REPORT NO: 14000/00/0101

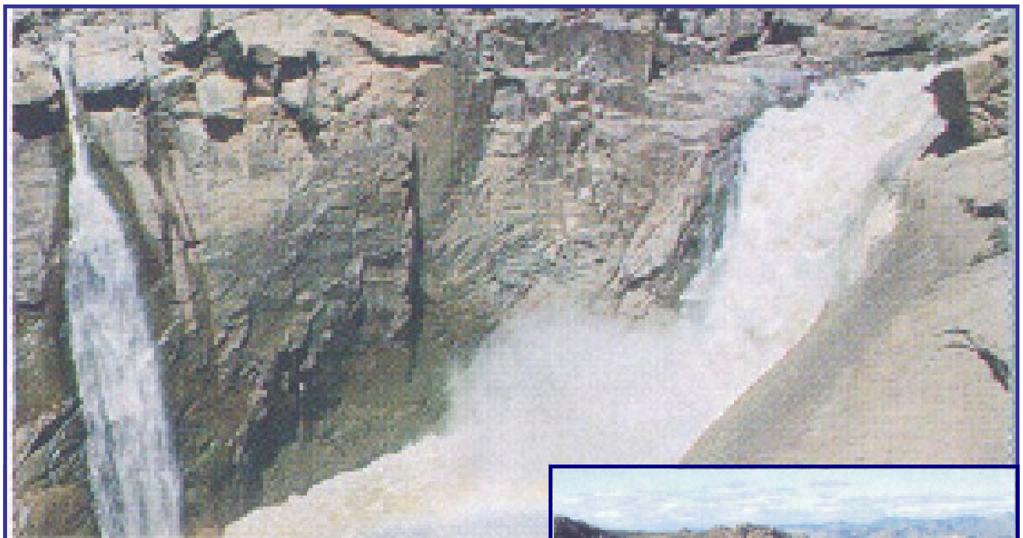
DEPARTMENT: WATER AFFAIRS AND FORESTRY

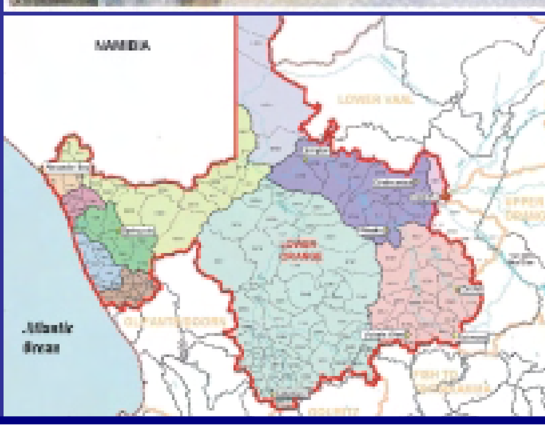
Directorate: Water Resources Planning

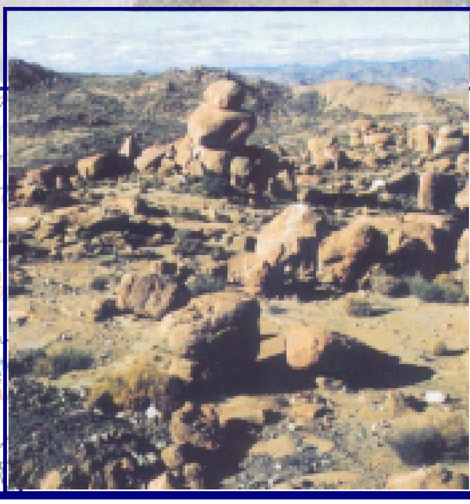
LOWER ORANGE
WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT
FINAL : MARCH 2002







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Title:	**Lower Orange Water Management Area (LOWMA): Water Resources Situation Assessment – Main Report – Volume 1 of 2**
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OVERVIEW OF THE WRSA

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-dependant 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 the year 1995 in the Lower Orange Water Management Area (LOWMA), which occupies portions of the Northern and Western Cape Provinces. The report does not address the water requirements beyond the year 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, National Water Resources Study (NWRS), 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 NWRS 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 (No. 36 of 1998), requires that a 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 NWRS 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 (CMA) established in terms of the National Water Act, 1998 (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 NWRS, 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 NWRS 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 NWRS rests with the Directorate: Strategic Planning of the Department of Water Affairs and Forestry, while the Directorate: Water Resources Planning is responsible for:

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

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

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

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

- Development of a computerised database

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

- Demographic study

  An important part in the development of the NWRS 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 (WSAM)

  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 WSAM 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 (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.

PREFACE TO ORANGE / VAAL WMA REPORTS

Orange / Vaal River Basin

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.

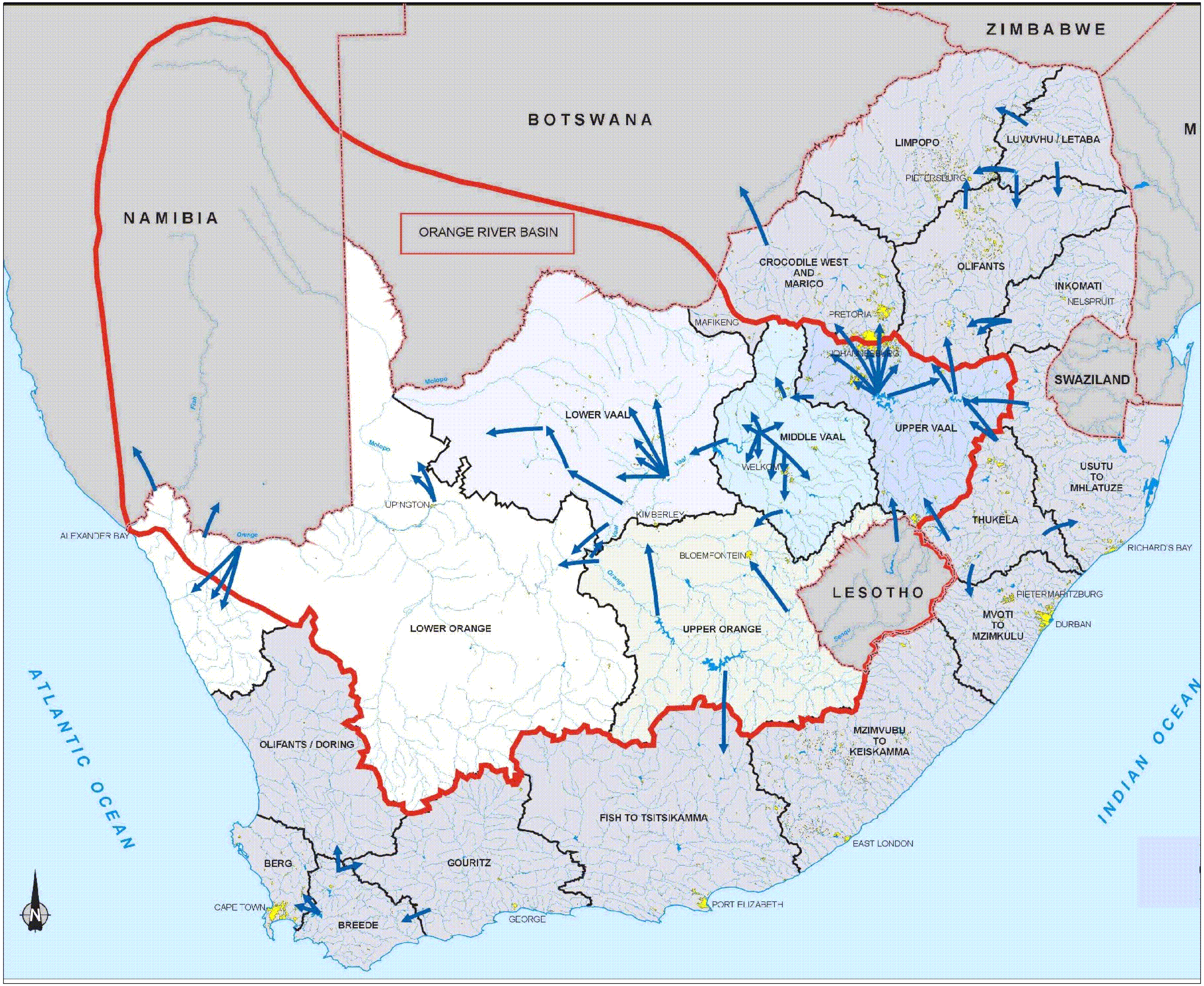
Within South Africa, the Orange/Vaal River Basin includes 5 of the 19 Water Management Areas (WMA). These are the Upper Vaal, Middle Vaal, Lower Vaal, Upper Orange and Lower Orange WMAs. The small portion of the Crocodile West and Marico WMA that falls within the Orange/Vaal River Basin has no significant 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.

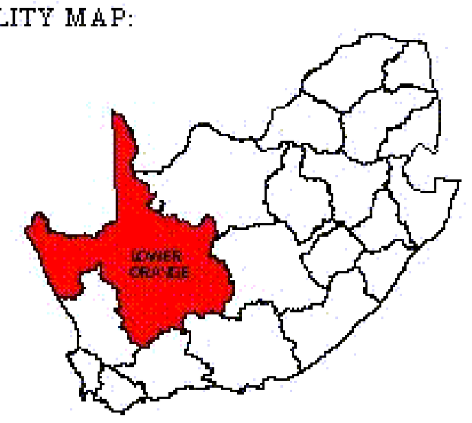
A summarised description of the main features of each of the Orange/Vaal WMAs, effecting other WMAs and countries, follows:

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.



LOCALITY MAP:



BASE MAP LEGEND: | GIS COV:

Water Transfers

Map Courtesy of BKS

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Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

N

TITLE:

LOWER ORANGE WMA

LAYOUT OF ORANGE/VAAL RIVER BASIN

Prepared by:		Diagram 1
Date:	February 2002	
Data Type:	PVO24044_p1.apr	

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 report numbers for the five water management areas are as follows :

- Upper Vaal WMA : P08000/00/0101
- Middle Vaal WMA : P09000/00/0101
- Lower Vaal WMA : P10000/00/0101
- Upper Orange WMA : P13000/00/0101
- Lower Orange WMA : P14000/00/0101

SYNOPSIS

1. INTRODUCTION

The National Water Act, 1998 (No. 36 of 1998) requires the Minister of Water Affairs and Forestry to establish a National Water Resources Strategy (NWRS) for the protection, use, development, conservation, management and control of water resources.

The Department of Water Affairs and Forestry (DWAF) appointed consulting engineers, to undetake a number of Water Resources Situation Assessments country wide. The purpose of the study was to gather information and reconcile the present water requirements across all user sectors with the presently available water resources. This data would provide information for collaborative planning of water resources development and utilisation by central government and future catchment management agencies.

The study was carried out as a desktop investigation using existing reports, databases and information supplied by associated studies, local authorities and DWAF. A base date of 1995 was chosen with all water requirements, water use, water resources and water related infrastructure being combined into a national data base.

A separate study provided detail on urban water use and demographic data. Additional studies provided data on the impact on water use and water quality on aspects such as; macro-economics, legal and institutional matters related to water resource management and supply, alien vegetation, groundwater, bacteriological contamination, irrigation, ecological water requirements, afforestation and storage-yield characteristics of rivers.

This report details the status of the Lower Orange Water Management Area (LOWMA), which is situated downstream of the Orange/Vaal River confluence (Douglas). The Orange /Vaal River System can be regarded as the most important river system in South Africa. Therefore the water resources in the Orange/Vaal WMAs should be managed in a well co-ordinated system and be viewed in an integrated context. The reader is reminded that the LOWMA is the last WMA in the Orange/Vaal River system and that the water related practices in the Upper Orange, Upper, Middle and Lower Vaal River WMAs all have a considerable bearing on the water quality and availability in the LOWMA. This report should therefore not be interpreted in isolation.

2. PHYSICAL FEATURES

The Lower Orange Water Management Area (LOWMA) dominates the Northern Cape Province with very small components falling into the Western Cape Province, east of Fraserburg and south of Garies.

The Orange River is the largest and longest river in South Africa and although it originates in a high rainfall area in Lesotho, its path through Northern Cape Province is dry and arid. The Vaal River joins the Orange River at Douglas while the Ongers and Sak Rivers (seasonal flow) converge from the south at Prieska and downstream of Kakamas respectively. The Molopo River joins the Orange River downstream of Augrabies Falls. The Fish River, from Namibia, is a non-perenial river which joins the Orange River in the Richtersveld. Several non perenial rivers drain the coastal belt between Garies, Springbok and Alexander Bay, discharging directly into the Atlantic Ocean.

The Orange River remains deeply incised in the interior plateau until the Boegoeberg, upstream of Groblershoop. It crosses a flatter reach from Boegoeberg to Kakamas before plunging into a deep canyon at Augrabies Falls. From here it meanders its way to the river mouth at Alexander Bay.

The study assessed the water requirements and available resources in terms of the quarternary catchment breakdown derived in the Water Resources Commission Report “The Surface Water Resources of South Africa, 1990” (WR90). The LOWMA consists of 143 quarternary catchments and is dominated by drainage regions D&F with a solitory quarternary catchment from region C. The southern parts of Botswana and Namibia also drain into the Orange River, and they were also included in the study, in terms of catchment areas, albeit not as refined as the WR90 data.

Minimal rainfall and prolonged droughts terminated by servere flooding are characterstics of the LOWMAs harsh climate. High summer temperatures, often in excess of 40ºC, result in very high evaporation (gross Syman’s pan : 2 000 mm/a to 3 050 mm/a). Winters are cold and dry with severe frosting. The mean annual precipitation across the WMA is in the order of 200 mm which is the lowest of all the WMA’s across the country. The coastal belt is a typical winter rainfall area and is also influenced by fog and onshore winds.

There are various geological and soil bands across the mass expanse of the LOWMA. Compact sedimentary, extrusive and intrusive rocks dominate the WMA together with compact arenaceous and argillaceous strata. The soil classes, varying in depth from shallow to deep, are generally sandy with a mixture of loam to be found between Douglas and Augrabies.

Tropical bush and savanna is dominant north of the 29º latitude (Pofadder/Douglas) while veld types Karoo and Karoid and False Karoo dominate the area south of this line.

A number of ecologically sensitive sites occur throughout the LOWMA, across a very broad spectrum. These include natural heritage sites (e.g. the limestone sinkhole at Cornellskop), national parks and nature reserves (e.g. Augrabies Falls NP, Richtersveld NP, Kgaladi Transfrontier Park and Namaqualand NP), the Orange River mouth, which is a RAMSAR site, as well as cultural and historical sites.

An index of the ecological importance and sensitivity class of the rivers in a quarternary were determined in an associated study. This formed the basis for estimating the water requirements to maintain a particular class of river. The importance and sensitivity class of the rivers was used to derive the default ecological management class which relates to a default ecological status class. The present and default ecological status classes were used to determine a suggested future ecological management class, on which water requirements would be based. There are a number of pans and dry streambeds in the study area that are of concern. The pans are situated near Victoria West and De Aar, Brandvlei as well as the Grootvloer-Verneuk Pan. The dry streambeds include reaches of the Kuruman, Molopo and Nossob rivers as well as those in the vicinity of Sutherland.

3. DEVELOPMENT STATUS

The first water related infrastructure to be built was for irrigation in 1889. Construction continued in 1908 and the 1930's. The Gariep (1971) and Van der Kloof dams (1976), which are both upstream of the LOWMA, regulate water flow in the Lower Orange WMA. Numerous white papers exist regarding proposals for future developments in the LOWMA. The most recent detailed study on the Orange River is the Orange River Development Project Replanning Study (DWAF, 1997). This study proposed various development options in the LOWMA, one of which is the construction of a dam at Vioolsdrift. This option was included in this study in the determination of the potential developed yield for the WMA.

The LOWMA has been divided into various drainage areas to simplify the evaluation and reporting. The drainage areas were chosen to represent a logical disaggregation of the catchment for purposes of summarising landuse and water requirements, as well as establishing the water balance. The drainage areas consist of a grouping of quarternary catchments (as per WR90). (See Figure S3.1.)

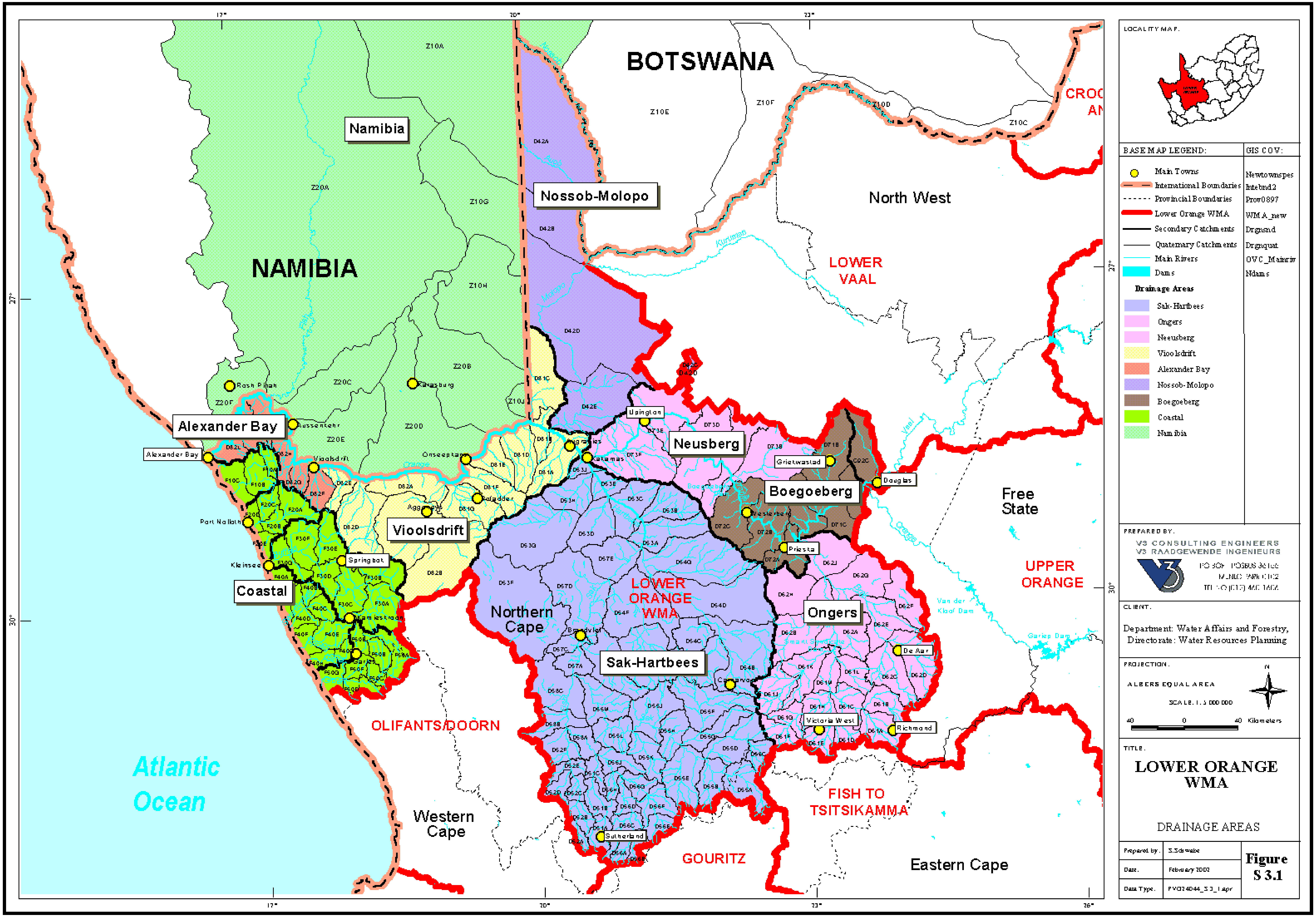
The following table describes the key points at the outlets to the drainage areas.

