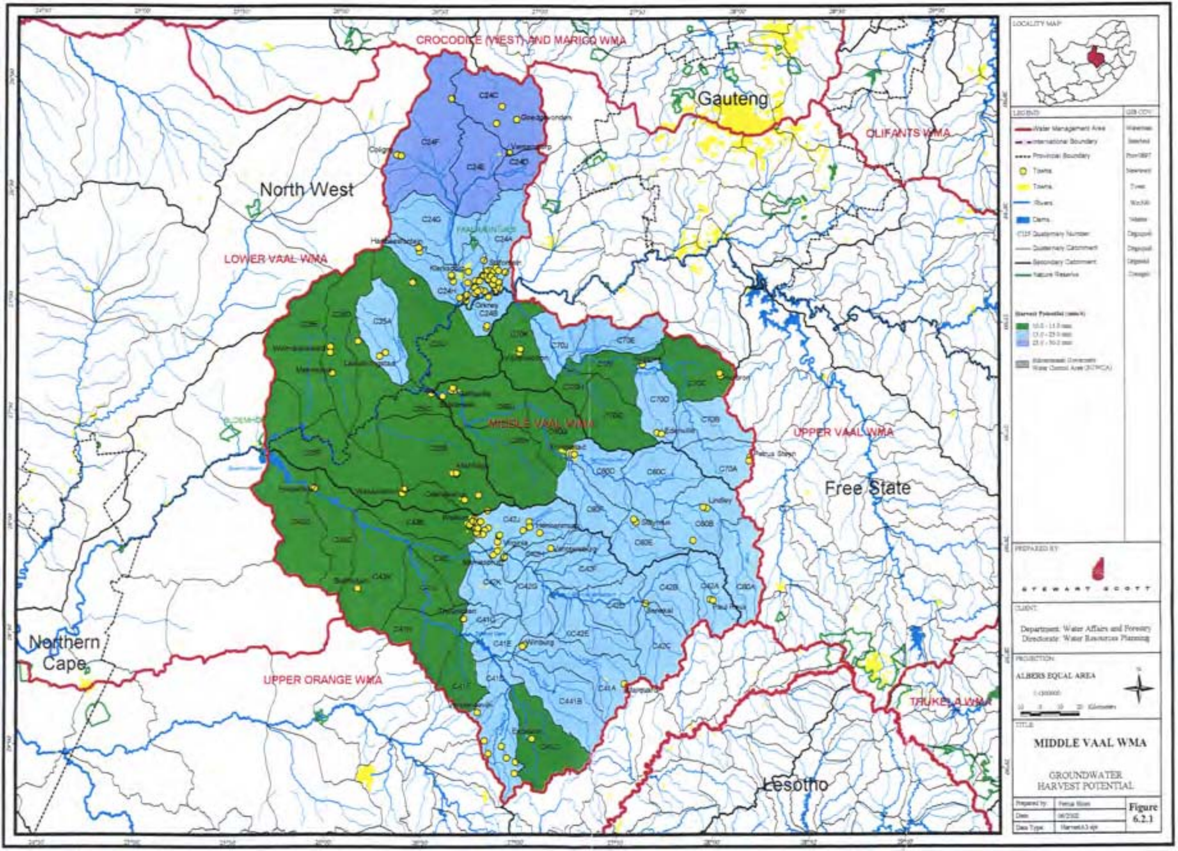
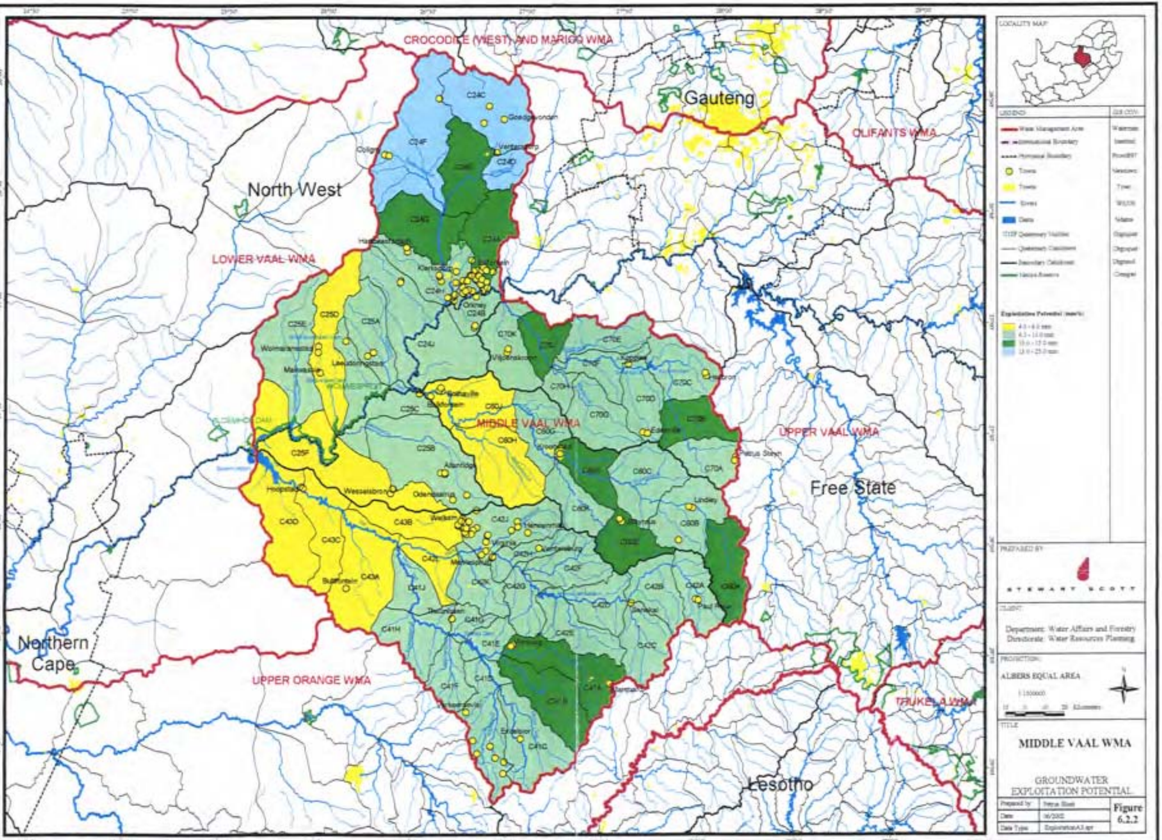
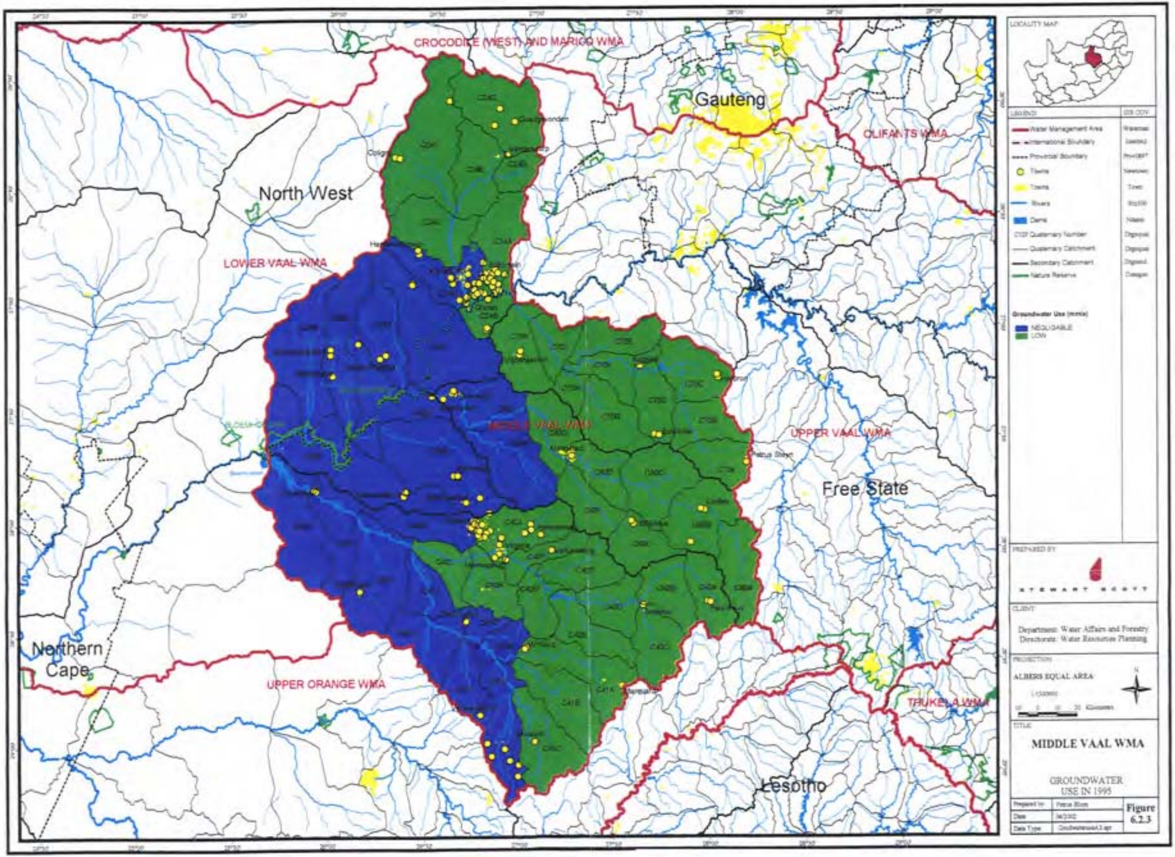
C42K
C43A
C43B
C43C
C43D
C41A
C41B
C41C
C41D
C41E
C41F
C41G
C41H
C41J
LOCALITY MAP
LEGEND
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
WATER TRANSFER SCHEMES
Figure 5.14.1