Key Points for Yield Determination

LOCATION OF KEY POINT		DESCRIPTION
DRAINAGE AREA	OUTLET QUATERNARY	
Ongers	D62J	Secondary Drainage Region D6, and tributary of Ongers River into Orange River
Boegoeberg	D72C	Location of Boegoeberg Dam on Orange River
Neusberg	D73F	Location of Neusberg Weir on Orange River
Nossob-Molopo	D42E	Part of Secondary Drainage Region D4, and tributary of Molopo River into Orange River
Sak-Hartbees	D53J	Secondary Drainage Region D5, and tributary of Hartbees River into Orange River
Vioolsdrift	D82E	Location of Vioolsdrift Weir and possible Vioolsdrift Dam on Orange River
Namibia	Z20A	Tributary of Fish River into Orange River, but area includes parts of Namibia supplied from Orange.
Alexander Bay	D82L	Outflow of Orange River into the sea
Coastal	Various	Primary Drainage Region F, which has multiple outlets to the sea
LOWER ORANGE WMA	D82L	Outflow of Orange River into the sea

Separate studies addressed the demography and macro-economics of the LOWMA, as a component of the respective national studies. The demographic study focussed on so-called functional urban centres having or likely to have reticulated water supply systems in the future. Data sources included the Development Bank of Southern Africa, the Demographic Information Bureau, the Bureau for Market Research as well as municipalities, sample surveys and census counts.

Estimates were also made of the rural population distribution.


BOTSWANA
NAMIBIA
Namibia
Nossob-Molopo
North West
LOWER VAAL
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
Ongers
Sak-Hartbees
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
Western Cape
GOURITZ
Eastern Cape
Atlantic Ocean
Upington
Kakamas
Augrabies
Griekwastad
Douglas
Prieska
Springbok
Port Nolloth
Kleinsee
Vioolsdrif
Onseepkans
Pofadder
Aggeneys
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Rosh Pinah
Karasburg
LOCALITY MAP.
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Drainage Areas
Sak-Hartbees
Ongers
Neusberg
Vioolsdrift
Alexander Bay
Nossob-Molopo
Boegoeberg
Coastal
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LOWER ORANGE WMA
DRAINAGE AREAS
Prepared by. S.Schwabe
Date. February 2002
Figure S 3.1

The population throughout the LOWMA is generally small in relation to other WMAs. The urban population growth rate is estimated at 2,37% while the non-urban growth rate is estimated at -2,26%. De Aar, Springbok and Upington are the major towns in the LOWMA. The estimates for the Namibian data are at a very superficial level in comparison to that for the LOWMA. The following table is a summary of the 1995 population data.

POPULATION IN 1995

Catchment						Population in 1995		
Primary		Secondary		Tertiary (Drainage Area)		Urban	Rural	Total
No.	Description	No.	Description	No.	Description	(Number)	(Number)	(Number)
C, D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	65 300	9 786	75 086
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	20 090	11 976	32 066
				D55	Sak-Hartbees (WC)	410	244	654
		D4	Molopo	D42	Nossob-Molo (NC)	6 353	4 943	11 296
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	36 750	10 260	47 010
				D73	Neusberg (NC)	70 400	52 320	122 720
				D81, D82	Vioolsdrift (NC)	12 150	12 080	24 230
				D82	Alexander Bay (NC)	4 000	1 897	5 897
	TOTAL IN NORTHERN CAPE PROVINCE					215 043	103 262	318 305
	TOTAL IN WESTERN CAPE PROVINCE					410	244	654
	TOTAL IN PRIMARY CATCHMENTS C + D					215 453	103 506	318 959
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	46 788	9 358	56 145
				F50	Coastal (WC	2 463	493	2 955
	TOTAL IN NORTHERN CAPE PROVINCE					46 788	9 358	56 145
	TOTAL IN WESTERN CAPE PROVINCE					2 463	493	2 955
	TOTAL IN PRIMARY CATCHMENT F					49 250	9 850	59 100
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						261 831	112 620	374 450
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						2 873	737	3 609
TOTAL IN LOWER ORANGE WMA						**264 704**	**113 357**	**378 059**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	31 240	55 140	86 380
TOTAL IN REPORTING AREA						**295 940**	**168 497**	**464 439**

* Rounding off errors do occur in the aggregation process.

The economic assessment of the LOWMA was based on the present economic development on a sectoral basis. A number of data sources were used including the Development Bank of Southern Africa (DBSA). Only the gross geographic product (GGP) and labour data/statistics were analysed across the major economic sectors of; agriculture, mining, manufacturing, electricity, construction, trade, transportation, finance and government and social services.

The GGP of the LOWMA was R3,9 billion in 1997. The economic profile is headed by the government sector (19,4%) followed by mining (17,4%), agriculture (15,9%) and trade (15,1%). A diverse grouping “other” makes up the balance (32,7%).

Income generators include dried fruits, grapes, wheat, lucerne, maize, vegetables, horticulture crops, sheep, venison, wine, alluvial diamonds, copper and zinc. There is a high demand from international markets for the variety of agriculture products grown in the LOWMA. The Namaqualand wild flower fields and the national parks (Augrabies, Richtersveld, Kalahari Gemsbok) also attract tourists to the LOWMA.

The unemployment rate is approximately 31,9% which is higher than the national average of 29,3%. The formal sector employs 56,3% of which 30.1% work for government, 29,8% are involved in agriculture and 11,71% in trade.

The water law in South Africa has seen numerous changes since the Water Act of 1912 with the National Water Act, 1998 (Act 36 of 1998) (NWA) replacing the Water Act of 1956 (Act No. 54 of 1956). The NWA is now the only Act dealing with water law and imposes some far reaching concepts, e.g.:

- Riparian ownership has been repealed, the water resources belong to the nation as a whole.
- The National Government, through the Minister of Water Affairs and Forestry becomes responsible as the public trustee of all water resources.
- All rights to use water derive from the NWA.
- Water must be available for the Reserve, which comprises a basic human needs component as well as a component to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water source.
- Extensive public participation is required.
- The abolition of the Water Courts and introduction of a Water Tribunal.
- Recognition of international obligations.

The NWA makes provision for the establishment of two water management strategies as well as creating institutions to implement the NWA. The National Water Resources Strategy (NWRS) is binding on the Minister and other organs of state and water management institutions. The Catchment Management Strategy (CMS) which will be binding on the Catchment Management Agencies (CMAs). CMAs will be established for each Water Management Area (WMA). Water User Associations (WUAs) will operate on a restricted local level. The old Irrigation Boards were required to be transformed into WUAs.

The NWA abolishes the historical distinction between public and private water. Water ownership no longer exists and all water is subject to a licensing system. The whole country is now effectively a government water control area, which was not the situation in the Water Act, 1956.

All water use requires a license unless it falls into a Schedule 1 use, such as reasonable domestic use, small gardening and animal watering. Feedlots are excluded. There are also other criteria which are applicable to Schedule 1 usage. Licenses can be issued for a maximum of 40 years are subject to a review period. Other legislation exists to which a water user and the State must comply, e.g. Physical Planning Act, 1991 (Act No. 125 of 1991), Development Facilitation Act, 1995 (Act No. 67 of 1995), Restitution of Land

Rights Act, 1994, (Act No. 22 of 1994) and Environmental Conservation Act, 1989 (Act No. 73 of 1989). The National Environmental Management Act, 1998 (Act No. 107 of 1998) and the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983) are also applicable.

The District Council areas and Magisterial Districts have changed since 1995. There are currently 3 District Councils (DCs) with the seats at De Aar (Karoo DC), Springbok (Namakwa DC) and Upington (Siyanda DC).

The irrigation districts, Irrigation Boards and Water Boards operational in the LOWMA in 1995 are in the process or have already been transformed into Water User Associates.

The climate and topography of the Lower Orange Water Management Area (LOWMA) does not lend itself to general high density land use. Scheduled irrigation, riparian to the Orange River, is the only high intensity land use. Dryland sugarcane farming and commercial forestry do not exist in the LOWMA. There are however scatterings of natural woodlands. Nature reserves, wilderness parks etc. are the largest land user in the WMA.

It is generally recognised that future growth in irrigation will be severly limited by the availability of water. It may even be necessary, in certain areas, to curtail some irrigation to meet the growing requirements of domestic and urban use.

Livestock and game farming occupies extensive tracks of land in the LOWMA. The most commonly found animals are sheep (wool/meat), Anghora goats (wool) and cattle (meat/diary). The Springbok is by far the dominant game animal in the LOWMA followed by Gemsbok, Eland, Kudu and Rooibok. The 1995 estimates for livestock and game equate to 719 700 equivalent large stock units (ELSU's) where an eland and a horse are used as the bench mark each with a unit value of 1,0.

Alien vegetation infestation is widespread across the LOWMA with much of the infested areas being found in the riparian zone, where the degree of infestation is largely independent of the rainfall in the surrounding area. The condensed coverage of alien vegetation in the LOWMA is estimated at 1 340 km^2 (0,5%), almost double that of any productive land use. There is an ongoing alien vegetation eradication programme in the LOWMA.

The settlement pattern in the LOWMA was determined by the irrigation and mining activities of the area. Critical mass is often not achieved to provide diversified municipal town services. The type of urbanisation could best be described as service centres to the surrounding farm lands or mines. The combined footprint of the few urban areas is negligable in relation to the surface area of the LOWMA. Upington is the most dominant centre.

Land-Use by Drainage Areas in km²

Catchment: Primary No,	Primary Description	Secondary No,	Secondary Description	Tertiary (Drainage Area) No,	Tertiary (Drainage Area) Description	Irrigation (km²)	Dryland Sugarcane (km²)	Other Dyrland Crops (km²)	Afforestation (km²)	Alien Vegetation (km²)	Nature Reserves * (km²)	Urban (km²)	Rural Settlements (km²)	Other** (km²)	Total (km²)
C D (Part)	Orange	D6	Ongers	D61 D62	Ongers (NC)	0,0	0,0	0,0	0,0	76,3	17,0	10,1	2,0	33 625	33 730
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	44,9	0,0	0,0	0,0	660,1	5,3	0,0	2,4	90 467	91 179
				D55	Sak-Hartbees (WC)	0,9	0,0	0,0	0,0	13,5	0,1	0,0	0,0	1 846	1 861
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	0,0	0,0	0,0	226,3	10 389,5	0,0	1,0	21 193	31 810
		C9 D7 D8	Orange	C92 D71 D72	Boegoeberg (NC)	208,4	0,0	0,0	0,0	161,2	23,6	0,0	2,1	15 695	16 090
				D73	Neusberg (NC)	248,0	0,0	0,0	0,0	8,4	53,5	14,3	10,5	17 395	17 730
				D81 D82	Vioolsdrift (NC)	118,4	0,0	0,0	0,0	45,8	44,1	0,0	2,4	27 299	27 510
				D82	Alexander Bay (NC)	13,6	0,0	0,0	0,0	0,1	1 622,8	0,0	0,4	3 874	5 511
	TOTAL IN NORTHERN CAPE PROVINCE					633,3	0,0	0,0	0,0	1 178,2	12 155,8	24,4	20,7	209 548	223 560
	TOTAL IN WESTERN CAPE PROVINCE					0,9	0,0	0,0	0,0	13,5	0,1	0,0	0,0	1 846	1 861
	TOTAL IN PRIMARY CATCHMENTS C + D					634,2	0,0	0,0	0,0	1 191,7	12 155,9	24,4	20,7	211 394	225 421
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0		0,0	0,0	136,8	42,1	0,0	1,9	24 358	24 539
				F50	Coastal (WC	0,0		0,0	0,0	7,2	2,2	0,0	0,1	1 282	1 292
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0	0,0	136,8	42,1	0,0	1,9	24 358	24 539
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0	0,0	7,2	2,2	0,0	0,1	1 282	1 292
	TOTAL IN PRIMARY CATCHMENT F					0,0	0,0	0,0	0,0	144,0	44,3	0,0	2,0	25 640	25 830
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						634,2	0,0	0,0	0,0	1 315,0	12 197,2	24,4	22,6	233 906	248 100
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,0	0,0	0,0	0,0	20,7	2,3	0,0	0,1	3 128	3 153
TOTAL IN LOWER ORANGE WMA						**634,2**	**0,0**	**0,0**	**0,0**	**1 335,7**	**12 200,2**	**24,4**	**22,7**	**237 034**	**251 253**
Z (Part)	Namibia	Z1 Z2	Namibia	Z10 Z20	Namibia	44,2	0,0	0,0	0,0	320,0	**0,0**	0,6	11,0	243 924	244 300
TOTAL IN REPORTING AREA						**678,4**	**0,0**	**0,0**	**0,0**	**1 655,7**	**12 200,2**	**25,0**	**33,7**	**480 958**	**495 553**

* Includes National Parks, wilderness areas, etc
** Balance of areas not otherwise defined, which could also include grazing and natural vegetation.

There are no major industries or power stations in the LOWMA. There are however a number of mines ranging from alluvial diamonds, on the lower portion of the river, to copper, lead, salt and zinc.

4. EXISTING WATER-RELATED INFRASTRUCTURE

The expanse and arid nature of the Lower Orange Water Management Area (LOWMA) has resulted in a sparse and widely distributed population. The major towns in the WMA are relatively small and therefore have a fairly small water requirement. Groundwater is the dominant source for municipal supply of the smaller centres, away from the Orange River. The towns situated alongside the Orange River naturally draw their municipal supply from the river.

Several Government Water Schemes (GWS) and irrigation districts exist along the main stem of the Orange River and include a number of small dams/weirs, e.g. Boegoeberg and Neusberg. A few dams have been built on the tributaries, such as the Smartt Syndicate and Van Wyksvlei dams built on the Ongers and Carnarvonleegte Rivers respectively.

There are a number of regional water supply schemes providing water for irrigation, urban/municipal use, mining, rural/stock watering or a combination thereof.

The following irrigation schemes/areas are riparian to the Orange River, supplying water via weirs and canal systems:

IRRIGATION SCHEMES/AREAS RIPARIAN TO THE ORANGE RIVER

Name	Location	Area within LOWMA
Douglas Irrigation Area	Downstream of Douglas	7 200 ha
Middle Orange Irrigation Area	Hopetown to Boegoeberg Dam	13 640 ha
Boegoeberg Irrigation Scheme	Between Boegoeberg Dam and Upington	8 623 ha
Upington Irrigation Area	The numerous islands in the Orange River between Upington and Kakamas.	Scheduled area of 10 935 ha, run of river abstractions 1 436 ha.
Kakamas Irrigation Area	Between Kakakmas and Augrabies Between Neusberg and Augrabies Augrabies to the Namibian border	6 029 ha 2 650 ha 622 ha
Onseepkans Irrigation Area	Left bank of the Orange River	314 ha
Namakwaland Irrigation Area	Downstream of Pelladrift	2 058 ha
Vioolsdrift and Noordoewer Irrigation Area	Vioolsdrift (South Africa) Noordoewer (Namibia)	600 ha 284 ha
Namibian Irrigation from Orange River	Noordoewer to the Fish River confluence	1 800 ha by run of river abstractions
Irrigation in the Fish River Catchment	Vicinity of the Hardap and Naute dams	2 150 ha

OTHER WATER SUPPLY SCHEMES

Name	Description
Karos Geelkoppen Rural Water Supply Scheme	A pumpstation upstream of Upington transfers water north in the direction of Vanzylsrus for stockwatering.
Kalahari West Rural Water Supply Scheme	Water is sourced from the Upington Municipal reservoir to supply a rural community north, north west of Upington.
Pelladrift Water Supply Scheme	This scheme abstracts water at Pelladrift to supply Pofadder, Aggenys and Pella mission.
Springbok Regional Water Supply Scheme	Water from the Henkriesmond purification works is pumped to the bulk and municipal consumers at Springbok, Okiep, Nababeep, Steinkopf, Concordia and Cardusburg. Kleinsee on the Atlantic coast is also supplied via this system.
Sendlingsdrift	The scheme supplies the little mining town of Sendlingsdrift as well as the Rosh Pinah mine in Namibia.
Alexander Bay	The Alexander Bay system provides Orange River water to Oranjemund and Alexander Bay as well as irrigation water for 1 360 ha upstream of the Oppenheimer bridge. Water is also supplied to Port Nolloth.
Municipal supply	The towns of Prieska and Upington draw their municipal supply direct from the Orange River.

The following table provides detail on the population and potable water systems capacities.

Combined capacities of Individual Town and Regional Potable Water Supply Schemes by Drainage Area

Catchment						Area	Population	Town and Regional Water Supply Schemes		
Primary		Secondary		Tertiary (Drainage Area)						
No,	Description	No,	Description	No,	Description	Area	Population	Number of people supplied	% of Drainage Area Population	Capacity*
						(km²)	(Number)	(Number)	(%)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	33 730	75 086	65 300	87	4,15
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	91 197	32 066	20 094	62	1,63
				D55	Sak-Hartbees (WC)	1 843	654	406	62	0,3
		D4	Molopo	D42	Nossob-Molo (NC)	31 810	11 296	6 353	56	0,15
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	16 090	47 010	36 750	78	5,48
				D73	Neusberg (NC)	17 730	122 720	71 006	58	20,34
				D81, D82	Vioolsdrift (NC)	27 510	24 230	12 150	50	9,17
				D82	AlexanderBay (NC)	5 511	5 897	4 000	68	4,52
	TOTAL IN NORTHERN CAPE PROVINCE					223 578	318 305	215 653	66	45,44
	TOTAL IN WESTERN CAPE PROVINCE					1 843	654	406	62	0,3
	TOTAL IN PRIMARY CATCHMENTS C + D					225 421	318 959	216 059	66	45,74

Combined capacities of Individual Town and Regional Potable Water Supply Schemes by Drainage Area (Continued)

Catchment						Area	Population	Town and Regional Water Supply Schemes		
Primary		Secondary		Tertiary (Drainage Area)						
No,	Description	No,	Description	No,	Description			Number of people supplied	% of Drainage Area Population	Capacity*
						(km²)	(Number)	(Number)	(%)	(10^6 m³/a)
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	24 552	56 145	46 812	83	0,67
				F50	Coastal (WC)	1 278	2 955	2 438	83	0
	TOTAL IN NORTHERN CAPE PROVINCE					24 552	56 145	46 812	83	0,67
	TOTAL IN WESTERN CAPE PROVINCE					1 278	2 955	2 438	83	0
	TOTAL IN PRIMARY CATCHMENT F					25 830	59 100	49 250	83	0,67
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						248 130	374 450	262 465	70	46,11
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						3 121	3 609	2 844	80	0,3
TOTAL IN LOWER ORANGE WMA						**251 251**	**378 059**	**265 309**	**70**	**46,41**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	-	-	-	-	9,2
TOTAL IN REPORTING AREA						**251 251**	**378 059**	**265 309**	**70**	**55,31**

* Where data is not available, the capacity of the individual town systems is assumed to be equivalent to the 1995 urban/municipal water demand plus any transfers out.

The main dams in the LOWMA are:

NAME OF DAM	DRAINAGE AREA	CATCHMENT	GROSS STORAGE CAPACITY (10^6 m³/a)
Boegoeberg	Boegoeberg	D72C	20.29
Modderpoort	Sak-Hartbees	D55A	10.00
Ratelfontein	Sak-Hartbees	D52F	6.91
Rooiberg	Sak-Hartbees	D53A	3.65
Smartt Syndicate	Ongers	D61M	101.12
Van Wyksvlei	Sak-Hartbees	D54C	143.08
Victoria West	Ongers	D61E	3.66

5. WATER REQUIREMENTS

This section describes the water requirements as calculated in the study. Water allocations and consumption patterns occur at varying levels of assurance of supply. The ecological and human Reserve components are provided for at a high level of assurance (low risk of failure/non-supply). The agricultural sector on the other hand is supplied at a much lower level of assurance. The water requirements for the different user sectors were all related to one another at an equivalent 1:50 year level of assurance, which is generally the norm for urban/industrial use.

The water requirements per user group as well as the water requirements per drainage area in 1995 and the equivalents at 1:50 year assurance are shown below.

Water Requirements per User Group in 1995

USER GROUP		ESTIMATED WATER REQUIREMENT (10^6 m³/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m³/a)
Urban		23,87	24,13
Rural		17,32	18,80
Bulk Use	Strategic	0,0	0,0
	Mining	8,64	9,11
	Other	0,0	0,0
Agriculture	Irrigation	901,40	774,50
Afforestation		0,0	0,0
Alien Vegetation		16,93	4,42
Water Transfers out		6,69	6,69
Hydropower		0,0	0,0
River Losses		527,3*	527,3*
TOTAL (LOWMA)		**1 502,15****	**1 364,95****
Ecological Reserve		65,16	65,16

* The impact of the ecological Reserve and river losses on yield have not been finalised.
** Excludes ecological Reserve

Water Requirements per Drainage Area in 1995 at 1:50 year Assurance Equivalent

Primary		Secondary		Tertiary (Drainage Area)		Urban	Rural	Bulk	Irrigation	Dryland Crops	Affore-station	Alien Vegetation	Transfers (Out)	River Losses	Total
No,	**Description**	**No,**	**Description**	**No,**	**Description**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	4,15	3,62	0,00	0,00	0,00	0,00	0,60	0,00	0,00	8,4
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	1,63	5,42	0,00	11,41	0,00	0,00	3,67	0,00	0,00	22,1
				D55	Sak-Hartbees (WC)	0,03	0,11	0,00	0,23	0,00	0,00	0,07	0,00	0,00	0,5
		D4	Molopo	D42	Nossob-Molo (NC)	0,15	1,81	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,0
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	3,45	1,63	0,00	199,20	0,00	0,00	0,00	0,00	119,30	323,6
				D73	Neusberg (NC)	9,00	2,36	0,00	383,20	0,00	0,00	0,05	0,46	131,00	526,1
				D81, D82	Vioolsdrift (NC)	1,19	1,63	3,52	162,00	0,00	0,00	0,00	5,56	163,00	336,9
				D82	AlexanderBay (NC)	0,42	0,30	3,43	18,46	0,00	0,00	0,00	0,67	114,00	137,3
	TOTAL IN NORTHERN CAPE PROVINCE					19,99	16,77	6,95	774,27	0,00	0,00	4,33	6,69	527,30	1 356,3
	TOTAL IN WESTERN CAPE PROVINCE					0,03	0,11	0,00	0,23	0,00	0,00	0,07	0,00	0,00	0,5
	TOTAL IN PRIMARY CATCHMENTS C + D					20,02	16,88	6,95	774,50	0,00	0,00	4,40	6,69	527,30	1 356,7
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	3,90	1,82	2,05	0,00	0,00	0,00	0,02	0,00	0,00	7,8
				F50	Coastal (WC)	0,21	0,10	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,4
	TOTAL IN NORTHERN CAPE PROVINCE					3,90	1,82	2,05	0,00	0,00	0,00	0,02	0,00	0,00	7,8
	TOTAL IN WESTERN CAPE PROVINCE					0,21	0,10	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,4
	TOTAL IN PRIMARY CATCHMENT F					4,11	1,92	2,16	0,00	0,00	0,00	0,02	0,00	0,00	8,2
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						23,89	18,59	9,00	774,50	0,00	0,00	4,35	6,69	527,30	1 364,1
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,24	0,21	0,11	0,00	0,00	0,00	0,07	0,00	0,00	0,9
TOTAL IN LOWER ORANGE WMA						**24,13**	**18,80**	**9,11**	**774,50**	**0,00**	**0,00**	**4,42**	**6,69**	**527,30**	**1 364,95**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	2,43	21,62	10,51	68,11	0,00	0,00	0,00	0,00	0,00	102,7
TOTAL IN REPORTING AREA						**26,56**	**40,42**	**19,61**	**842,60**	**0,00**	**0,00**	**4,42**	**6,69**	**527,30**	**1 467,65**

* Rounding errors do occur.

Ecological component of the Reserve

The ecological component of the Reserve is the largest water requirement sector in the Lower Orange Water Management Area (LOWMA). The majority (88%) of the quarternary catchments were rated as class B (largely natural) with the balance being rated as class C (moderately modified) except for a single class D rating (largely modified). It is estimated that 1 534 million m^3/a should be set aside each year for the aquatic biota and ecosystems of the LOWMA.

There are numerous assumptions and limitations to the method involved in determining the ecological reserve, the above estimate should therefore not be deemed as final but rather as an indication of the volume of water required. The ecological Reserve is considered at the outlet of the WMA, viz. Alexander Bay. The instream flow requirements were used for the rivers in the coastal catchment as fresh water requirements at the river mouths are unknown. The net impact of the ecological Reserve on the 1 in 50 year yield is a total deficit of 126 million m^3/a.

Urban and Rural

The urban and rural requirements in the LOWMA are almost insignificant in relation to the ecological Reserve, irrigation and river loss components. The urban demand is generally concentrated along the main stem of the Orange River as a result of agricultural developments or at places such as Springbok, Aggeneys and Port Nolloth due to mining activities. Rural communities and a few urban centres such as De Aar, Richmond, Sutherland and Victoria West rely on ground water resources.

The study accepted an amount of 25 ℓ/c/d as the minimum quantity to satisfy the human need component of the Reserve.

Urban water requirements were classified into direct use by the population plus indirect use by commerce, industries, institutions and municipalities related to the direct use. The direct water use was calculated using per capita water use figures which were determined for varying levels of service and income groups.

Indirect water use was determined taking cognisance of the urban centres characteristics related to water use. Urban centres were classified accordingly.

The urban centres within the WMA were evaluated to determine their 1995 consumption figures. The largest urban water demands are in the Neusberg catchment and is predominately driven by Upington’s requirements.

Return flows are generally fed into evaporation ponds, Upington is the only significant source of return flows.

Water losses in the bulk supply and network distribution systems were taken into account in terms of blanket percentages being applied. Bulk losses, including purification losses were assumed as 5% unless otherwise indicated. Distribution losses of 20% were accepted. See the following table for details.

Rural water use

Rural water use includes direct domestic use (which was assumed to be 45 ℓ/c/d), subsistence irrigation and stock watering. The live stock watering was based on the consumption of an equivalent large stock unit (ELSU) equal to 45 ℓ/unit per day. Water losses were assumed to be 20%. There are no return flows into the river systems. The details on rural water use are summarised below.

Bulk water use

There are no strategic or large industrial water users in the LOWMA. There are however a few mines, predominately concentrated in the Vioolsdrift (Aggenys and Pofadder area), Alexander Bay (Alexcor) and Coastal drainage areas (Okiep/Nababeep, Kleinsee, Hondeklipbaai and coastal belt). The on-site demand is relatively small at 7,85 million m^3/a with an estimated 10% losses to be added to this figure. There are no return flows, effluent is evaporated.

Neighbouring states

The water requirements of the neighbouring states were determined using the same principles as those for the South African quarternary catchments. The approach was however simplified whereby the land-use of the neighbouring state catchment was determined on a pro-rata basis in relation to the land-use and surface area of the corresponding South African quarternary catchment. Better information was used as and when available. The Namibian data is included as a separate line item in the reporting tables where relevant.

Irrigation and dryland agriculture

Most of the irrigation in the WMA is supplied from the Orange River, with releases made from Van der Kloof Dam specifically for this purpose. Small amounts of opportunistic irrigation using rainfall harvesting also takes place in the catchments away from the Orange River.

The irrigation water requirements along the Orange River were determined using scheduled areas and quotas due to the legal nature of the water allocations. This is the same method used in the Orange River Development Replanning Study — ORRS (BKS 1997). The scheduled areas used in the 1997 study were updated in accordance with the "Orange River System 1999/2000 Operating Analysis" (BKS 2000). Scheduled areas and quotas are independent of farming practices such as double cropping and do not relate directly to crop distributions. The SAPWAT crop factors used in this study were therefore adjusted so that the relevant field requirements (excluding conveyance losses) were equal to the quota independent of crop distribution or farming practices. Estimates of irrigation efficiencies and conveyance losses to field edge were also included.

Return flows were assumed to equal 10% of the 1 in 50 year irrigation requirement along the Orange River and 0% in areas remote from the Orange River. See the table below for details.

There is no dryland sugarcane production in the LOWMA.

Water losses from rivers, wetlands and dams

Water losses from rivers, wetlands and dams in the context of the Lower Orange Water Management Area (LOWMA) are effectively evaporation losses due to the arid climate of the WMA.

The evaporative losses from the river channels was based on the report "Evaporation Losses from South African River" (BKS, 1999). Operational losses are incurred with the releases from Van der Kloof Dam as the water travels for over 1 400 km (4 to 8 weeks) to the downstream users. The losses incorporated in the study represent the losses when releases from Van der Kloof Dam average approximately 50 m^3/s over the year.

Afforestation and Hydropower

There is no afforestation or hydropower in the Lower Orange Water Management Area (LOWMA). However, the hydropower releases from the Van der Kloof Dam impact on the water users in the LOWMA. Uneven flow patterns are generated, which together with the high sediment load in the river makes river abstractions very difficult for riparian farmers. The interaction between hydropower releases and the ecological Reserve in the middle and lower Orange River also requires further investigation and careful management by DWAF and Eskom.

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 and 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 impact of alien vegetation on water resources is difficult to assess because of the lack of available information.

The most important alien invader in the Northern Cape is Mesquite (*Prosopis spp.*), which has a condensed area of approximately 173 150 ha and an estimated water consumption of 192 million m^3/a. The main concentrations of this tree are in the Sak River system and the Van Wyksvlei and Britstown-De Aar area (D54, D57) and the Nossob, Auob and Molopo area (D42).

Water conservation and water demand management

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and use. This concept has been strongly emphasised, both in legislation and through key demonstration water conservation and water demand management projects. The Department of Water Affairs and Forestry is therefore developing a National Water Conservation and 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.

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 initiatives also impact on future planning considerations such as water resource and distribution of supply management, management measures of the customer or end-user as well as return flows.

The Working for Water Programme and the eradication of alien vegetation contributes to the enhancement of surface runoff. Water restrictions on the other hand is a mandatory means of kerbing water usage, they do however have financial implications on both the end user (higher tariffs/penalties) and service provider (loss of sales).

The following water conservation and water demand management actions are in place in the LOWMA.

- Eradication of alien vegetation.

- A pilot project is currently underway as part of the establishment of the Orange/Vaal water users association in the Douglas area.

- Best Practice Management Guidelines and Water Conservation and Water Management Strategy content is included in comments on environmental management practice reports from the mines as well as individual license applications.

The per capita consumption in the rural areas is very low and it is unlikely that there is much scope for a reduced demand in these areas. It is assumed that water consumption in the urban areas can be reduced by upto 20 to 25% through improved management, maintenance and operational measures.

Water allocations

Water allocations were previously made in terms of Article 56(3) and Article 63 of the Water Act, 1956 (Act No. 54 of 1956) and Special Water Acts. These Acts were however repealed between 1 October 1998 and 1 October 1999 by the National Water Act, 1998 (Act No. 36 of 1998). Water usage that took place lawfully at any time between 1 October 1996 and 30 September 1998 has been regarded as existing lawful use for the purposes of the National Water Act of 1998. Such usage will have certain preferences and protection when water is allocated in terms of the National Water Act of 1998.

All the water usage from the Orange River in the Lower Orange Water Management Area (LOWMA) is quantified in legal documents. There is however minimal quantification of water usage from sources other than the Orange River.

Groundwater is abstracted mainly for stock watering, domestic and urban purposes a small amount is used for irrigation. These rights may be exercised without permission. Very little documentation stating the right to use this water is therefore available. There are title deeds and agreements setting out and regulating the use of the water between individual owners.

Many of the municipalities buy groundwater from farmers in the neighbourhood. Formal agreements between the municipalities and farmers are concluded, a practice that seems to be followed by all municipalities.

Irrigation out of Government Water Scheme (GWS) is in terms of scheduled areas and quotas, Section 63 of the Water Act of 1956 was applicable. Section 56(3) of the same Act provided allocations to other water use sectors from the GWS's.

There are also four Special Water Acts in the LOWMA which either granted land ownership to local Management Board's or empowered them to control and maintain specific irrigation works, they are:

- Brandvlei Land and Irrigation Works Act, 1926 (Act No. 4 of 1926).
- Van Wyksvlei Settlement Regulation Act, 1970 (Act No. 68 of 1970).
- Cannon Island Settlement Management Act, 1939 (Act No. 15 of 1939).
- Skanskop Settlement Act, 1947 (Act No. 24 of 1947).

The DWAF regional office is currently registering all water users and their allocations. This data base is expected to be available in the new future.

The water allocations and 1995 water requirements were compared to determine the potential for future allocations. The water allocations far exceed the locally available resources and are therefore dependant on upstream inflows.

Existing water transfers

There are 5 transfer schemes (excluding irrigation schemes) within the Lower Orange Water Management Area (LOWMA), in all cases water is sourced from the Orange River.

- The Karos-Geelkoppen Rural Water Supply Scheme provides water for stock watering purposes. It is located slightly upstream of Upington.
- The Kalahari-West Rural Water Supply Scheme draws treated water from the Upington purification plant and pumps it north for stock watering and rural domestic supply.
- The Pelladrift Water Supply Scheme is operated by the Pella Water Board and provides water to Poffadder, Pella and the mines at Aggenys and Black Mountain.
- The Springbok Regional Water Supply Scheme draws water from Henkriesmond, via the Henkries purification works and supplies the area of Springbok, Okiep, Carolusberg and Kleinsee.
- Water is abstracted at Alexander Bay and pumped south to supply Port Nolloth.

There is a transfer scheme from Sendlingsdrift on the Orange River to the Rosh Pinah mine in Namibia.

The irrigation transfer schemes are a series of weirs and canals providing water to riparian farmers on both the left and right bank of the Orange River. The transfers include the following:

- Boegoeberg Irrigation Scheme.
- Upington Irrigation Area.
- Kakamas Irrigation Area.
- Onseepkans Irrigation Area.
- Namakwaland Irrigation Area.
- Vioolsdrift – Noordoewer Irrigation Area.

Water losses and return flows

The estimated total water losses and return flows in the LOWMA are given in the following table. The losses from rivers, wetlands and dams totally dominate the situation with bulk, urban and rural losses effectively being insignificant.

Summary of Water Requirements, Losses and Return Flows

CATEGORY		**ON-SITE REQUIREMENTS**	**LOSSES**		**RETURN FLOWS**
		(10^6 m³/a)	**(10^6 m³/a)**	**(%)**	**(10^6 m³/a)**
Irrigation		826,00	75,40	9	90,14
Urban		17,84	6,03	20	1,05
Rural		13,62	3,70	20	0,00
Bulk	Strategic	0	0	0	0,00
	Mining	7,85	0,79	10	0,00
	Other	0	0	0	0,00
Hydropower		0	0	0	0
Rivers, Wetlands and Dams		-	589,50	-	0,0
TOTAL		**865,31**	**675,92**	**-**	**91,19**

The figures in the above table are all unassured values.
* Excludes operational losses.

6. WATER RESOURCES

The water resources in the Lower Orange Water Management Area (LOWMA) are very scarce. Rainfall and natural runoff is extremely limited and very sporadic with a total incremental Mean Annual Runoff (MAR) of only 471 million m³ for a catchment area of 251 300 km².

Groundwater

Groundwater is the dominant means of urban/rural water supply in the LOWMA as one moves away from the main stem of the Orange River. The groundwater resource is currently underdeveloped with only an estimated 25 million m³/a coming from this source in 1995. The sustainable groundwater potential of the LOWMA is estimated to be in the order of 660 million m³/a for a 1:50 year level of assurance.

The Groundwater Harvest Potential (Seward and Seymour, 1996) was used as the basis for the evaluation. 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. The interaction of the groundwater and the surface water was taken into account.

The existing groundwater use was determined by Baron and Seward (2000). The information was then verified at a workshop held in the Lower Orange WMA by the national water resources strategy assessment team.

The groundwater balance compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilized.