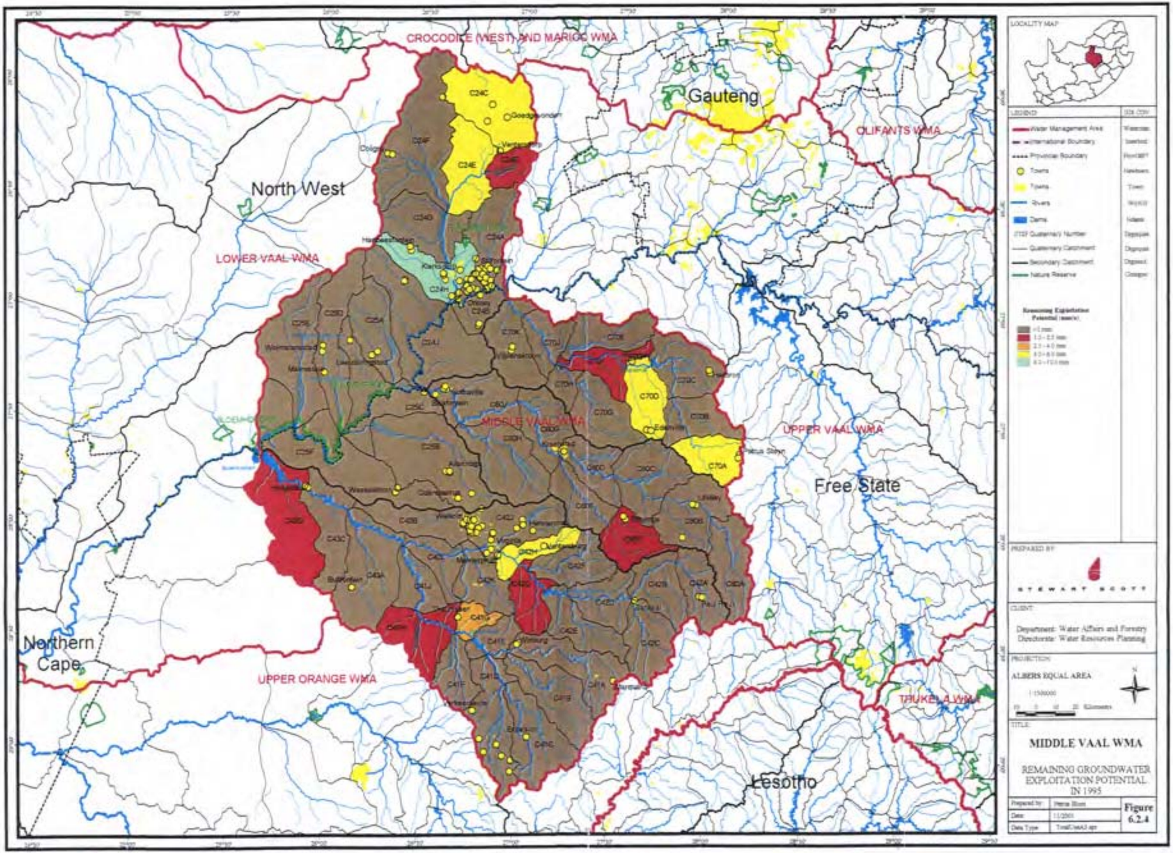

CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Total Water Resources
15
30
60
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE AS DEVELOPED IN 1995
Figure 6.1.1