Surface Water Resources

Surface water resources are highly dependant on the releases from the Gariep and Van der Kloof Dams in the Upper Orange WMA. There are a few small dams in the WMA, but nothing of significant storage capacity except for the Smartt Syndicate ($99,3 \times 10^6$ m³), Van Wyksvlei (143×10^6 m³) and Boegoeberg ($20,4 \times 10^6$ m³) dams. There are no formal transfer schemes importing water into the LOWMA except for the one near Douglas. The developed yield from surface water in 1995, at an assurance of 1:50 years is 5 million m³/a. The potential yield of the WMA taking into account a proposed dam at Vioolsdrift could well be increased to 293 million m³/a. The surface water yields have been calculated without the impact of the ecological Reserve being taken into account, i.e. the Reserve has not been deducted from the surface water yield.

The basis for the analysis of the surface water resources was the synthesised streamflow data at quaternary catchment level developed for the Water Research Commission (Midgley *et al,* 1994). It is commonly referred to as WR90.

The Orange River Development Replanning Study (ORRS, BKS 1997) updated the hydrology of the Upper Orange WMA. However, due to the relatively low and sporadic nature of runoff in the Lower Orange Water Management Area (LOWMA), the WR90 hydrology was deemed sufficiently accurate for analysing contributions to the lower Orange River.

The Orange River is wide, and carries a heavy silt load, resulting in accurate measurement of low-flows being very difficult. Significant contributions from the tributaries are usually masked by high-flows in the Orange River at the same time, making accurate determination of the tributary contributions very difficult. The runoff information in the Lower Orange Water Management Area (LOWMA) is therefore not regarded as accurate, but is sufficient given the low and sporadic contributions to the Orange River.

The impact that the Fish River (in Namibia) has on the Orange River was also taken into account.

It was the intention of the Water Resource Situation Assessment (WRSA) studies to estimate the total potential yield available from the catchments within the Water Management Area, using postulated future storage dams of a particular maximum net storage capacity. However, the dams on tributaries to the Orange River receive low and sporadic inflows, and are subject to extremely high evaporation losses. Similarly even dams on the lower Orange River are very inefficient in terms of yield compared to dams in the upper Orange River. The only dam therefore considered was a dam upstream of Vioolsdrift, which can capture operational losses from upstream, as well as hydropower released during winter, and release the water as required for downstream irrigation and ecological requirements at the river mouth. Various sizes of dam at Vioolsdrift were analysed during the ORRS, and further studies on the Orange River are planned which will investigate inter alia the feasibility of a Vioolsdrift Dam. A large dam with a live storage capacity of 1 500 million m^3 (2 220 m^3 million m^3 gross storage) was considered.

Yield

A broad estimate of total yield can be obtained by combining the 1995 development yields for both the surface and groundwater components and the potential yields from both sources. On this basis, it is estimated that the Lower Orange Water Management Area (LOWMA) could yield, at a 1:50 year assurance, approximately 954 million m^3/a instead of the 1995 yield of 25 million m^3/a. Although this is a dramatic increase on a local scale, it must be interpreted in the context of the resource potential of the entire Orange River Basin. Developments upstream also influence the efficiency with which a potential Vioolsdrift Dam could convert excess runoff into yield.

Water quality

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 database of the Department of Water Affairs and Forestry.

The monitoring stations in the Lower Orange Water Management Area (LOWMA) are predominantly situated along the main stem Orange River. Most of the water quality monitoring stations on the tributaries are closed and are no longer functioning. Samples are taken as and when the rivers flow depending on personnel location at the time.

Domestic and irrigation water use were considered in evaluting the water quality. 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.

Water quality was assessed at a quaternary catchment level of resolution, where such data was available. The final classification of the mineralogical surface water quality of a quaternary catchment was based on both average conditions and extreme conditions.

Water Resources

Catchment						Surface Water Resources				Sustainable Groundwater Exploitation Potential Not Contributing to surface base flow		Total Water Resource (Yield)	
Primary		Secondary		Tertiary (Drainage Area)		Natural Runoff	1:50 Year Developed Yield 1995	Future Dam Yield	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,	Description	No,	Description	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$	$(10^6\ m^3/a)$
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	84,6	2,0		2,0	3,44	140,52	5,44	142,52
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	191,98	3,09		3,09	9,66	299,94	12,75	303,03
				D55	Sak-Hartbees (WC)	3,92	0,06		0,06	0,05	1,58	0,11	1,64
		D4	Molopo	D42	Nossob-Molo (NC)	6,9	0,0		0,0	2,51	20,57	2,51	20,57
		C9, D7, D8	Orange	D92, D71, D72	Boegoeberg (NC)	72,1	0,0		0,0	3,89	92,04	3,89	92,04
				D73	Neusberg (NC)	71,4	0,0		0,0	0,93	38,09	0,93	38,09
				D81, D82	Vioolsdrift (NC)	14,8	0,0	288,0	288,0	1,42	21,90	1,42	309,90
				D82	AlexanderBay (NC)	1,2	0,0		0,0	0,2	2,63	0,2	2,63
	TOTAL IN NORTHERN CAPE PROVINCE					443,00	5,09	288,0	293,09	22,05	615,69	27,14	908,76
	TOTAL IN WESTERN CAPE PROVINCE					3,92	0,06	0,0	0,06	0,05	1,58	0,11	1,64
	TOTAL IN PRIMARY CATCHMENTS C + D					446,92	5,15	288,0	293,15	22,1	617,27	27,25	910,42
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	22,90	0,0		0,0	2,54	39,61	2,54	39,61
				F50	Coastal (WC)	1,21	0,0		0,0	0,15	3,57	0,15	3,57
	TOTAL IN NORTHERN CAPE PROVINCE					22,90	0,0	0,0	0,0	2,54	39,61	2,54	39,61
	TOTAL IN WESTERN CAPE PROVINCE					1,21	0,0	0,0	0,0	0,15	3,57	0,15	3,57
	TOTAL IN PRIMARY CATCHMENT F					24,1	0,0	0,0	0,0	2,64	43,18	2,64	43,18
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						465,9	5,1	288,0	293,09	24,59	655,3	29,68	948,39
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						5,13	0,06	0,0	0,06	0,20	5,15	0,26	5,21
TOTAL IN LOWER ORANGE WMA						**471,0**	**5,1**	**288,0**	**293,1**	**24,74**	**660,45**	**29,94**	**953,6**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	514,6	98,7	0,0	98,7	-	46,4	98,7	145,1
TOTAL IN REPORTING AREA						**985,6**	**103,8**	**288,0**	**391,8**	**24,74**	**706,86**	**128,64**	**1 908,7**

Rounding off errors occur.

The mineralogical surface water quality of the LOWMA is generally good. This is however a very subjective statement as it is based on 7 measuring stations situated along the main steam of the Orange River.

High TDS loads from the Vaal River system, upstream of the study area, have a large impact on the water quality of the Orange River.

It is estimated that by the year 2030, TDS concentrations would increase by about 27% at Kakamas and 58% at the Orange River Mouth over the year 1995 levels. This was regarded as a worst case scenario, the data used in the modelling was poor and the confidence in the calibration was low.

There is a high TDS rating in the Sak River catchment which can mostly be ascribed to natural hydrogeological sources and the high evaporation in the area. The water quality is effectively unacceptable for domestic and irrigation water supply.

Concerns have been raised about high concentrations of algae in the Orange River causing problems in the potable water treatment works at Upington during the summer months. Releases from the Van der Kloof Dam, inflows from the Vaal River system and intensive agricultural activities next to the river are believed to be the source of this problem.

Contamination of the Orange River with pesticides and herbicides from the intensive agriculture next to the river has not been raised as a major concern. Neither has contamination of the river with asbestos from the Prieska area been raised as a specific concern to domestic water users.

The **groundwater** quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO3 as N) and flourides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality was evaluated in terms of TDS and potability. The groundwater quality was classified on the same system used for surface water quality.

The mineralogical ground water quality in the Lower Orange Water Management Area (LOWMA) is not particularly good in terms of its TDS rating. In general the ground water quality is rated as class 2 to class 4, marginal to completely unacceptable. The southern portion of the inland region, De Aar, Victoria West and Sutherland has a class 2 rating, together with the areas surrounding Prieska, Griekwastad, Upington and Springbok. The rest of the WMA, particularly north of Brandvlei and Carnarvon and the coastal strip are rated as class 3 and 4. The Sutherland, De Aar, Upington belt has a varying range of potable groundwater from a moderate 50% to approximately 90%. The balance of the WMA, has a predominant potable usage of less than 30%, with the occassional improvement to 50%.

Microbial contamination of surface water and groundwater resources was addressed in terms of the risk of faecal contamination in various catchments. It has been confirmed that the highest faecal contamination rate is derived from high population densities with poor sanitation services. Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution. This information is intended for planning purposes only and is not suitable for detailed water quality assessments.

An informal survey of bacteriological water quality in the Upington area found high incidences of water borne diseases in communities where people drank untreated or partially treated water directly from the river or from the irrigation canals. In an assessment of the risk to surface water of faecal contamination (DWAF, 2000), the Upington area (D73F) was regarded as the only area in the Northen Cape study area that had a medium risk of contamination. The rest of the study area was regarded as low risk.

Sedimentation

"The catchments in the Orange River basin vary from the highest sediment yield areas in Southern Africa (along the upper reaches of the Orange River) to very low sediment yield areas comprising arid and slow drainage areas along the Lower Orange River." (DWAF 1997, PD000/00/5497, pg 5-1). There are large quantities of sediment available for transport but because the transporting capacity of the runoff is low, all the sediment very seldomly reaches the river course. A large portion of the catchment is also made up of enclosed drainage basins and pans which further prevent sediment accumulation. Hence, it is the transporting mechanism rather than the availability of sediment which is the limiting factor in determining the sediment yield.

Assessment data on sediment accumulation in the lower Orange River catchment is scarce. The following table is a summary of the available sediment data.

Recorded Reservoir Sedimentation Rates for Reservoirs in the Lower Orange Water Management Area (LOWMA)

QUARTER-NARY CATCH-MENT NO,	RIVER	DAM NAME	ECA (KM²)	PERIOD	V_T (10^6 M³)	V_{50} (10^6 M³)	SEDIMENT YIELD (T/KM²/A)
D72C	Orange	Boegoeberg	89 752	1931-1983	14,272	14,066	4,23
D61M	Ongers	Smartt Syndicate	13 114	1912 – 1980	2,175	1,950	4,01
D54B	Van Wyksvlei	Van Wyksvlei	1 339	1884 – 1979	2,248	0,049	36,52
D61E	Dorp	Victoria West	280	1924 – 1954	0,44	0,545	52,5

ECA = Total catchment area — catchment area of next major dam upstream,
V_T = Sediment volume at end of period,
V_{50} = Estimated sediment volume after 50 years at the same average yield,

No recorded sedimentation data is available at the proposed reservoir development site at Vioolsdrift.

7. WATER BALANCE

The water balance was investigated at the outlet to each of the selected drainage areas (see Figure S3.1). The tributaries to the Orange River and the coastal area all appear to be approximately in balance for the 1995 scenario, i.e the the balance shows a very small surplus of deficit. The balance for the key points on the Lower Orange River show deficits, if viewed in isolation, due to higher water requirements and losses than yield. However, their cummulative balance is still in surplus due to unutilised surplus yield from the Upper Orange. The accuracy of water requirements in the upstream WMAs and neighbouring countries, as well as the inter WMA water transfers also affect the surplus yields in the LOWMA.

The number of simplications employed to derive the water balance results coupled to known data limitations all have bearing on the yield balance results. The results provided should therefore only be regarded as draft estimates, being neither final nor highly accurate.

The following table is a summary of the water requirements and availability at a 1 in 50 year level of assurance. The local water balance within the LOWMA shows a deficit of 1 200 million m^3/a, however, when the upstream inflows are included, the estimated balance is a surplus of 1 670 million m^3/a.

Water Requirements and Availability

Catchment						Available in 1:50 Year yield in 1995			Water Transfers at1:50Year Assurance		Return Flows at 1:50Year Assurance		Water Require-ments at 1:50 Year Assurance	Local Water Balance*	Received from Upstream	Water Balance at 1:50 Year Assurance **
Primary		Secondary		Tertiary (Drainage Area)												
No,	Description	No,	Description	No,	Description	Surface water	Ground Water	Total	Imports	Exports*	Re-usable	To Sea				
						(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	2,0	3,44	5,44		0,0	0,3		8,4	-2,96	0,0	-2,96
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	3,09	9,66	12,75		0,0	0,0		22,1	-9,35	0,0	-9,35
				D55	Sak-Hartbees (WC)	0,06	0,05	0,11		0,0	0,0		0,5	-0,39	0,0	-0,39
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	2,51	2,51		0,0	0,0		2,0	0,51	0,0	0,51
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,0	3,89	3,89		0,0	19,92		192,1	-188,21	2 885,0	2 696,79
				D73	Neusberg (NC)	0,0	0,93	0,93		0,46	39,07		531,6	-531,13	2 696,3	2 165,17
				D81, D82	Vioolsdrift (NC)	0,0	1,42	1,42		5,56	16,20		336,9	-341,04	2 165,2	1 824,16
				D82	AlexanderBay (NC)	0,0	0,2	0,2		0,67	0,0	1,85	137,3	-137,77	1 829,0	1 691,23
	TOTAL IN NORTHERN CAPE PROVINCE					5,09	22,05	27,14	0,0	6,69	75,49	1,85	1 230,3	-1 200,99	2 885,0	8 374,51
	TOTAL IN WESTERN CAPE PROVINCE					0,06	0,05	0,11	0,0	0,0	0,00	0,00	0,5	-9,35	0,0	-9,35
	TOTAL IN PRIMARY CATCHMENTS C + D					5,15	22,1	27,25	0,0	6,69	75,49	1,85	1 230,8	- 1 210,34	2 885,0	8 365,16
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0	2,54	2,54		0,0	0,0		7,8	-5,26	0,0	-5,26
				F50	Coastal (WC)	0,0	0,15	0,15		0,0	0,0		0,4	-0,25	0,0	-0,25
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	2,54	2,54	0,0	0,0	0,0	0,0	7,8	-5,26	0,0	-5,26
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,15	0,15	0,0	0,0	0,0	0,0	0,4	-0,25	0,0	-0,25
	TOTAL IN PRIMARY CATCHMENT F					0,0	2,64	2,64	0,0	0,0	0,0	0,0	8,2	-5,51	0,0	-5,51
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						5,09	24,59	29,68	0,0	6,69	75,49	1,85	1 238,1	-1 206,25	2 885,0	1 678,75
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,06	0,20	0,26	0,0	0,0	0,0	0,0	0,9	-9,60	0,0	-9,60
TOTAL IN LOWER ORANGE WMA						**5,15**	**24,79**	**29,94**	**0,0**	**6,69**	**75,49**	**1,85**	**1 239,0**	**-1 215,85**	**2 885,0**	**1 669,15**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	98,7	-	98,7		0,0	6,8	-	102,7	4,0	0,0	4,0
TOTAL IN REPORTING AREA						**103,8**	**24,79**	**128,64**	**0,0**	**6,69**	**82,3**	**1,85**	**1 341,7**	**-1 211,85**	**2 885,0**	**1 673,15**

* To avoid double accounting, water exports within the WMA are not included in the “water requirements” column. Water losses and water exports from the WMA are included

** Negative numbers indicate deficits.

8. COST OF WATER RESOURCES DEVELOPMENT

The cost of potential surface and groundwater development opportunities in the Lower Orange Water Management Area (LOWMA) are based on cost functions supplied by DWAF. Both cost functions have a base date of the year 2000.

This study considered a dam at Vioolsdrift, as proposed in the Orange River. Development Replanning Study. The estimated cost of the dam with a live storage of 1 500 million m³ (2 200 million m³ total storage) is R1,5 billion (year 2000).

There is considerable potential for groundwater development in the LOWMA. The estimated year 2000 development cost is R3,8 billion.

9. CONCLUSIONS AND RECOMMENDATIONS

The nature and extent of the Lower Orange Water Management Area (LOWMA) results in different problems being encountered along the Orange River to those experienced in land or along the coast.

- **Study Areas**

  Virtually every study on the mainstem Orange River has broken the river course into different reaches. This often poses problems when correlating data from previous reports to current data. The creation of the Catchment Management Agencies will hopefully provide a more regulated framework within which future water related information can be recorded.

- **Infrastructure**

  The infrastructure database is incomplete and needs to be further updated. This will require greater input from the various service providers and municipalities who did not provide information when previously approached. The DWAF Kimberley office is/will be attending to this matter as part of the CMA's requirements. It is assumed that this data will be made available to the Water Resources Planning Directorate.

- **Water Requirements**

  The estimated consumptive water requirements for the Lower Orange Water Management Area (LOWMA) equate to 1 502 million m³/a (1 365 million m³/a at 1:50year assurance). The dominant sectors along the Orange River are irrigation and river losses, which together constitute approximately 95% of the total requirement. The dominent sectors in the interior are urban and rural use followed by irrigation. The ecological Reserve has been omitted from these figures due to the difficulty in ascertaining accurate and reliable figures.

- **Ecological Reserve**

  The ecological importance and sensitivity of the rivers, established for this study are general and unrefined estimates. The ecological Reserve has a major impact on the Lower Orange Water Management Area (LOWMA) and needs careful future attention.

There is also limited information available in the parts of the LOWMA away from the mainstem Orange River, regarding input data for the determination of the ecological Reserve. Such a database needs to be created to improve the confidence level of the information provided for the reserve. These are unlikely to have a significant effect on the flows in the Orange River, but are important for local management of the tributary rivers.

- **Mines**

  Future studies of this nature must be aware of the opening and closing of mines in the Lower Orange Water Management Area (LOWMA) due to their associated water requirement. The re-assigning of water rights (entitlements) must be borne in mind with the closure of mines in the future.

- **Namibian Data**

  The Namibian data is very superficial and requires far more in-depth study. The proportion of runoff commanded by dams in the Fish River basin (Z20A quaternary catchment) also requires clarification.

- **Irrigation**

  Irrigation is the largest water use sector in the Lower Orange Water Management Area (LOWMA), and yet there is a general lack of accurate information concerning its water requirements. There are a few key items in the irrigation component which need to be addressed in terms of improving the quality of the data base. They are :

  - The use of crop requirements versus actual scheduled areas, including the crop factors and seasonal distributions associated with the data.
  - The scheduled areas in terms of the new water law.
  - Better information is required on the current practice of opportunistic irrigation through rainfall harvesting.
  - A better measurement of the return flows from irrigation back to the river course.
  - A better understanding of the economic impact of restrictions is required as a sound basis for determination of assurance profiles in the irrigation sector.

- **River Losses**

  River losses consume a large proportion of the surface water resources in the LOWMA. The manner in which the river losses were estimated and the overlap with riparian alien vegetation and dam surface areas must be re-addressed, as the chances of double counting and the impact on the water consumption are critical issues. The behaviour of river losses in ephemeral rivers such as the Fish and Molopo rivers should be given consideration.

The wetlands/pans, particularly in the Sak-Hartbees drainage area, also play a role in the river losses.

- **Alien Vegetation**

  There was much dispute over the alien vegetation coverage in the Lower Orange Water Management Area (LOWMA). Information is also required on the riparian proportion of the infested areas, and their potential overlap with river loss estimates.

- **Water Allocations**

  A number of discrepancies were found in records of irrigation water allocations between previous reports and permits as per the various registers. This is an important factor that must be re-addressed, especially with irrigation being the largest water use sector in the WMA.

- **Water Resources**

  The estimated surface water and groundwater resources in the Lower Orange Water Management Area (LOWMA) equate to 35 million m^3/a (excluding runoff from the Fish River in Namibia).

- **Groundwater**

  The information in the groundwater database used in this study needs to be updated. The Lower Orange Water Management Area (LOWMA) is highly dependant on groundwater in regions away from the main stem of the Orange River. The data base reflects zero usage in many outlying quarternaries where groundwater is the only possible source. There are discrepencies between the information received and recorded in Table 6.2.1 and that entered into the WSAM data base.

- **Dam Critical Area**

  Evaporation is a critical aspect in the Lower Orange Water Management Area (LOWMA). The average proportion of a dam's full supply area exposed to evaporation over the critical period needs to be established, particularly in arid areas where yield is extremely sensitive to evaporation from dams. Consideration should be given to allowing the WSAM to adjust the area proportion based on the surplus yield, which could account for both operating rules and aridity of the catchment.

- **Water Quality**

  Water quality is becoming more and more important as the availability of water resources becomes more and more scarce. There are very few surface water quality measuring stations in the LOWMA with acceptable records for assessing the water quality in the WMA. Additional points need to be established to generate better information. The mineralogical surface water quality along the Orange River in the LOWMA is classified as "good" with the area immediately downstream of Upington carrying a medium faecal contamination rating of the surface water, due to the sewage plant at Upington.

The mineralogical ground water quality varies from marginal to completely unacceptable with the affect that almost half of the WMA has a potable water rating of less than 30%. A band along the southern and eastern boundary including Sutherland, Carnarvon, Victoria West, De Aar, Prieska and Griekwastad has a moderate (50%) to high (90%) potable groundwater source. This risk of groundwater contamination is medium to high in the area where the groundwater potability is good. This generally occurs in the populated areas with poor sanitation systems. The central band of the WMA carries a low risk rating.

- **Water Balance**

The Lower Orange Water Management Area (LOWMA) is a net recipient of water. The shortfall is supplied mainly from yield generated in Lesotho and the Upper Orange WMA, and also to a lesser extent from the Vaal River.

The surface water consumption and especially the surface water available for further exploitation in the Lower Orange Water Management Area (LOWMA) is highly dependant on the water use in the upstream catchments. Changes in water consumption patterns, dam operating rules, hydropower releases etc also have a significant impact on the incremental yields that can be derived by providing additional storage in the Lower Orange Water Management Area (LOWMA). It is imperative that water resources are interpreted not only locally, but also in the context of a larger system (ie including Upper Orange WMA). The water balance estimates should be readdressed as and when the database is improved.

- **Costs of Water Resource Development**

The surface water resources of the Lower Orange Water Management Area (LOWMA) can be increased by approximately 288 million ^{3}/a, through the construction of a large dam at Vioolsdrift. The dam, with a gross storage capacity of 2 220 million m^3, is estimated to cost approximately R1,5 billion (2000 base date) that groundwater yield can be increased by approximately 300 million m^3/a, at an estimated cost of R3,83 billion (2000 base date). Due to the cost, groundwater resource development is considered more feasible for small scale, local supply than for major regional supply.

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ABBREVIATIONS

AEMC	Suggested Ecological Management Class
AMSL	Above mean sea level
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management
DESC	Default Ecological Status Class.
DOC	Dissolved Organic Carbon
DWAF	Department of Water Affairs and Forestry
EISC	Ecological importance and sensitivity class
GIS	Geographical Information System
ha	hectare
HIS	Hydrological Information Services (of DWAF)
IFR	Instream Flow Requirement
km	kilometre
km^2	square kilometre
ℓ/c/d	litres per person per day
LOWMA	Lower Orange Water Management Area
m	metre
MAP	mean annual precipitation
MAR	mean annual runoff
Mℓ	megalitre
Mℓ/d	megalitre per day
NWA	National Water Act (Act No. 36 of 1998)
NWRS	National Water Resources Study
mℓ	millilitre
mg/ℓ	milligram per litre

10^6m^3	million cubic metres
$10^6m^3/a$	million cubic metres per annum
ORRS	Orange River Development Replanning Study
PESC	Present Ecological Status Class
RDP	Reconstruction and Development Programme
SAR	sodium adsorption ratio
THM	trihalomethane
TLC	Transitional Local Council
TRC	Transitional Rural Council
$t/km^2.a$	ton per square kilometre per annum
WMA	Water Management Area
WRC	Water Research Commission
%	percent
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model

GLOSSARY OF TERMS

SUGGESTED ECOLOGICAL	A class of water resource indicating the suggested
MANAGEMENT CLASS	management objectives of an area which could possibly 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.
ASSURANCE OF SUPPLY	The reliability at which a specified quantity of water can be provided, usually expressed either as a percentage or as a risk. For example "98% reliability" means that, over a long period of time, the specified quantity of water can be supplied for 98% of the time, and less for the remaining 2%. Alternatively, this situation may be described as a "1 in 50 year risk of failure" meaning that, on average, the specified quantity of water will fail to be provided in 1 year in 50 years, or 2% of time.
BASIN	The area of land that is drained by a large river, or river system.
BIOTA	A collective term for all the organisms (plants, animals, fungi. bacteria) in an ecosystem.
CONDENSED AREA	The equivalent area of alien vegetation with a maximum concentration/density that represents the more sparsely distributed alien vegetation that occurs over a large area.
CAIRN	Mound of rough stones packed as a monument or landmark.
CATCHMENT	The area of land drained by a river. The term can be applied to a stream, a tributary of a larger river or a whole river system.
COMMERCIAL FARMING	Large scale farming, the products of which are normally sold for profit.
COMMERCIAL FORESTS	Forests that are cultivated for the commercial production of wood or paper products.

DAM	The wall across a valley that retains water, but also used in the colloquial sense to denote the lake behind the wall.
DEFICIT	Describes the situation where the availability of water at a particular assurance of supply is less than the unrestricted water requirement.
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).
DRAINAGE REGION	The drainage regions referred to in this document are either single large river basins, or groups of contiguous catchments or smaller catchments with similar hydrological characteristics. They follow the division of the country into drainage regions as used by the Department of Water Affairs and Forestry.
ENVIRONMENTALLY SENSITIVE AREA	A fragile ecosystem which will be maintained only by conscious attempts to protect it.
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.
EDAPHIC	Pertaining to the influence of soil on organisms. or

	Resulting from or influenced by factors inherent in soil rather than by climatic factors.
ENDANGERED SPECIES	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.
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). In such catchments the water generally drains to pans where much of the water is lost through evaporation.
EPHEMERAL RIVERS	Rivers where no flow occurs for long periods of time.
FORMAL IRRIGATION SCHEME	The term applies to a scheme where water for irrigation purposes is stored in a dam controlled by DWAF or an Irrigation Board and supplied in predetermined quotas to irrigators registered under the scheme.
HETEROGENEOUS	Not uniform. Disparate. Consisting of dissimilar parts or ingredients.
HISTORICAL FLOW SEQUENCE	A record of river flow over a defined period and under a defined condition of catchment development in the past, calculated from a record of observed flow corrected for inaccuracies, or from records of observed rainfall, or a combination of the two.
HYDROLOGICAL YEAR	The twelve-month period from the beginning of October in one year to the end of September in the following year.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.

IRRIGATION QUOTA	The quantity of water, usually expressed as m^3/ha per year, or mm per year, allocated to land scheduled under the scheme. This is the quantity to which the owner of the land is entitled at the point at which he or she takes delivery of the water and does not include conveyance losses to that point.
LOTIC	Flowing water.
MEAN ANNUAL RUNOFF	Frequently abbreviated to MAR, this is the long-term mean annual flow calculated for a specified period of time, at a particular point along a river and for a particular catchment and catchment development condition. In this report, the MARs are based on the 70-year period October 1920 to September 1990 inclusive.
OPPORTUNISTIC IRRIGATION	Irrigation from run-of-river flow, farm dams, or compensation flows released from major dams. As storage is not provided to compensate for reduced water availability in dry years, areas irrigated generally have to be reduced in dry years.
PRESENT ECOLOGICAL STATUS CLASS	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.
QUATERNARY CATCHMENT	The basic unit of area resolution used in the WR90 series of reports published by the Water Research Commission and also in this report. The primary drainage regions are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been created to have similar mean annual runoffs: the greater the runoff volume the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example

	R30D, may be interpreted as follows: the letter R denotes Primary Drainage Region R, the number 3 denotes secondary catchment 3 of Primary Drainage Region R, the number 0 shows that the secondary catchment has not, in this case, been sub-divided into tertiary catchments, and the letter D shows that the quaternary catchment is the fourth in sequence downstream from the head of secondary catchment R30.
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.
RELIABILITY OF SUPPLY	Synonymous with assurance of supply.
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 No. 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 the National Water Act (Act No. 36 of 1998).

RESERVOIR	The lake formed behind a dam wall. In this report the colloquial term dam is generally used for reservoir.
RESILIENCE	The ability of an ecosystem to maintain structure and patterns of behaviour in the face of disturbance or the ability to recover following disturbance.
RESOURCE QUALITY	The quality of all the aspects of a water resource including: (a) the quantity, pattern, timing, water level and assurance of instream flow; (b) the water quality, including the physical, chemical and biological characteristics of the water; (c) the character and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of the aquatic biota.
RESOURCE QUALITY OBJECTIVE	Quantitative and verifiable 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.
RIVER SYSTEM	A network of rivers ranging from streams to major rivers, and, in some cases, including rivers draining naturally separate basins that have been interconnected by man-made transfer schemes.
SCHEDULED LAND	Irrigable land to which a water quota has been allocated.
SUB-CATCHMENT	A sub-division of a catchment.
SUBSISTENCE FARMING	Small-scale farming where almost all produce is consumed by the farmer's household or within the local community.
SPATIO — TEMPORALLY ROBUST	Does not change significantly with time in relation to spatial distribution.
STROMATOLITE	A rocky cushion-like growth formed by the growth of lime-secreting blue-green algae, thought to be abundant 200 million years ago, when blue-green algae were the most advanced form of life on earth.
SWALE	A small earth wall guiding surface runoff away from the stream back onto fields.

TAXON	A taxonomic group referring 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.
WATER IMPORTS	Water imported to one drainage basin or secondary sub-catchment from another.
WATER TRANSFERS	Water transferred from one drainage basin or secondary sub-catchment to another. Transfers in are synonymous with water imports.
YIELD	The maximum quantity of water obtainable on a sustainable basis from a dam in any hydrological year in a sequence of years and under specified conditions of catchment development and dam operation.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act, 1998 (No 36 of 1998) requires the Minister of Water Affairs and Forestry to establish a National Water Resource Strategy (NWRS) 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 should as well as in the subsequent scenario studies referred to above, should in addition to contributing to the establishment of the National Water Resources Strategy (NWRS), provide information for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

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

1.2 APPROACH TO THE STUDY

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

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to other consultants appointed to carry out a separate national demographic study, in relation to water requirements (Schlemmer et al 2001).

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

Both the demographic data and the estimated water requirements in 1995, as supplied for the Lower Orange Water Management Area (LOWMA) by the national demographic study (Schlemmer et al 2001), are presented in this report. In addition to the separate studies on the water situation assessment model and demography referred to above, a number of separate studies were carried out to provide information on a national basis. Information provided on a national basis included the following:

- 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 the ecological component of the Reserve.
- Effects of afforestation on runoff.
- Storage-yield characteristics of rivers.

Information from all the above studies, that is relevant to the Lower Orange Water Management Area (LOWMA), is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect to the Lower Orange Water Management Area (LOWMA) are presented in the nine chapters that make up the main body of this report. A number of appendices containing mainly statistics for the quaternary hydrological sub-catchments that make up the water management area are also included. (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
	References

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 water losses and return flows. Chapter 6 describes the groundwater and surface water resources of the water management area, and Chapter 7 compares water requirements with the available resource. In Chapter 8, rough estimates are given of the cost of developing the portion of the total water resource that was not developed by 1995, and the conclusions and recommendations arising from the study are presented in Chapter 9.

CHAPTER 2: PHYSICAL FEATURES

2.1 THE STUDY AREA

The Lower Orange Water Management Area (LOWMA) dominates the Northern Cape Province with very small components falling into the Western Cape Province on the southern boundary.

The original boundary of the LOWMA gazetted (Government Notice 11609 of 1 October 1999) included the tertiary catchment D33. It was subsequently decided to move D33 to the Upper Orange WMA. Although the change has not yet been formally gazetted, this report has been written with tertiary catchment D33 excluded from the LOWMA.

The Orange River is the largest and longest river in South Africa stretching over 2 300 km with large variations in climate along its course. It traverses some of the wettest and driest parts of Southern Africa from its origin as the Senqu River in the Maluti mountains of Lesotho to its mouth in the Atlantic Ocean at Alexander Bay. **Figure 2.1.1** indicates the Orange River water-course including the Vaal River and contributing catchments from Botswana and Namibia.

Figure 2.1.2 details amongst others the main tributaries of the Orange River as well as the major towns in the WMA. Excluding the inflows from the Upper Orange WMA and Lower Vaal WMA. The main tributaries are:

Left Bank

Ongers River	-	joins the Orange River just upstream of Prieska.
Hartebeest River	-	joins the Orange River approximately 80 km downstream of Upington.

The Carnarvonleegte, Fish, Riet, Rhenoster and Sak Rivers are the main tributaries of the Hartebees River and together they drain the majority of the Hantam and southern portion of the Benede-Orange District Council regions. **Figures 3.4.9.1 and 3.4.9.2** detail the district council areas. These rivers have seasonal flow which is captured by pans or irrigation dams.

The Ongers River also has seasonal flow and most of its potential runoff is stored in the Smartt Syndicate Dam due west of De Aar.

Right Bank

Molopo River	-	joins the Orange River approximately 120 km downstream of Upington. The Nossob and Kuruman rivers join the Molopo River near the LOWMA/Botswana boundary.

The Kuruman, Molopo and Nossob Rivers, which drain the Kalahari and northern Benede-Orange District Council regions, are not considered to make a meaningful contribution to the surface water resources.

Fish River	-	joins the Orange River approximately 100 km upstream of the river mouth, and drains a large portion of Namibia.

In the western part of the WMA, several non-perennial rivers occur that drain directly into the Atlantic Ocean. These include the Buffels, Groen, Spoeg and Swartlintjies Rivers.

The Orange River remains deeply incised in the interior plateau from the point where it enters the LOWMA, downstream of the Van der Kloof Dam until the Boegoeberg, upstream of Groblershoop. The river meanders across a somewhat flatter reach between Boegoeberg and Kakamas, which is the main irrigation area in the WMA. The river plunges into a deep canyon at Augrabies Falls and winds its way through the broken country of the Richtersveld to emerge on a broad stretch of desert across which it meanders to the sea.

Large proportions of the LOWMA are dependant on groundwater resources. This is particularly important since it is the only source for many users. Groundwater quality is poor in most areas and recharge rates are generally low. The well points generally do not lie on major aquifers.

The topography on the eastern boundary of the WMA is predominantly in the 1 200 m (masl) range while it is over 1 400 m in the south. The interior of the WMA is relatively flat with numerous pans abounding. **(See Figure 2.1.3.)**

For purposes of assessing the water requirements and the available water resources, the water management area has been divided into quaternary catchments **(see Figure 2.1.4)**. These are the basic unit of area used in the Water Research Commission Report, "The Surface Water Resources of South Africa, 1990", which is the main source of the hydrological data used in this study.

In this system, primary drainage regions throughout the country are divided into secondary, tertiary and quaternary catchments. The quaternary catchments are numbered alpha-numerically. A quaternary catchment number, for example F30C, may be interpreted as follows. The letter F denotes Drainage Region F (sometimes referred to as a primary catchment). The number 3 denotes secondary catchment 3 of Drainage Region F. The number 0 shows that the secondary catchment has not, in this case, been sub-divided into tertiary catchments. The letter C shows that the quaternary catchment is the third, mostly in sequence, downstream from the head of secondary catchment F3.

The LOWMA consists of portions of the drainage regions C, D and F. The WMA includes a total of 143 quaternary catchments from these drainage regions.

The southern parts of Botswana and Namibia drain directly into the Orange River or its tributaries, the Molopo and Nossob. They therefore have an impact on the yield available from the Orange River and have been taken into consideration in this study. Detailed information on these particular areas is not readily available to the same standard as that of the LOWMA. This study has therefore adjusted its approach to Botswana and Namibia accordingly, eg. the size and distribution of the catchment areas. The numbering system adopted for the international catchments is similar to that of the South African catchments, but to a far lesser extent.

Detailed descriptions of the characteristics of the international catchments, the water resource/requirements and other matters addressed in terms of the South African WMAs are not all fully addressed for the international catchments.

2.2 CLIMATE

2.2.1 Overview

Topography is an invariant feature of the physical landscape which is described by altitude, as well as the rate of change in altitude. Such altitudes exert major influences on climate. Climate is defined by Shulze as an enduring regime of the atmosphere and it represents a composite of day-to-day weather conditions and atmospheric elements within a specified place or region or over a long period of time (RE Schulze, 1997). Of the great natural patterns that dominate the earth's environment, viz patterns of climate, plant distribution and soil, climate is inevitably perceived as the principal dynamic component, and the obvious independant variable shaping the other two. (Akin, 1991.)

The Lower Orange River Management Area (LOWMA) is characterised by a harsh climate with minimal rainfall and prolonged droughts only to be terminated by severe flooding. The area's arid climate is accompanied by high evaporation due to the intense heat of the summer months. In contrast, the winters are cold and dry with regular and severe frosting. Warm northerly winds drum up dust storms from August to December, while the prevailing westerly winds intensify the cold during the winter months.