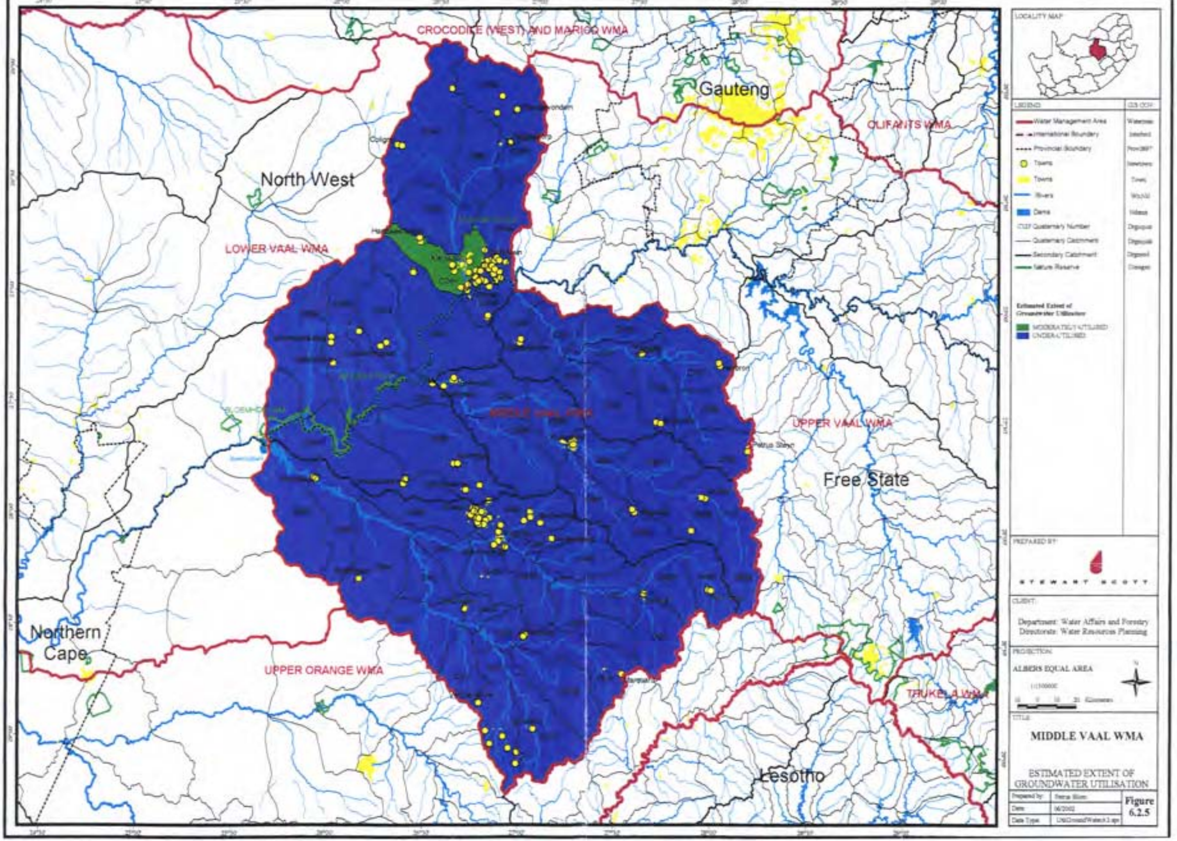

CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
Lesotho
THUKELA WMA
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
GROUNDWATER
HARVEST POTENTIAL
Figure
6.2.1



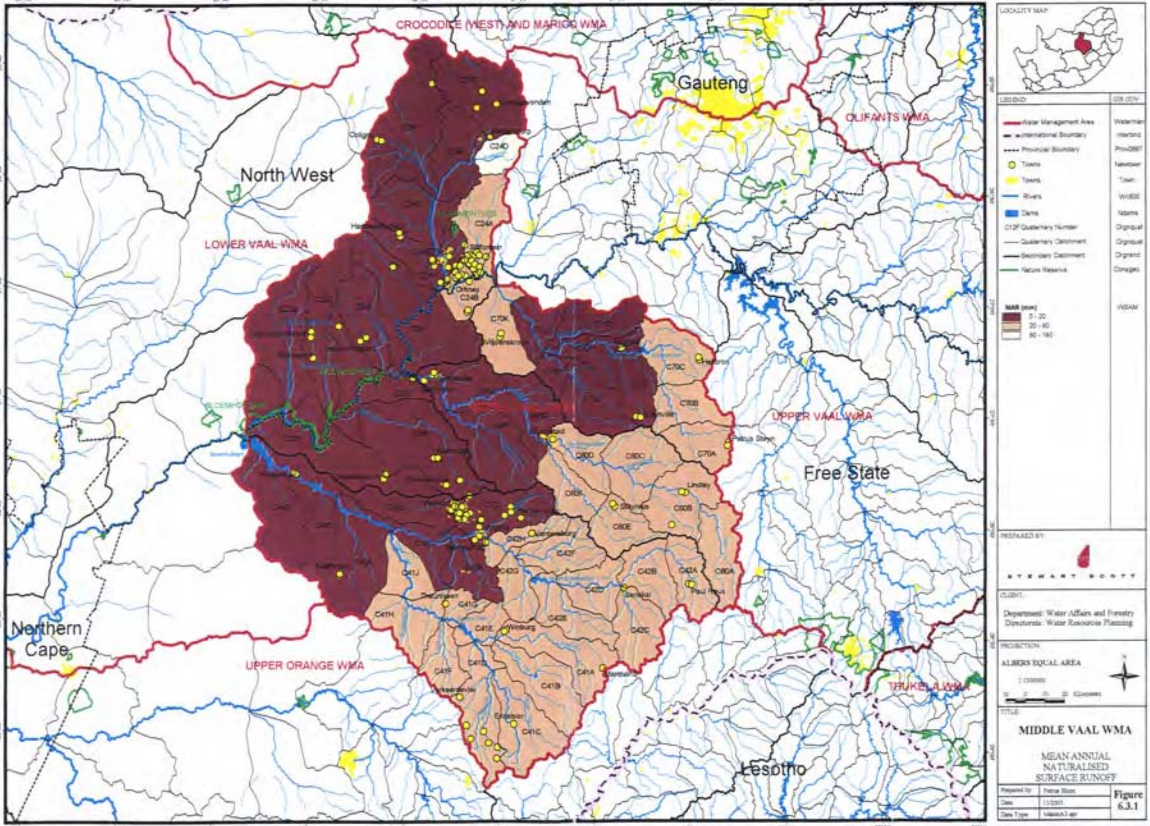
CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
GROUNDWATER
EXPLOITATION POTENTIAL
Figure
6.2.2