2.2.2 Temperature

The mean annual temperature for the LOWMA is 17,4º C. It ranges between 12º C in the south to 20º C in the north.

The highest maximum temperatures are experienced in January and the lowest minimum temperatures occur in July. The following table summarises temperature data for the LOWMA for these two months (Schulze et al, 1997). Temperatures in excess of 40ºC and 50ºC have been recorded in the northern portion of the LOWMA.

Table 2.2.1: Temperature Data

MONTH	TEMPERATURE (ºC)		
	MEAN VALUE	MAXIMUM VALUE	MINIMUM VALUE
<u>January</u>			
Daily maximum temperature	32,0	35,3	23,2
Daily minimum temperature	15,6	18,9	9,9
Temperature range	16,4	19,6	11,5
<u>July</u>			
Daily maximum temperature	18,0	23,7	10,2
Daily minimum temperature	2,3	9,7	-3,0
Temperature range	15,8	19,0	10,2

Frost occurs throughout the LOWMA in winter, typically over the period mid-May to mid-September. The average number of days with heavy frost for the LOWMA ranges between 1 in the northern parts to 60 in the southern parts. Only isolated areas along the Lower Orange River and coastal plain are frost free.

2.2.3 Rainfall

Figure 2.2.1 details the LOWMA mean annual precipitation, which is highly seasonal and occurs dominantly in the very late summer. The coastal region is however typically a winter rainfall area. The peak rainfall month is March. The average hail day frequency is one per annum and the lighting flash density is 0 to 3 flashes per km² per annum.

The LOWMA is the WMA that experiences the lowest rainfall in the country, with large parts having a Mean Annual Precipitation (MAP) of 200 mm or less. The MAP ranges between 20 mm on the west coast boundary to approximately 300 mm on the eastern boundary. Part of the Kamiesberg, east of Kamieskroon usually receives in excess of 400 mm/a. The monthly coefficient of variation (CV) is predominantly in the 35 to 40% bracket with higher values above 40% in the Richtersveld and Alexander Bay areas.

For the driest year in five (80% exceedance probability) the annual rainfall is 129 mm. The annual rainfall for the wettest year in five (20% exceedance probability) is 284 mm.

The mean annual percipitation for the LOWMA as a whole is in the order of 200 mm.

2.2.4 Humidity and Evaporation

In general the relative humidity over most of the LOWMA is low. It is higher in summer than in winter, with the highest daily average being recorded in March (62,1%), and the lowest in August (57,3%). This is in accordance with the rainfall pattern. The coastal belt reacts somewhat differently, with higher relative humidity in the winter months as would be expected for a winter rainfall area. The coastal belt is also influenced by fog and onshore winds from the Atlantic Ocean.

The relative humidity generally decreases from the coastal belt to the central region of the WMA before increasing towards the southern and eastern boundaries.

Figure 2.2.2 details the mean annual evaporation of the LOWMA.

The mean annual evaporation for the LOWMA is approximately 2 366 mm (as measured by S-pan). It ranges from roughly 2 000 mm on the coastal belt to 2 350 mm on the eastern boundary. The southern boundary varies from 1 950 mm to 2 150 mm while the evaporation in the northern region varies between 2 550 mm and 3 050 mm. The highest evaporation is in December, and the lowest is in June.

2.3 GEOLOGY

The Lower Orange Water Management Area (LOWMA), as shown on **Figure 2.3.1**, is underlain by very diverse lithologies. Several broad lithostratigraphic units fall within the boundaries defined by the LOWMA. In oldest to youngest these units comprise the following:-

- Namaqualand-Natal Basement Complex. Rock of this complex, ranges from homogenous granites through to migmatites and gneisses. The area underlain by the Namaqualand-Natal Complex is situated in the vicinity of the Orange River between Upington and Springbok. The area is an assembly of compact sedimentary, extrusive and intrusive rocks.

- Ventersdorp Supergroup, represented by andesitic lavas and occasional sedimentary rocks related to post extensive erosion, are encountered in very small isolated inliers between Prieska and Douglas. They are mainly tillites of the Dwyka formation.

- Dolomitic and related carbonate rocks of the Postmasberg Group, Campbell and Griquatown Sequence, all forming part of the Griqualand West Sequence, occupy the north-eastern lobe of the LOWMA. Dolomites, limestones and related sedimentary rocks (often iron or manganiferous ore bearing) make up this broad lithostratigraphic unit.

- Abbabis and Kheis Groups are represented by relatively small inliers of diverse sedimentary successions consisting of shales, sandstones, banded iron formations and conglomerates. These rocks are encountered in the vicinity of Upington and are not widespread.

- Damara Sequence, encountered in the immediate vicinity of Alexander Bay and Port Nolloth, is represented by the Fish River, Schwarzrand, Kuibis, Malmesbury, Gariep, Swakop, Otavi, Nosib, Rehoboth and Sinclair Groups. Lithologies in these various groups are very diverse, ranging from shales, sandstones, diamictites, banded iron formation through to limestones and calcareous sedimentary formations.

- Karoo Sequence, represented by the Ecca Group and Dwyka Formation, and to a lesser extent the Beaufort Group, occupy the southern lobe of the LOWMA, and comprises thick successions of sedimentary rocks. Sedimentary rocks range from mudrocks through coarser varieties (sandstones, conglomerates) to diamictites and rhythmites (pleistocene deposits). Karoo or Jurassic dolerite is fairly common throughout the sequence and also frequently intrudes older rocks.

- Quaternary and Tertiary dune deposits, consisting of “Kalahari red sands”, occupy the extreme northern part of the LOWMA bordering on Namibia. These dune deposits are of considerable thickness and comprise fine aeolian sands with occasional coarser gravel deposits.

2.4 SOILS

Figure 2.4.1, obtained from the WR90 study, shows a generalised soils map of the study area using some 16 broad soil groupings. The groupings were derived by the Department of Agricultural Engineering of the University of Natal using a national base map that 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.

The following soil types occur in the Lower Orange Water Management Area (LOWMA):

- Class B soils dominate the LOWMA southern boundary. They are moderate to deep soils and generally sandy. The relief is undulating.

- Class C soils are found in a band from south of Kamieskroon through Springbok and Steinkopf into the Richtersveld. The soil depth is moderate to deep and is predominately sandy.

- Class D soils are found in a band from the Orange River in the south heading north east between Griekwastad and Douglas. This is a very shallow, sandy soil type.

- Class I soils occupy a very small portion of the WMA and are found near Richmond. The soil depth is moderate to deep and of a clayey-loam nature.

- Class K soils are found on the southern most portion of the LOWMA in the Sutherland vicinity. Soil depths are moderate to deep and interspersed with exposed rock. The area has a sandly-loam soil.

- Class L soils dominate the eastern side of the LOWMA from De Aar, through Prieska to Upington. Soil depths are moderate to deep and are sandy-loam.

- Class M soils cover a vast portion of the central region, as well as a strip along the Orange River from Boegoeberg to Augrabies. These soils are moderate to deep and are composed of sandy-loam.

- Class N soils cover a very small area north, south and west of Griekwastad. Unlike its eastern neighbour (Class D) these soils are shallow and of a more sandy-loam nature.

- Class P soils occupy the greatest coverage in the LOWMA. They occupy the entire coastal belt and large tracts south of the Orange River between Vioolsdrift and Upington. An area north and west of Upington also falls under this soil type. The soil depths are shallow and are generally sandy. Exposed rock will also be found in these areas.

- Class Q soils are found north of Upington and continue into the wedge between Namibia and Botswana (Kalahari Gemsbok Park — See **Figure 2.6.3.2)**. The soil is sandy.

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 soils information is given as general background information for this report only and its outdatedness is not considered to be critical. 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 dependant on the prevailing climatic (especially rainfall) and edaphic (soil) conditions. For the purposes of identifying and managing the heterogenous range of vegetation within South Africa, it is necessary 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. These "simplified" Acocks veld type categories are used for the purposes of this report, and accordingly the description of the natural vegetation types occurring within the Water Management Area (WMA) is rather broad.

Table 2.5.1.1: 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 Shrub	25	
Karroid Broken Veld	26	
Central Upper Karoo	27	
Western Mountain Karoo	28	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Arid Karoo	29	Karoo and Karroid (Cont.)
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 Shrub
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	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
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

The main factors affecting the type of natural vegetation are soil conditions, topography (including the longitudinal and latitudinal position) and climate. These factors are briefly discussed elsewhere in this chapter.

2.5.2 Natural Vegetation types in the Lower Orange Water Management Area (LOWMA)

Figure 2.5.2.1 shows the Acocks natural vegetation for the LOWMA. South of 29º latitude, the LOWMA is dominated by two veld types, namely Karoo and Karroid, and False Karoo. The dominant veld type north of 29º latitude is Tropical Bush and Savanna.

The above mentioned veld types occur under conditions of low MAP. (400 mm per annum to less than 100 mm per annum.) The altitude ranges from sea level to 1 400 m (amsl) in the southern most parts. The largest part of the LOWMA is at an altitude between 600 m and 800 m above sea level.

Tropical Bush and Savanna

This veld type lines the north eastern border of the WMA, its predominant “sub-type” is Kalahari Thornveld. The tufted grasses occur on deep loose sand over calcareous tufa. The sparse tuftedness of the grass and the looseness of the sand make this veld extremely vulnerable to grazing pressure.

Karoo and Karroid

This veld type dominates within the LOWMA, occupying some 60% of its area. The flora is characteristically low, typically less than 1 m in height, and includes shrub, bushes, dwarf trees and a few grasses. Rainfall within this vegetation type typically ranges between 150 mm and 500 mm. Karoo and Karroid veld occurs at any altitude from sea level to 1 700 m above mean sea level.

This veld type consist of 12 “sub”-veld types of which seven occur in the LOWMA. They are:

- Orange River Broken Veld (along the Orange River, east of 20º latitude).
- Arid Karoo.
- Western Mountain Karoo (southern most parts near Sutherland).
- Strandveld (along the coast).
- Succulent Karoo (along the coast, but inland from the Strand veld).
- Namaqualand Broken Veld (along the Orange River, west of 20º latitude and also inland from succulent Karoo).
- Central Upper Karoo.

False Karoo

This veld type generally occurs on the eastern and south eastern portion of the WMA. Patches are also found to the north, east and south of Springbok as well as at Sutherland.

The False Karoo vegetation is typified by low vegetation, but contains more grassy elements than the Karoo and Karoid veld. The areas occupied by this veld type are typically very arid with low rainfall and generally occur below 1 200 m in elevation.

Nine “sub”-veld types make up the False Karoo. The following three are found in the LOWMA:

- Mountain Rhenosterveld.
- False Succulent Karoo.
- False Arid Karoo (eastern parts, south of the Orange River).

Sclerophyllous Bush

This veld type, otherwise known as Fynbos, exists in an isolated area of the Rooiberg, north east of Garies.

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.
- Protected Land/Seascapes.

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[1] 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 (Act 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.

In this report, Sensitive Ecosystems include the following:

- Areas that are considered fragile in terms of water quality and quantity, and will be maintained only by conscious attempts to protect them.

[1]The RAMSAR Convention is an inter-governmental treaty that provides the framework for international co-operation for the conservation of wetland habitats. Because wetlands are very important for ecological processes as well as their rich flora and fauna, the broad objectives of the Convention are to stem the loss of wetlands and to ensure their conservation. To meet these objectives, the Convention places general obligations on contracting parties relating to the conservation of wetlands throughout their territory, and special obligations pertaining to those wetlands that have been designated in a List of Wetlands of International Importance. South Africa is a contracting party to the Convention.

- Areas that are Ecologically Important (i.e. they contribute towards the healthy functioning of an ecosystem). Aspects that were considered in this respect included habitat diversity, biodiversity, connectivity, and the presence of unique, rare or endangered biota or landscapes.

- Areas that are protected in terms of the RAMSAR Convention.

- Areas that are protected in terms of South Africa's schedule of protected areas.

2.6.2 River Classification

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

This section describes the procedures and methods adopted to estimate the various status and management classes of the rivers that will be used to estimate the corresponding quantities of water required for that component of the Reserve that is necessary to protect the aquatic ecosystems according to the designated class.

The procedure that has been followed to determine the various classifications is illustrated in **Diagram 2.6.2.1**. The descriptions of the various ecological importance and sensitivity classes (EISC), default ecological management classes (DEMC), default ecological status classes (DESC), present ecological status classes (PESC) and the suggested future ecological management class (AEMC) are given in **Diagram 2.6.2.2.**

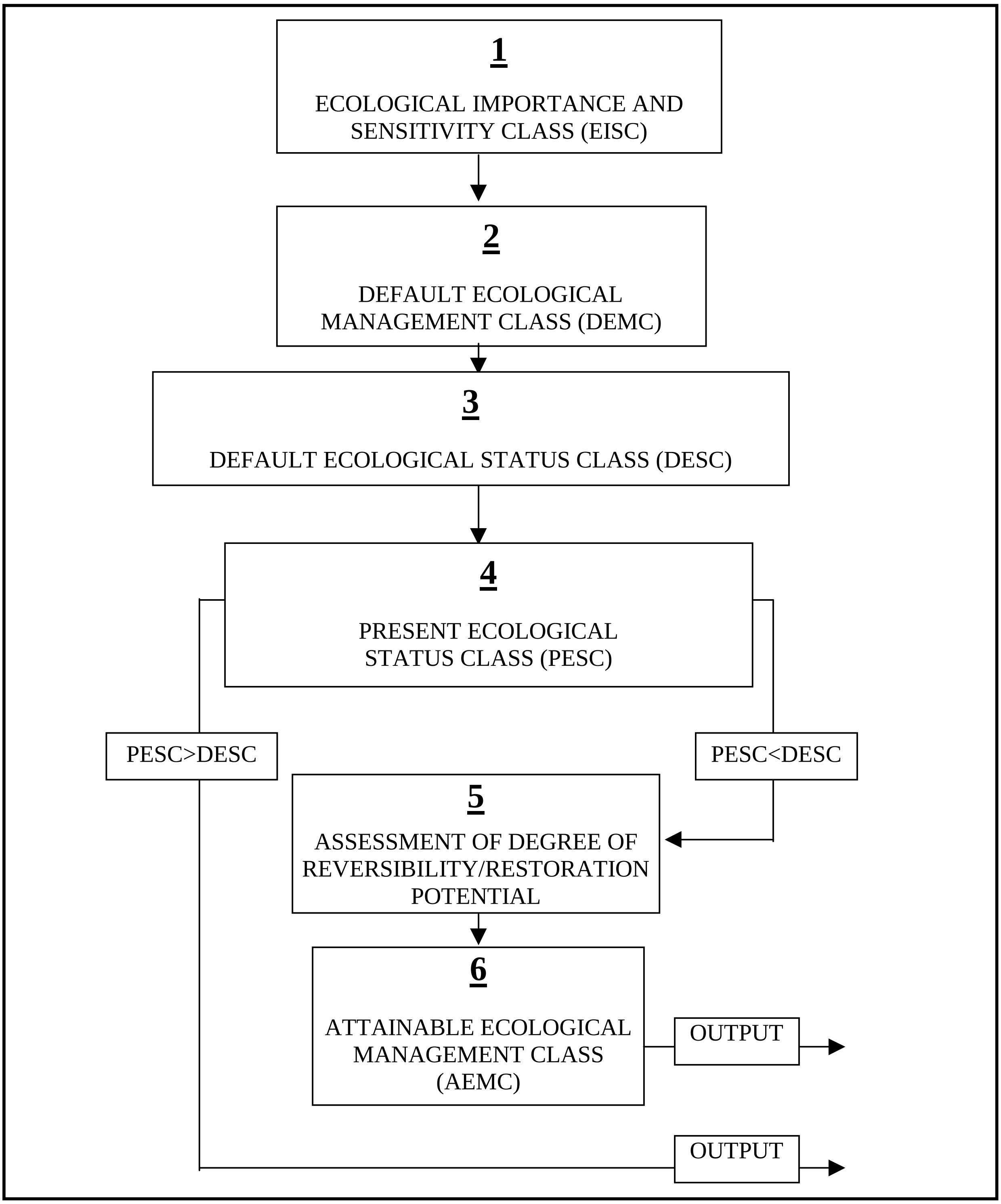


Diagram 2.6.2.1: Procedure followed to determine the river classifications

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

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

→ : indicates relationship.

⟶ : indicates possible direction of desirable change.

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

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

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

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

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

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

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

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

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

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

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

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

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

Ecological Importance and Sensitivity Class (EISC)

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

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

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

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

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

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

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

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

Present Ecological Status Class (PESC)

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

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

Suggested Future Ecological Management Class (AEMC)

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

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

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

2.6.3 Aquatic Ecosystems of Concern to the Study

It is important to recognise that within the context of the current report, sensitive ecosystems refer specifically to ecosystems that 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. **Figures 2.6.3.1, 2.6.3.2 and 2.6.3.3** detail the Lower Orange Water Management Area's ecological class/status and the ecologically sensitive sites.

A total of seven areas within the LOWMA were identified as aquatic ecosystems of concern. A description of these areas is given as follows:

***i) Pans*[2]**

Pans are important nodes of biological diversity, and usually support a highly specialised biota, which at times are exceedingly abundant. The pans are characterised by concentric bands of vegetation types, with most grasses having a significantly higher nutritional value than grasses in surrounding areas. The low-lying parts of the pan contain salt-licks and seasonal waterholes, and are therefore important to game and stock. The pans in the LOWMA are likely to harbour many

[2] Information on pans was deliberately excluded from the WSAM database, which considered rivers and river courses only.

rare and endemic species, but information on these systems (of pans) is limited, not only in South Africa, but worldwide (Breen, 1991). Although these pans are inundated at infrequent intervals, they are rapidly colonised by mobile organisms, particularly birds. There are numerous pans in the LOWMA, but the following areas are of particular concern.

The Grootvloer-Verneuk Pan complex (D57D)

Noble and Hemens (1978) considered this area of special conservation interest. More recently, a survey of the invertebrate fauna in Grootvloer Pan found an exceptionally high diversity of crustaceans (Hamer & Rayner, 1996). These pans are also important for fish migration, especially smallmouth yellowfish, *Barbus aeneus*, between the Orange and Sak Rivers (Hocutt & Skelton, 1983).

Pans in the vicinity of Victoria West and De Aar (D61 and D62)

These pans are extremely important for the highly threatened and endemic Blue Crane, which need standing water in which to roost (M. Anderson, pers. comm. 1999).

Pans in the vicinity of Brandvlei (D57, D58)

These pans are important at times for flamingos and the chestnutbanded plover. These birds are listed as "indeterminate" and "rare" respectively in the Red Data Book for birds (Brooke, 1984).

The biggest threats to these pans are trenches that are dug to supply stock with water, as a trench can change the entire flooding pattern of a pan. Many of the pans consist of calciferous aquifers perched on Kalahari sands. Digging a trench on these pans, or any attempts to deepen them, is a highly effective and irreversible way of draining them.

Another problem is that telephone and powerlines in the close proximity to pans cause significant mortality among large birds, particularly during high rainfall years when large numbers of birds congregate at the pans. Other threats to pans include mining of salt and farming of wheat.

ii) Dry streambeds in the Kalahari Desert

Dry streambeds within the Kalahari Desert (D42) are characterised by a much higher faunal density than the surrounding sandveld (Parris, 1984). The sides of the riverbeds are often ridged with limestone that provide shelter for a wide range of fauna. For example, Dent’s horseshoe bat (*Rhinolophus denti*) roosts in crevices along the edge of the Molopo River (Smithers, 1983). The dry riverbeds are also important corridors for the movement of fauna.

Although the composition of the vegetation along dry riverbeds is not significantly different from that found in the open veld, the vegetation is considered important for structural reasons, simply because the trees in the riverbed are significantly bigger and more abundant than those in the open veld. These trees provide important nesting sites for large birds in an area that is otherwise devoid of cliffs suitable for nesting of such birds.

Several species of rare and endangered raptors are found along dry riverbeds in the Kalahari Desert (e.g. Bateleur, Cape Vulture, Lappet Faced Vulture, Martial Eagle, Tawny Eagle and White Headed Vulture). These birds tend to migrate along river courses, and prefer to nest in large trees that grow in dry riverbeds (e.g. Nossob and Molopo Rivers).

Dry riverbeds are also important for the migration of insects, particularly those with an aquatic and terrestrial phase. For example, adult blackfly females need a warm blood meal (i.e. from a bird or mammal) in order to develop their eggs. Having fed, they then need to return to the mainstream to lay their eggs. The chances of them finding the river in an arid area like the LOWMA by chance alone are highly unlikely. The vegetation along a dry riverbed provides not only a favourable microclimate for insects to rest and feed, but also provides a visual cue with which the insects can navigate. Furthermore, cooler air tends to collect in dry riverbeds and move downstream each evening, which is the time of day when blackfly adults, like many other insects, are most active. The unidirectional movement of air inadvertently carries with it the gravid (pregnant) blackflies, and returns them to the mainstream to lay their eggs. The dry riverbeds are therefore an integral part of the ecology of the mainstream.

Stream beds in the Kalahari also provide habitat for the African Rock Python, which is the only species of snake which is listed in the Red Data Book for reptiles and amphibians, and which is associated with rivers within the LOWMA (Branch, 1988). This species is found in riparian vegetation along the Kuruman and Molopo Rivers (D42C, D42D).

Dry streambeds are used extensively as access routes throughout the area, and most human settlements, including those within the National Parks, are situated close to or along a streambed. The streambeds are therefore highly vulnerable to the impacts of development.

iii) Dry streambeds in the vicinity of Sutherland

The dry streambeds and associated riparian bush in the vicinity of Sutherland (D51B, D52C, D52F) are important for the conservation of the riverine rabbit *Bunolagus monticularis.* This rabbit is among the rarest of Southern African mammals, and is listed internationally as an endangered species (Smithers, 1983, Smithers, 1986).

This species of rabbit occurs on the alluvial floodplains adjacent to the seasonal rivers or "leegtes". This habitat is very well defined, being much thicker and taller than adjacent "vlakte" habitat on shallower or stonier soils. The most important threat is habitat destruction due to dry-land cultivation along the alluvial floodplains — which is extensive along the Sak River. The animals get their moisture from the vegetation, so water availability is not an issue for them (A. Duthie pers. comm. 1999).

iv) The Asbestos Mountains near Prieska

The Asbestos Mountains between Westerberg and Boegoeberg Dam are ecologically important because of the high priority of conserving a distinct and threatened vegetation type: the Orange River Broken Veld (Lloyd, 1990). The area is also important for conservation because of its aesthetic appeal, relatively undisturbed condition, diversity of habitats, altitudinal gradient, and extensive stands of *Aloe dichotoma* (Kokerboom).

The aquatic biota inhabiting this area is similar to that found in the rest of the middle and lower Orange River, and is characterised by a low diversity of fish and invertebrate species. However, the river supports a number of taxa that are of conservation importance. The largemouth yellowfish, *Barbus kimberleyensis*, is distributed in low numbers throughout the middle and lower Orange River. This species is considered rare and endangered on an international scale. Fish species sensitive to changes in flow in this area include two species of *Labeo* (*L. umbratus* and *L. capensis*), that need clean gravel bars for laying eggs, and the rock catlet *Austroglanis sclateri*, which inhabits rapids and riffles. The rock catlet is endemic to the Vaal and Orange Rivers, although it appears to be fairly common.

The blackfly *(Simulium gariepense)* is restricted to large and turbid rivers, and is currently found in low numbers in the middle and lower Orange River only (Palmer and De Moor, 1998). This species is considered rare and endangered on an international scale.

v) Undeveloped "floodplains" in the Orange River in the vicinity of Onseepkans

The Orange River downstream of Upington is characterised by a steep gradient, numerous islands and a highly anastomosed (multi-channelled) main channel with numerous secondary (seasonal) channels (Palmer, 1997). Most of these areas have been developed for irrigation, but a few areas remain undeveloped. The remaining areas are important ecological nodes, particularly as refuge areas in an area that is biologically very isolated, and therefore vulnerable to disturbance. The diversity of riverine habitats in these "flooplain" areas is high, and includes waterfalls, cataracts, rapids, riffles, runs, deep pools, quiet backwaters and magnificent riparian vegetation. Consequently, the area supports an interesting and varied fauna.

The undeveloped "floodplains" in the vicinity of Bontebos and Bontborseiland, upstream of Onseepkans, have been identified as areas of particular conservation importance (Palmer, 1996). The area also contains a few hot springs. This area is now included in the proposed Gariep Transfrontier Conservation Area (Jardine & Owen, 1998).

The area is noted for the presence of the Namaqua barb, *Barbus hospes*, which is found downstream of the Augrabies Falls only (Skelton, 1987). This species is considered rare and endangered on an international scale. Other fish species of note in the biogeographically isolated stretch of river downstream of Augrabies Falls include genetically distinct populations of the threespot barb *Barbus trimaculatus*, and the river sardine *Mesobola brevianalis.* The area is also noted for the presence of the Cinnamonbreasted Warbler, listed as "rare" in the Red Data Book for birds (Brooke, 1984).

The Orange River is not important for eel migration, as there are only five records of eels from the Orange-Vaal System (Abrahams pers. comm.). Part of the reason for the low numbers is that the breeding grounds for southern African eels are thought to be off the coast of Madagascar, and it is unlikely that they enter the Orange River via the estuary. Furthermore, the 10-15 year flood cycle of the

Orange River provides little opportunity for eel migration. It is hypothesised that the eels enter the Orange River by crossing the watershed in the upper reaches.

vi) Richtersveld and Little Namaqualand

The Richtersveld and Little Namaqualand are renowned for their high diversity of succulents, beetles, reptiles and amphibians, including a number of vulnerable, rare and endemic species. However, few of these species are associated with running water. Notable exceptions are an isolated population of the clicking stream frog *Rana grayii* (D82J), and the endemic Namaqua stream frog *Strongylopus springbokensis* (F10A, F20A, F30A, F30C, F40B, F40E) (Passmore & Carruthers, 1979).

The Black Stork, listed as "indeterminate" in the Red Data Book, is found along the Orange River downstream of Vioolsdrift. This stork has a winter breeding season, which is thought to be an adaptation to the abundance of prey when many rivers and water bodies are drying up (Siegfried 1967b in Harrison et al 1997). Several species of birds were considered rare and endangered on an international scale, including white pelicans, which occur along the lower Orange River (D82H, D82J, D82K, D82L).

vii) Orange River Mouth[3]

The Orange River Mouth (D82L) consists of a delta-type river mouth that comprises a distributory channel system between sandbanks covered with pioneer vegetation, a tidal basin, and an extensive salt-marsh on the south bank (Cowan, 1995). The mouth is characterised by an almost complete lack of estuarine fauna (Brown, 1959, Seaman & Van As 1998). The mouth is considered ecologically important mainly because of its strategic locality for migrating birds, including 14 species considered rare or endangered (Williams, 1986). It is one of only nine wetlands situated along the arid south-western coast of Africa, and has been ranked as the sixth most important coastal wetland in South Africa.

The area provides habitat for breeding of birds, and populations can be as high as 20,000 to 26,000, representing 57 species (ORETG, 1989). The area of inundation, and hence availability of food for migrating birds, depends on river levels and the opening and closing of the mouth. The river mouth is therefore highly sensitive to changes in flow, and is also susceptible to salinisation during low-flow periods.

The nearest wetland to the Orange River mouth is about 400 km to the south. The isolated nature of the mouth highlights the ecological importance of this wetland.

The ecological condition of the mouth has changed considerably due to siltation and upstream impoundment. In the 1960s the salt marsh was drained in an attempt to control mosquitoes. In 1986 concerns over the deteriorating status of the Orange River Mouth led to a workshop on the environmental water requirements of the estuary (ORETG, 1989). The main concerns included conservation of birdlife, re-establishment of the salt marsh on the southern bank, and control of

[3] Estuaries were explicitly excluded from the EcoInfo database, but they were included in the Water Situation Assessment Balance Model in terms of their water requirements.

salinisation, which was anticipated to become a critical factor during low-flow conditions (ORETG, 1989). Remedial measures included flow regulation, periodic flushing, controlled inundation of the saltmarsh, consideration of alternatives to the present oxidation ponds, and installing culverts and stormwater pipes under an access road that dissects the estuary, preventing flow from one side to the other (ORETG 1989; Bickerton 1993).

Nine years later, in 1995, the conditions of the salt marsh had deteriorated further due to poor mouth management and leakage of process water into the salt marsh (South African Wetlands Newsletter, No 5. November 1995).

Two international agreements are directly relevant to the Orange River Mouth. In 1991 the mouth was designated to the list of wetlands of international importance in terms of the RAMSAR Convention (Cowan & Marneweck 1996). The Orange River mouth has also been proposed as a transfrontier park which would make it the first and only transfrontier, RAMSAR site in South Africa. Due to the anthropogenic impacts in the demarcated wetland area (flood protection works of the mine and other constructions such as the oxidation ponds), the wetland was placed on the Montreux record in September 1995 (Abrahams, 2001). In 1999 South Africa signed the African Eurasian Waterbird Agreement (AEWA), an agreement under the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention or CMS). The Bonn Convention provides a framework within which governments may work together to conserve migratory species and their habitats. The next phase is to ratify the agreement.

2.6.4 Natural Heritage Sites, Proclaimed Game and Nature Reserves, 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 Lower Orange 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 those areas listed in Section 2.6.1, viz. Scientific and Wilderness Areas, National Parks and Equivalent Reserves, Natural 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 LOWMA. 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 LOWMA

AREA NAME	CATEGORY	GRID REFERENCE
Kogelbeen-Grot	Natural Heritage Site	28°41’S; 23°22’E
Sterboom	Natural Heritage Site	32°27’S; 21°14’E
Klipgatsfontein	Natural Heritage Site	31°20’S; 22°37’E
Cornellskop	Natural Heritage Site	28°25’S; 16°53’E
Noute se Berg	Natural Heritage Site (Not yet proclaimed)	29°27’S; 22°44’E
Augrabies Falls National Park	National Park	28°35’S; 20°19’E
Richtersveld National Park	National Park	28°15’S; 17°00’E
Kgalagadi (formerly Kalahari) Gemsbok National Park/ Kgalagadi Transfrontier Park	National Park	25°S; 20°E
Namaqualand National Park	National Park	30°12’S; 17°46’E
Groen-Spoeg National Park	National park (Not yet proclaimed)	32°20’S; 17°40’E
Gariep Transfrontier Park	Proposed Transfrontier Park	28°45’S; 19°25’E
Orange River Mouth Transfrontier Park	Proposed Transfrontier Park	28°35’S; 16°25’E
Aalwynprag Nature Reserve	Nature Reserve	29°28’S; 16°32’E
Aggeneys Private Nature Reserve	Nature Reserve	29°15’S; 18°47’E
Die Bos Nature Reserve (on the banks of the Orange River near Prieska)	Nature Reserve	29°40’S; 22°44’E
Goegap Nature Reserve, formerly the Hester Malan Nature Reserve (near Springbok)	Nature Reserve	29°40’S; 18°00’E
Klaarwater Nature Reserve (near Griquatown)	Nature Reserve	28°47’S; 23°15’E
Prieska Koppie Nature Reserve (near Prieska)	Nature Reserve	29°40’S; 22°44’E
Kokerboom Forest (near Kenhardt)	Nature Reserve	29°23’S; 21°06’E
Spitskop Nature Reserve (near Upington)	Nature Reserve	28°20’S; 21°08’E
Tierberg Nature Reserve (near Keimoes)	Nature Reserve	28°43’S; 20°58’E
Victoria West Nature Reserve (near Victoria West)	Nature Reserve	31°28’S; 23°10’E
Witsand Nature Reserve (near Groblershoop).	Nature Reserve	28°33’S; 22°28’E
Nababeep	Nature Reserve	28°40’S; 17°23’E

The aforementioned list of protected areas should be regarded as dynamic, since other protected areas are likely to be identified within this WMA in the future. Accordingly, it is the developer’s responsibility to ensure he is familiar with the most recent status of protected areas within the LOWMA.

Natural Heritage Sites

There are five Natural Heritage Sites within the LOWMA, only two of which could be affected by water resource developments. The first is Klipgatsfontein on the Klein Brak River (between Loxton and Victoria West) (D61F), which covers 17,760 ha in the Central Karoo. This is where the rare and endangered riverine rabbit (*Bunolagus monticularis*) is known to occur. The second is Cornellskop, near Kuboes, where there is a natural limestone sinkhole, 50 m deep, supposedly inhabited by the supernatural hero Heitsi Eibib (Nama mythology).

The other two sites are Sterboom, approximately 95 km east of Sutherland and Kogelbeen Cave, approximately 40 km north of Griekwastad.

The Camel thorn (Acacia erioloba) forest at Kathu is a natural heritage site.

Noute se Berg, near Prieska (D72B, D72C), qualifies as a Natural Heritage Site, but it has not been registered (Anderson pers. comm. 1999). This area may be affected by water resource developments, as it is situated along the Orange River.

National Parks

The LOWMA includes three National Parks and three proposed National Parks, two of which have frontage along the Orange River.

- **The Augrabies Falls National Park** (D81A, B, C), on the Orange River, is best known for its spectacular waterfall and gorge. The size of the park has recently been increased to 880 km², allowing the re-introduction of black rhinoceros.

- **The Richtersveld National Park** (D82K, J), is situated further downstream, covers an area of 1,624 km². The park was proclaimed in 1991 on account of its scenic beauty, wilderness and highly adapted succulent fauna.

- **The Kgalagadi Transfrontier Park (formerly Kalahari Gemsbok National) Park** (D42A), is the largest park in the study area, and the second largest National Park in South Africa. The park covers an area of 9,590 km², and forms part of the Kgalagadi Transfrontier Park. The Nossob and Auob Rivers, which seldom flow, provide the main transport routes through this park.

- **The Namaqualand National Park**, situated on the Swartlientjies River near Kamieskroon is to be proclaimed on account of its scenic beauty and succulent flora (1999).

- A new National Park is planned for the West Coast between the Groen and Spoeg Rivers (F40F, F40H, F50G). The park is planned to extend 10 km inland. The area is currently in good condition, and is one of the few places where Strandveld Succulent Karroo could be formally protected.

- The **Ais-Ais Transfrontier Park** on the southern portion of the Fish River Canyon will include the Richtersveld National Park. The park is expected to be proclamated in October 2002.

Transfrontier Conservation Areas

The study area includes three existing or proposed transfrontier conservation areas:

- **The Kgalagadi Transfrontier Conservation Area** links the former Kalahari Gemsbok National Park in South Africa with the Gemsbok National Park in Botswana.

- **The proposed Gariep Transfrontier Conservation Area** is situated in the vicinity of Onseepkans (D81E).

- **The proposed Orange River Mouth Transfrontier Conservation Area** stretches from the mouth to 30km upstream.

Nature Reserves

A number of conservation areas are located in the area, as shown on **Figure 2.6.3.2.**

Wilderness Areas

There are no wilderness areas in the LOWMA, although certain areas within the Richtersveld National Park have been zoned as wilderness.

Greenbelt Areas

There are no greenbelt areas in the LOWMA.

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 the development of dams, pipelines, canals, water services infrastructure and enterprises following on the provisions of water.

The National Monuments Act, 1969 (Act 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the Environment Conservation Act, 1989 (Act 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 therefore essential 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.

Also, developers should take cognisance of the fact that the National Heritage Act is likely to supercede the National Monuments Act in April 2000, and should undertake to familiarise themselves with the contents of the new Act.

The purpose of this section is to give the reader a general insight into the history of the WMA, as well as to highlight any cultural/historical sites which may influence the further development and utilisation of water resources. These can be defined broadly as natural or manmade areas that are associated with human activity and history, and which carry social, cultural, religious, spiritual or historic significance. The National Monuments Act protects all palaeontological, archaeological and historical sites and material older than 50 years.

The National Monuments Council has a very limited database on archaeological and palaeontological sites in South Africa. It is the responsibility of the developer to ensure that any site earmarked for development is surveyed for archaeological sites, and necessary steps are taken to conserve them if they are present. Legislation which provides clarification on the declaration and classification of such areas include the National Monuments Act, 1969 (Act 28 of 1969) s 9c, 10, 12 and the National Parks Act, 1976 (Act 57 of 1976) s 4.

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.

National Monuments

There are several National Monuments within the LOWMA. Those that may be affected by water resource developments are listed below: **(See Figure 2.6.3.2.)**

- Glacial pavements at Blaauwbosch Drift.
- Glacial pavements at Bucklands, near Douglas.
- Old wagon bridge over the Orange River, Hopetown.
- Several water wheels in the vicinity of Kakamas and Keimoes.
- Van Wyksvlei Dam Wall and Tower, Van Wyksvlei.
- Water furrows and dry-stone walling, Kakamas.
- Water mill, Upington.

The following national monuments can also be found in the LOWMA:

- Simon van der Stel’s Copper Mine, near Carolusberg.
- Old smelting furnace, between Springbok and Okiep.
- Fort of Manie Maritz, at the south-eastern point of the Namibian border.
- Moffat’s Pulpit, just outside Griekwastad.
- Corbelled houses (six), on the road between Carnarvon and Williston.
- House of Olive Schreiner, at De Aar.