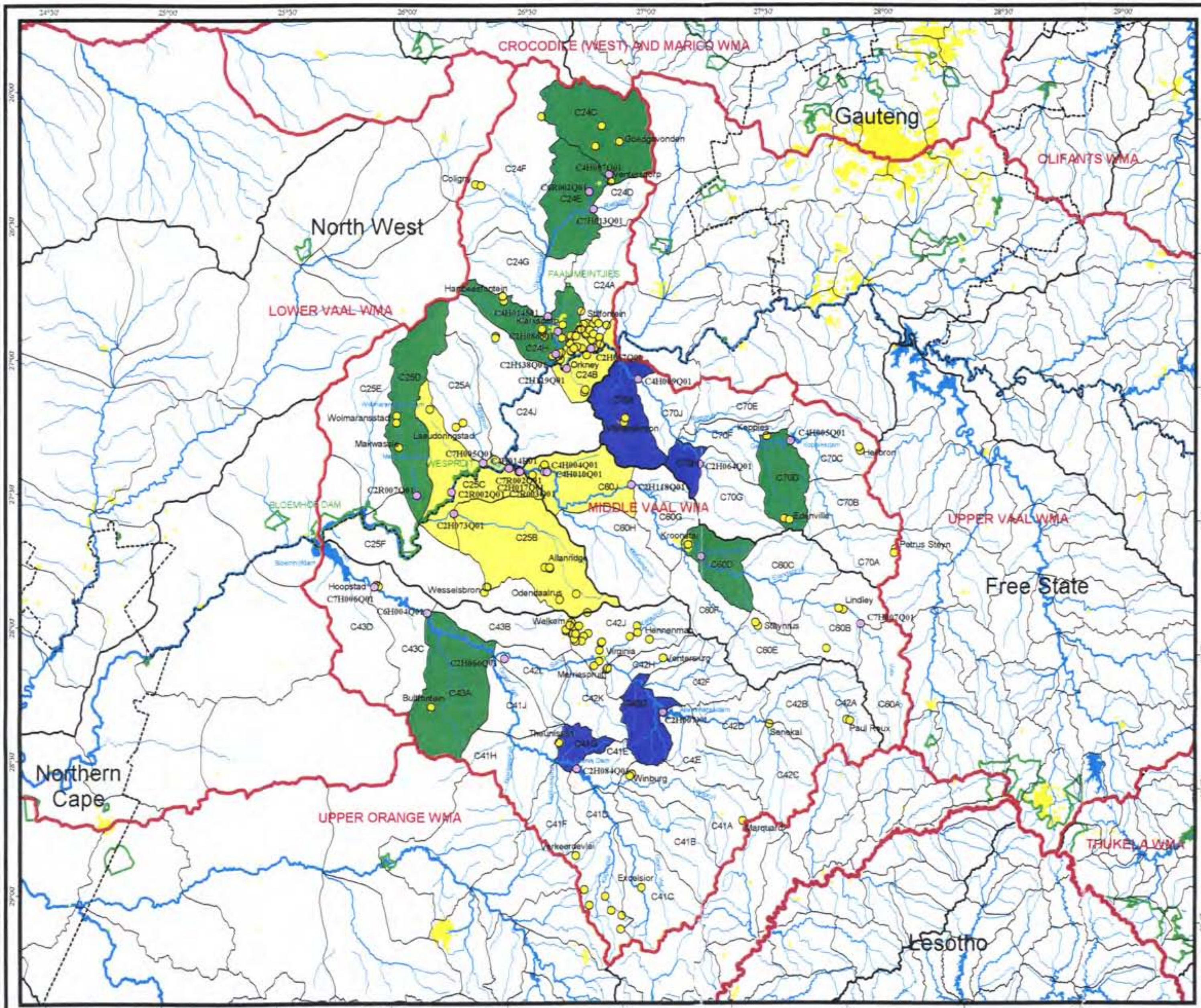

CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Groundwater Use (mm/a)
NEGLIGIBLE
LOW
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
GROUNDWATER USE IN 1995
Figure 6.2.3


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Remaining Exploitation Potential (mm/a)
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
REMAINING GROUNDWATER EXPLOITATION POTENTIAL IN 1995
Figure 6.2.4



CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Estimated Extent of Groundwater Utilisation
MODERATELY UTILISED
UNDERUTILISED
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
ESTIMATED EXTENT OF GROUNDWATER UTILISATION
Prepared by:
Date:
06/2002
Data Type:
Figure 6.2.5


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
MAR (mm)
0 - 20
20 - 80
80 - 160
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
MEAN ANNUAL NATURALISED SURFACE RUNOFF
Figure 6.3.1



LOCALITY MAP

LEGEND	GIS COV
Water Management Area	Waterman
International Boundary	Interbod
Provincial Boundary	Prov0897
Towns	Newtown
Towns	Town
Rivers	Wr500
Dams	Ndams
C12F Quaternary Number	Drgnquat
Quaternary Catchment	Drgnquat
Secondary Catchment	Drgnsecd
Nature Reserve	Consgeo

Mineralogical Surface Water Quality Class

- Ideal
- Good
- Marginal

Surface Water Quality Class

- Adequate Data

PREPARED BY:

STEWART SCOTT

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

1:1500000

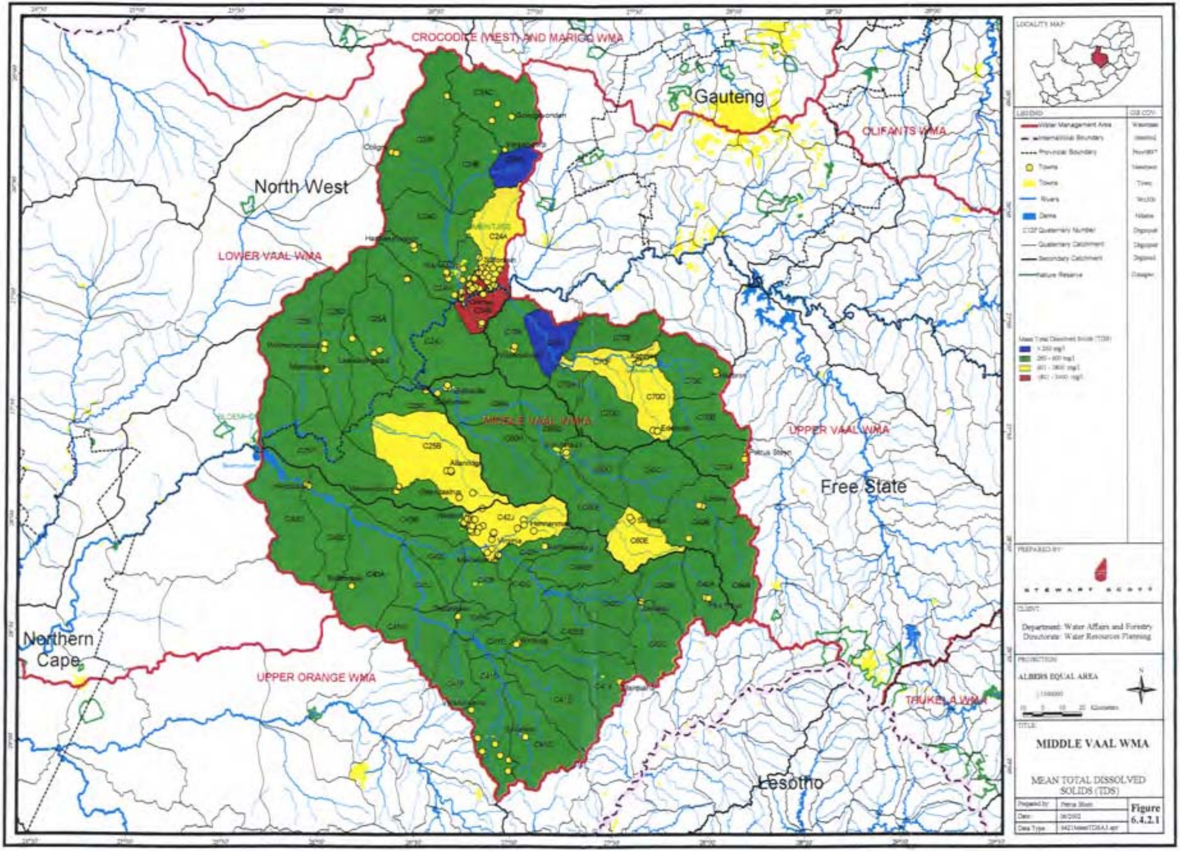
10 0 10 20 Kilometers

TITLE:

MIDDLE VAAL WMA

MINERALOGICAL SURFACE WATER QUALITY

Prepared by:	Petrus Blom	**Figure 6.4.1.1**
Date:	06/2002	
Data Type:	MineralSurfaceA3.apr	


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
C24A
C25B
C42J
C70D
C60E
LOCALITY MAP
LEGEND
PREPARED BY
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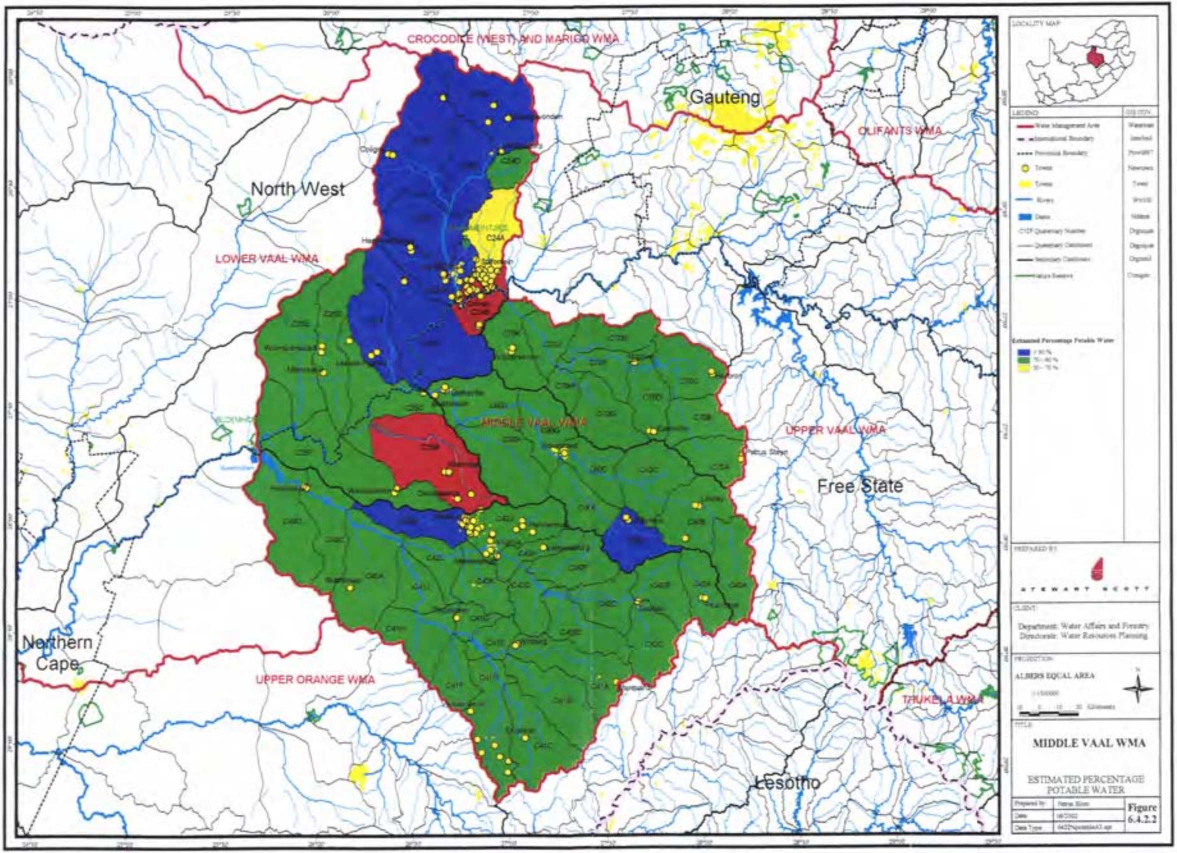
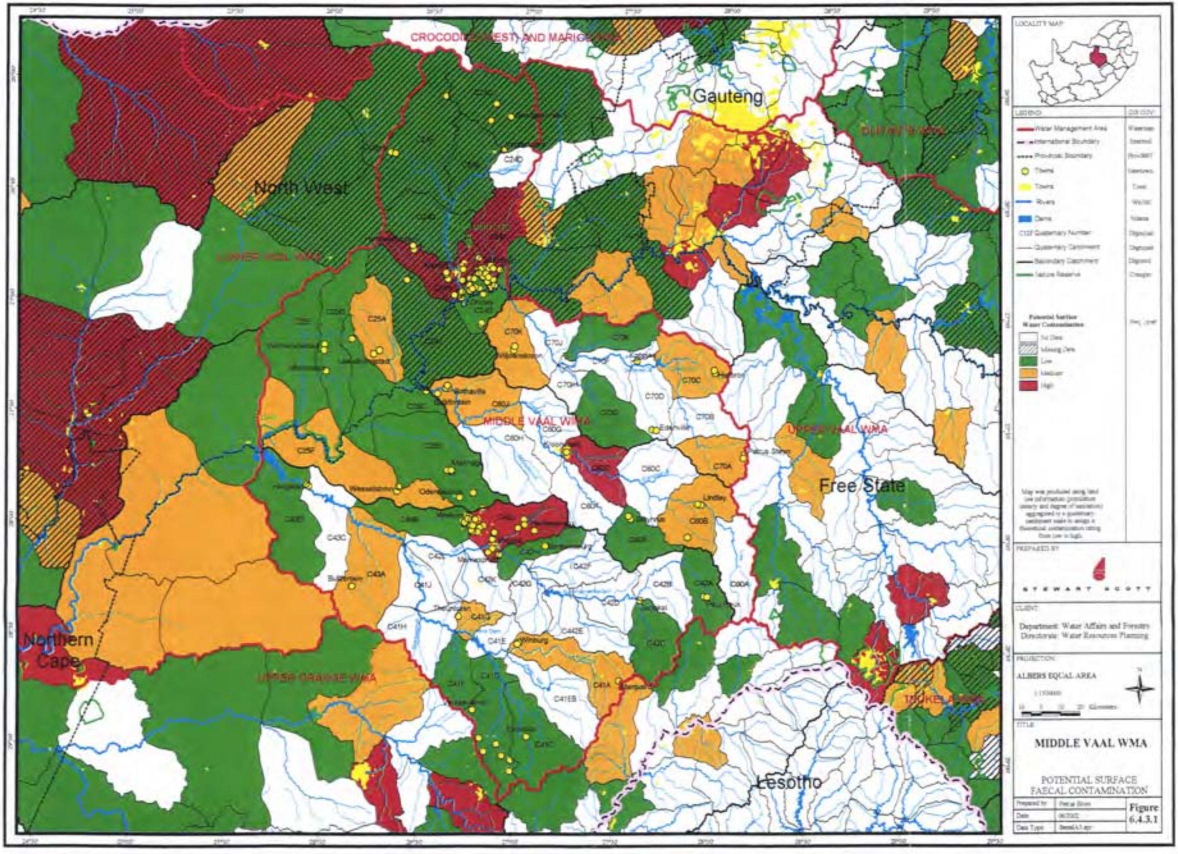
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
MEAN TOTAL DISSOLVED SOLIDS (TDS)
Figure 6.4.2.1


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
C24A
LOCALITY MAP
LEGEND
Estimated Percentage Potable Water
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
ESTIMATED PERCENTAGE POTABLE WATER
Prepared by:
Date:
Data Type:
Figure 6.4.2.2


CROCODILE (WEST) AND MARICO WMA
Gauteng
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
Lesotho
THUKELA WMA
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Potential Surface Water Contamination
No Data
Missing Data
Low
Medium
High
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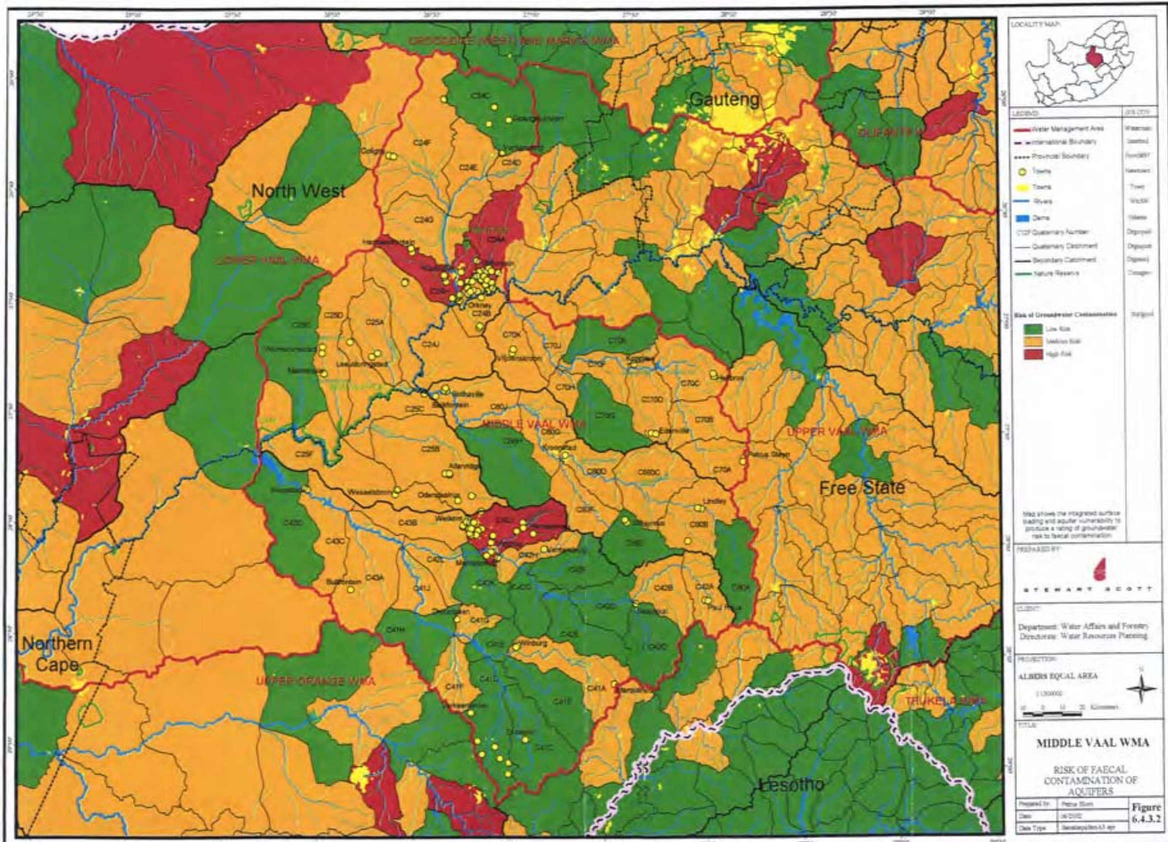
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
POTENTIAL SURFACE FAECAL CONTAMINATION
Figure 6.4.3.1


North West
Gauteng
Free State
Northern Cape
Lesotho
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
LOCALITY MAP
LEGEND
Water Management Area
International Boundary
Provincial Boundary
Towns
Rivers
Dams
Quaternary Catchment
Secondary Catchment
Nature Reserve
Low Risk
Medium Risk
High Risk
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
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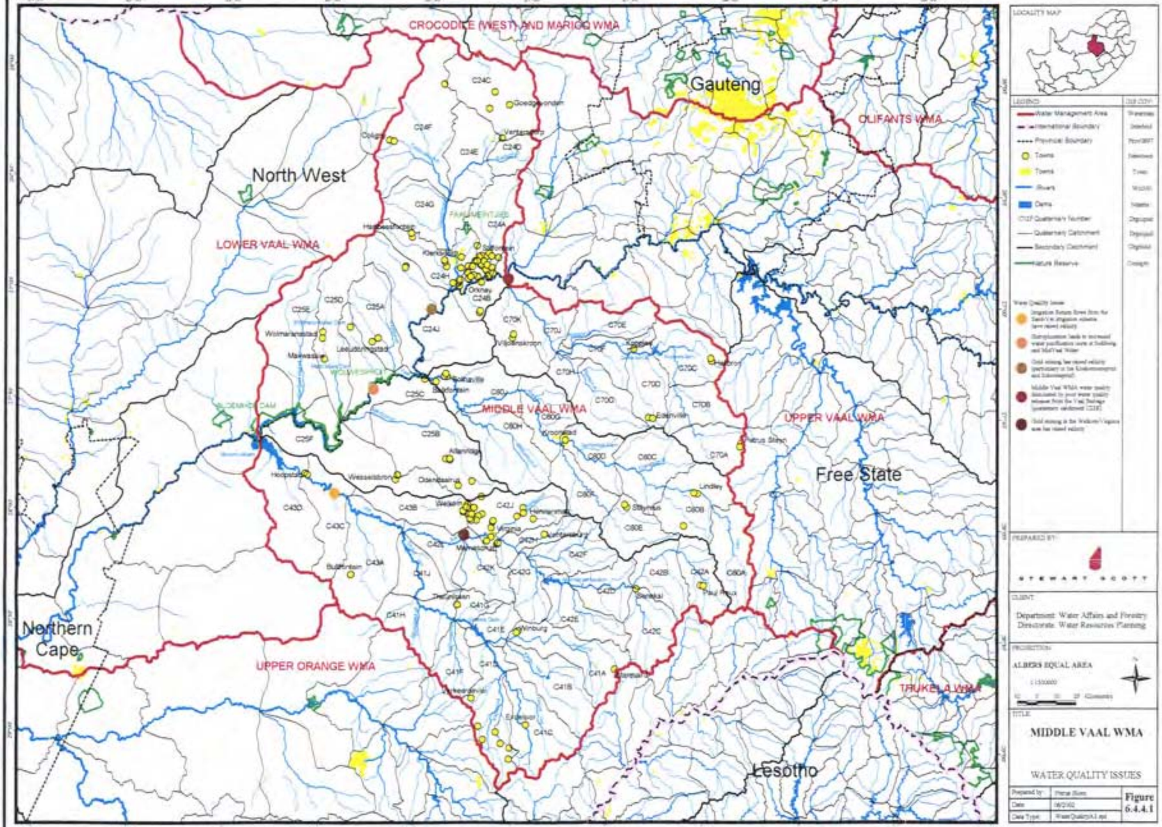
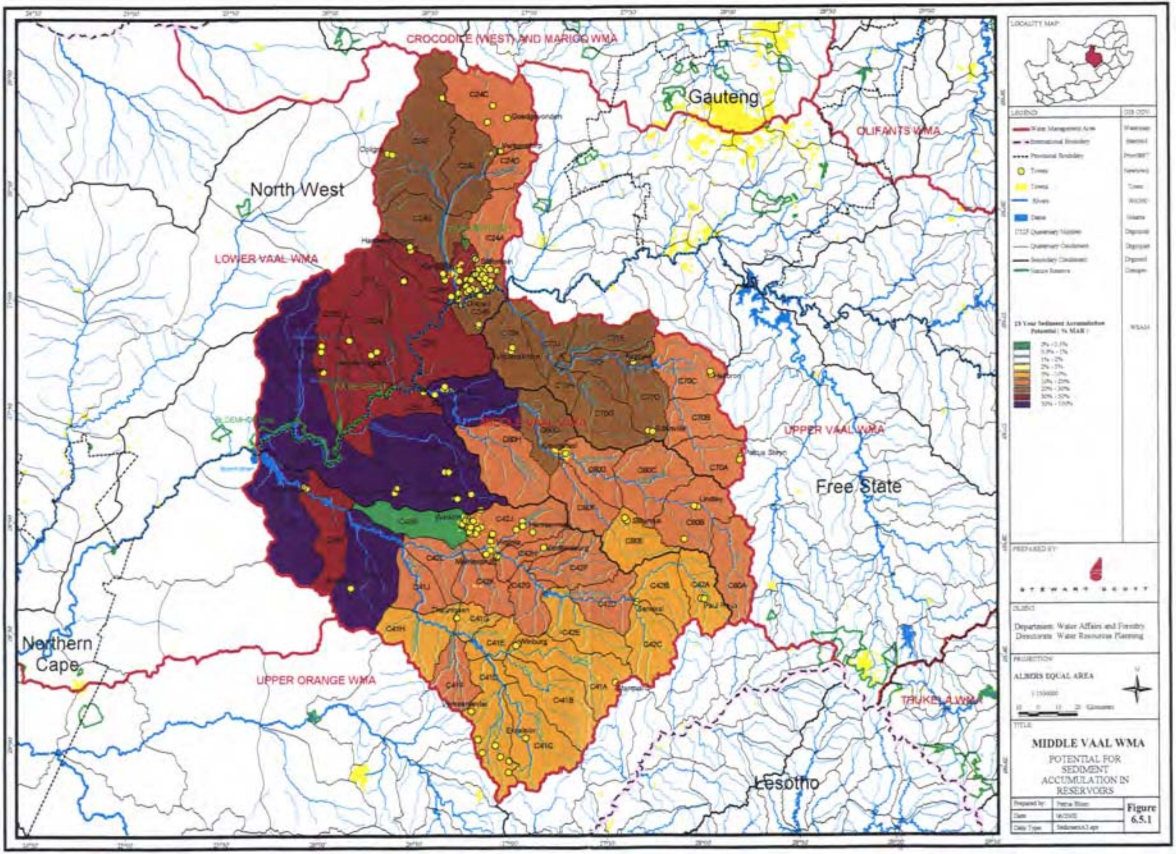
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
RISK OF FAECAL CONTAMINATION OF AQUIFERS
Figure 6.4.3.2


CROCODILE (WEST) AND MARICO WMA
Gauteng
OLIFANTS WMA
North West
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Orkney
Wolmaransstad
Hoopstad
Bultfontein
Theunissen
Winburg
Kroonstad
Lindley
Hennenman
Virginia
Welkom
Wesselsbron
Senekal
Paul Roux
Excelsior
Viljoenskroon
Bothaville
Heilbron
Petrus Steyn
Steynsrus
Ventersdorp
Coligny
Klerksdorp
Edenville
Goedgevonden
Makwassie
Leeudoringstad
Allanridge
Odendaalsrus
Marquard
Verkeerdevlei
Ventersburg
Brandfort
Stilfontein
Hartbeesfontein
Koppies
Bloemhof Dam
Wolwespruit
Faan Meintjies
Potchefstroom
C24C
C24F
C24E
C24D
C24G
C24A
C24H
C24B
C24J
C25D
C25E
C25A
C25C
C25B
C25F
C70K
C70J
C70E
C70F
C70H
C70C
C70D
C70G
C70B
C70A
C60J
C60G
C60H
C60D
C60C
C60F
C60B
C60E
C60A
C42J
C42H
C42F
C42K
C42G
C42D
C42B
C42A
C42E
C42C
C43D
C43B
C43C
C43A
C41J
C41H
C41G
C41E
C41F
C41D
C41A
C41B
C41C
LOCALITY MAP
LEGEND
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
MIDDLE VAAL WMA
WATER QUALITY ISSUES
Figure
6.4.4.1



CROCODILE (WEST) AND MARICO WMA
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OLIFANTS WMA
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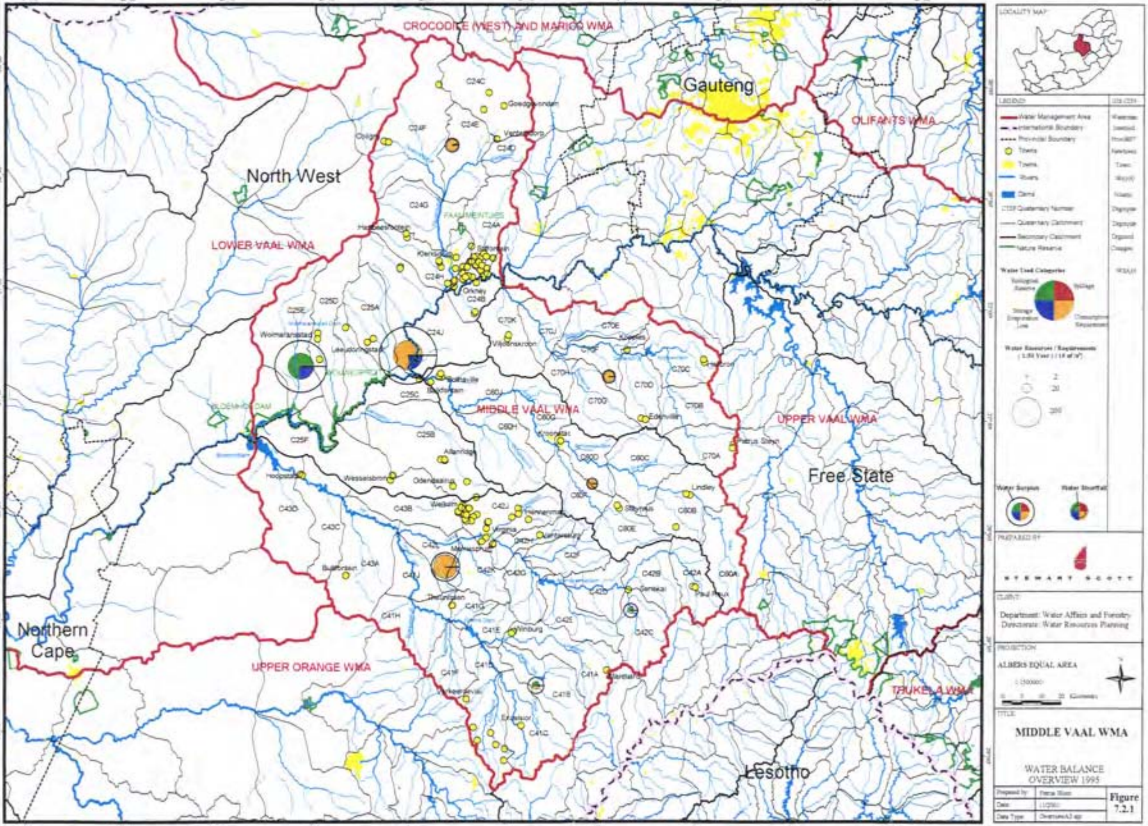
LOWER VAAL WMA
UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
LOCALITY MAP
LEGEND
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
MIDDLE VAAL WMA
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Figure 6.5.1


CROCODILE (WEST) AND MARICO WMA
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OLIFANTS WMA
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UPPER VAAL WMA
Free State
Northern Cape
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Water Surplus
Water Shortfall
STEWART SCOTT
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Directorate: Water Resources Planning
ALBERS EQUAL AREA
MIDDLE VAAL WMA
WATER BALANCE
OVERVIEW 1995
Figure
7.2.1