Archaeological Sites

Little information was available on the archaeology of the LOWMA. However, it is reasonable to assume that any major river in an arid area is likely to have been a major focus of human activity. It is therefore no surprise that the banks of the Orange River contain a number of sites of extreme archaeological importance. These include sites in the vicinity of Koegas, Kakamas, Daberas, Onseepkans, Arrisdrift and Bloeddrift, where bones and artefacts including pottery, metal and petroglyphs, have been found (Willcox, 1986). The sites provide valuable information on the life of early Khoi Khoi and Bantu inhabitants, dating back several thousands of years (Willcox, 1986). It is reasonable to assume that the entire length of the Orange River contains highly valuable archaeological material, but most of the area has not been studied (D. Morris, pers. com. 1999).

Palaeontological Sites

The lower reaches of the Orange River, downstream of Vioolsdrift, are characterised by numerous alluvial terraces. These contain fossil remains that date back to the Miocene age (about 16 million years ago). The most famous of these are terrace deposits in the vicinity of Arrisdrift (in Namibia), which contain one of the most important fossil assemblages in southern Africa of the Miocene age (Willcox, 1986). Fossils of at least 28 vertebrate species, including 22 mammal species and one crocodile species, have been recorded from these deposits (Hendey, 1978). Notable species include a prehistoric ostrich, the giant Cape horse, an elephant with tusks in the upper and lower jaws, a bear-dog and a giant tortoise (Williamson, 1995). The fossil evidence suggest that the area was once densely vegetated, and that the present Namib Desert is relatively young (Hendey, 1978). The terraces also contain high concentrations of diamonds. Consequently, these areas are highly threatened.

The Kuruman River is noted for limestone containing fossil diatoms, and fossile remains of the freshwater bivalve *Corbicula africana* have been collected from the Kuruman and Molopo riverbeds (Thomas & Thomas, 1989).

Another area of palaeontological interest is at Grasdrift (D82J), within the Richtersveld National Park. Here Dwyka tillite pavements contain fossil remains of arthropods, dating back about 300 million years (Williamson, 1995).

Outcrops of Dwyka rocks that contain evidence of glacial erosion are common along the old course of the Molopo River and around many of the pans in the vicinity of Noenieput (Thomas & Thomas, 1989). The pans in the vicinity of Noenieput also contain evidence of algal stromatolites (Thomas & Thomas, 1989).

Meteorites

There are no protected meteorite sites in the LOWMA (Laubscher pers. comm., Council for Geoscience).

Battle Sites

Schuitdrif is historically important as the site of Korana Wars of 1868–1869 and 1878–1879. There are also a number of South African War sites, such as the fort at Prieska and the battle site just east of Kakamas (Battle of Kakamas 1915).

Burial Sites

There are numerous grave cairns of San and Khoi origin all along the Orange River, particularly in the vicinity of the Augrabies Falls.

Areas/Sites of Religious or Spiritual Significance

There are a number of mission stations in the study area, for example at Pella, Augrabies, Onseepkans, Keimoes and Blaauwskop.

Healing waters of hot spring are located at Warmbad Noord, Wondergat and at Cornellskop.

Areas/Sites of Special Social, Cultural or Historical Interest

The Grootvloer-Verneukpan area is of historical importance as this is where Sir Donald Campbell attempted the world land speed record in the "Bluebird" in 1929.

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The Cape Parliament presented two farms to the Dutch Reformed Church in 1897, by which time the first irrigation settlement was already established on the left bank of the Orange River about 100 km downstream of Upington. The first group of settlers arrived at Kakamas late in 1887 and the South Furrow Canal Scheme, from the Orange River, was commissioned in July 1889.

Construction began on the North Furrow in 1908 after additional farms were acquired on the north bank of the river. By 1930 the number of irrigators increased to 600 with the completion of a canal to Rhenosterkop Island. Boegoeberg Dam was constructed in 1931 in the Lower Orange River during the 1930s depression. In the years to follow, a network of canals, including several syphons, was constructed in the area downstream of Boegoeberg Dam.

The Gariep Dam (formerly known as Hendrik Verwoerd Dam) was commissioned in 1971. The Van der Kloof Dam (formerly known as PK le Roux Dam) was completed in 1976. The purpose of these two dams was to regulate water flow in the Lower Orange River, to generate hydro power and to supply water for irrigation and urban purposes.

The previous Water Act, 1956 (Act 54 of 1956) made provision for the submission of final proposals for water schemes, in the form of White Papers, to Parliament for investigation and comments. These White Papers include well-motivated proposals with the costs of the proposed scheme as well as the benefits of the scheme. The White Papers therefore provided the mechanism through which proposed new developments were officially documented for public scrutiny.

Many White Papers have been published in connection with the Orange River Development Project.

It is not the intention of this report to discuss the previously published White Papers. Summarised comment on the papers is given in the relevant ORRS Report. DWAF (1997), Report PD000/00/4297, Orange River Development Project Replanning Study. Existing Water Infrastructure in the Orange River Basin.

The main water use sectors in the Lower Orange Water Management Area (LOWMA) are the ecological Reserve, irrigation and river losses.

Vast quantities of the irrigated crops are sold to the export market generating valuable foreign exchange for the country and the region in particular.

Most of the development within the LOWMA has occurred adjacent to the Orange River or receives its water from the river through transfer schemes. In effect, the Orange River can be regarded as the lifeline to many of the developments in the LOWMA.

The LOWMA has been divided into various drainage areas to assist with the evaluation and reporting components. These areas are made up of a grouping of individual quaternary catchments, as illustrated in **Figure 3.1.1**. The drainage areas were chosen to represent a logical disaggregation of the catchment for the purpose of summarising land-use and water requirements, as well as establishing the water balance. Information in this report is provided on a drainage area basis as well as a WMA basis. In certain areas, the quaternary catchments lie across provincial boundaries and an apportionment factor had to be introduced. Information is also provided on a provincial basis.

Apportionment refers to distributing portions of quarternary information to the relevant drainage areas and/or provincial subtotals. Where only a part of a quaternary falls into the LOWMA, then only that same portion appears in the provincial subtotals. Details of the apportionment used can be found in **Appendix D2**. For some parameters, namely those associated with irrigation, urban use and river losses, special opportionment was required. This was necessary due to distribution of water requirements in these sectors which differed significantly from the area distribution. The aggregated totals for the various areas of interest are sometimes rounded off when extracting the information from the WSAM.

A very simplified approach to determine the water requirements for the Namibian catchments, impacting on the Orange River was adopted. This is further explained in Chapter 5.5.

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 of Study

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 to provide a basis for developing estimates of urban water use for the entire country (see Section 5.3).

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

- The Development Bank of Southern Africa.
- The Demographic Information Bureau.

- The Bureau for Market Research.
- Local authority estimates, where available.

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

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

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

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

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

3.2.3 Historical Population Growth Rate

Historical population data is based on the provincial boundaries and not any particular WMA boundary. Given the nature of the area, the trends previously identified for the province can be accepted as being the same as that of the lesser WMA area.

Information dating back to 1980 shows an annual urban population growth rate of 2,37% while the non-urban population showed an annual decline of 2,26%. The urban growth rate is higher in the “larger towns” than in the “smaller towns”. The Namaqualand District Council Area **(see Figures 3.2.4.1 and 3.4.9.1)** has the greatest predicted growth rate in the WMA, in excess of 3,5% per annum over the period 1980 to 2010. The areas of De Aar and Prieska showed a negative, non-urban population growth rate in excess of 2,5% per annum for the same period. The Benede Oranje area showed the greatest level of urbanistion.

The Northern Cape is a net receiver of migrant workers with a positive male presence of 4,3% (1991). The decline of the mining industry has decreased the rate from 13,9% to 4,3% (1991). This rate is expected to fall even further.

There is no information readily available on refugees from neighbouring countries. It is however assumed that there is a very small impact if at all due to the sparse population distribution in the southern portions of the neighbouring states.

3.2.4 Population Size and Distribution in 1995

The population throughout the WMA is generally small in relation to other WMAs elsewhere around the country. De Aar, Springbok and Upington are the major urban centres. Smaller urban areas are found along the Orange River or its main tributaries.

The population size and distribution in the WMA as at the base year of 1995 is given in **Table 3.2.4.1**. The figures given are in terms of the drainage areas considered with additional totals for the provincial breakdowns.

A detailed listing of the population figures, per town and quarternary catchment, for the 1995 base year, is included in **Appendix A1.**

Table 3.2.4.1: Population in 1995

Catchment						Population in 1995		
Primary		Secondary		Tertiary (Drainage Area)		Urban	Rural	Total
No,	Description	No,	Description	No,	Description	(Number)	(Number)	(Number)
C, D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	65 300	9 786	75 086
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	20 090	11 976	32 066
				D55	Sak-Hartbees (WC)	410	244	654
		D4	Molopo	D42	Nossob-Molo (NC)	6 353	4 943	11 296
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	36 750	10 260	47 010
				D73	Neusberg (NC)	70 400	52 320	122 720
				D81, D82	Vioolsdrift (NC)	12 150	12 080	24 230
				D82	Alexander Bay (NC)	4 000	1 897	5 897
	TOTAL IN NORTHERN CAPE PROVINCE					215 043	103 262	318 305
	TOTAL IN WESTERN CAPE PROVINCE					410	244	654
	TOTAL IN PRIMARY CATCHMENTS C + D					215 453	103 506	318 959
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	46 788	9 358	56 145
				F50	Coastal (WC	2 463	493	2 955
	TOTAL IN NORTHERN CAPE PROVINCE					46 788	9 358	56 145
	TOTAL IN WESTERN CAPE PROVINCE					2 463	493	2 955
	TOTAL IN PRIMARY CATCHMENT F					49 250	9 850	59 100
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						261 837	112 620	374 450
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						2 873	737	3 609
TOTAL IN LOWER ORANGE WMA						**264 704**	**113 357**	**378 059**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	31 240	55 140	86 380
TOTAL IN REPORTING AREA						**295 940**	**168 497**	**464 439**

* Rounding off errors do occur in the aggregation process.

3.3 MACRO-ECONOMICS

3.3.1 Introduction

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

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

Selected diagrams 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 macro-economic indicators that was prepared by Urban-Econ: Development Economists from a number of sources, including the Development Bank of Southern Africa (DBSA). **Appendix B.2** contextualises each WMA's 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 national 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 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 (Central Statistics Services, 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 GGP figures for government and social services are available. However, in the labour market these figures are combined into one sector, namely community services. 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 Water Management Areas (WMA's) 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 dependant on population *per se*, but are dependant 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 factor's, 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 LOWMA was R3,9 bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

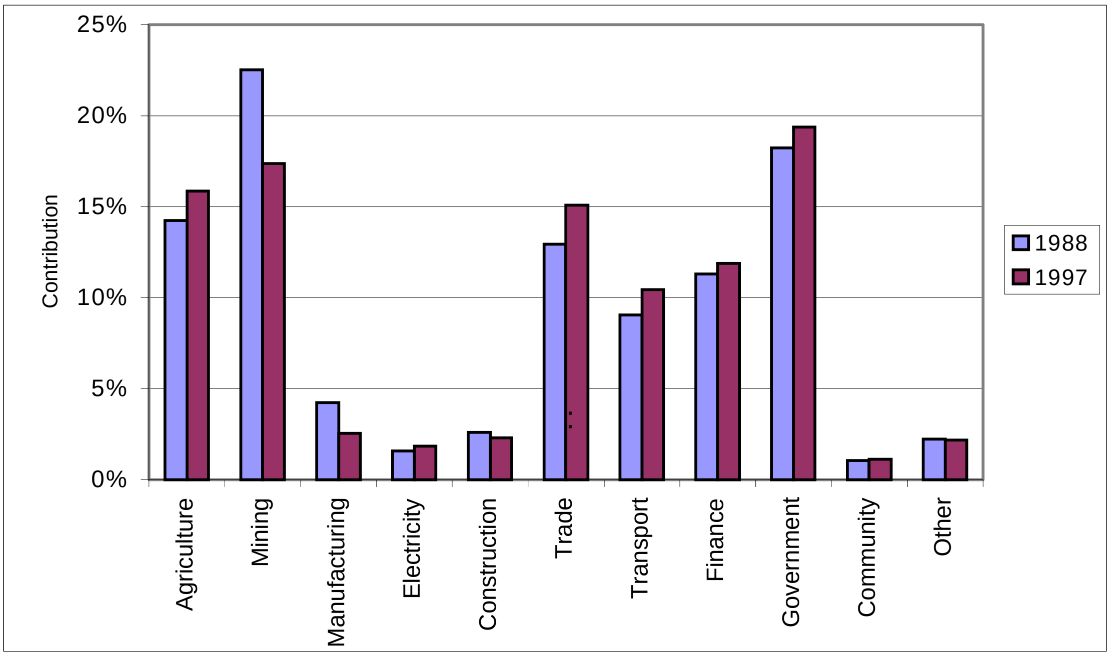
- Gordonia 35.5%
- Namaqualand 21.0%
- De Aar 11.3%
- Kenhardt 6.7%
- Other 25.5%

Economic Profile

The composition of the LOWMA economy is shown in **Diagram 3.3.1.** The figures for the year 1997 are shown below:

- Government 19.4%
- Mining 17.4%
- Agriculture 15.9%
- Trade 15.1%
- Other 32,2%

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



The LOWMA is the largest WMA in the country, but also the driest and most sparsely populated. Activities occur mainly along the Orange River itself. The towns of Upington, Prieska, Groblershoop, and Hopetown have all been built on the banks of the Orange River.

The agricultural products found in the Gordonia region of the LOWMA are dried fruits, which include dates, raisins and peaches. Dates are virtually unique to this part of the country. Grapes are grown especially in the Orange River Valley near Upington. This climate produces sweet grapes that can be used in the production of fortified wines. Cotton also grows well in this area. Crops such as wheat, lucerne and maize, vegetables, flowers and pistachio nuts are also grown. Horticulture crops are, to a large extent, cultivated for export purposes to European markets.

In the Karoo, sheep are raised for wool and meat.

In the LOWMA area, mining activities consist mainly of the extraction of alluvial diamonds, amphibole asbestos and Tiger's Eyes the extraction and processing of alumni silicate and other salts, limestone and dolomite.

Alluvial diamonds are one of the most important minerals found in Namaqualand. Copper is mined in the Okiep Copper District, an area of 1 500 km² stretching through Okiep, Springbok and Nababeep. Copper is also found at Aggeneys, whilst lead, zinc, limestone, dolomite and other minerals and metals are also found in the Namaqualand district.

The importance of the trade sector can, in the first instance, be attributed to the export of deciduous viticulture which is focused on European and Namibian markets. The exports of venison, ostrich, fortified wine as well as a growing tourism market also contribute to the importance of the trade sector.

Due to the Namaqualand wild flower fields, this area attracts an increasing number of tourists annually. The Richtersveld, Augrabies National Park and Kalahari Gemsbok Park also attract tourists to the LOWMA.

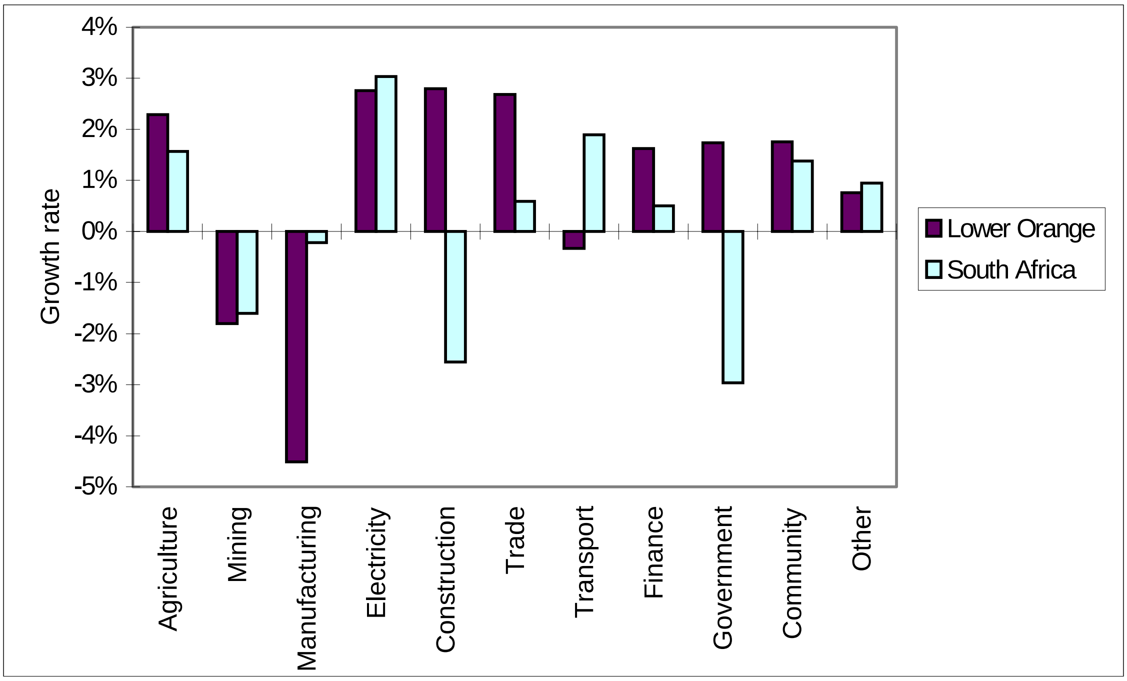
Economic Growth

The average annual growth in production by sector is shown in **Diagram 3.3.2.** The following sectors recorded the highest average annual growth rates between 1987 and 1997:

- Electricity : 2.8%
- Construction : 2.8%
- Trade : 2.7%
- Agriculture : 2.3%

The demand from overseas markets for venison, ostrich and wine might contribute to the future growth of agriculture and trade in the LOWMA. The increasing popularity of game farming as a tourist attraction will also play a role in the future performance of trade activities. Due to annual increases in the number of tourists visiting the area, ongoing growth could be expected in the tourism industry.

Diagram 3.3.2: Average Annual Economic Growth by Sector of Lower Orange Water Management Area (LOWMA) and South Africa, 1988 - 1997



Labour

Of the total labour force of 122 000 persons, 31,9% are unemployed, which is higher than the national average of 29,3%. Fifty six percent (56,3%) are active in the formal economy. Thirty percent (30,1%) of the formally employed labour force work for government, while 29,8%, are involved in agriculture, and 11,71% in trade.

Employment growth was only recorded in the financial services sector (1,4% per annum) during the period 1980–1994.

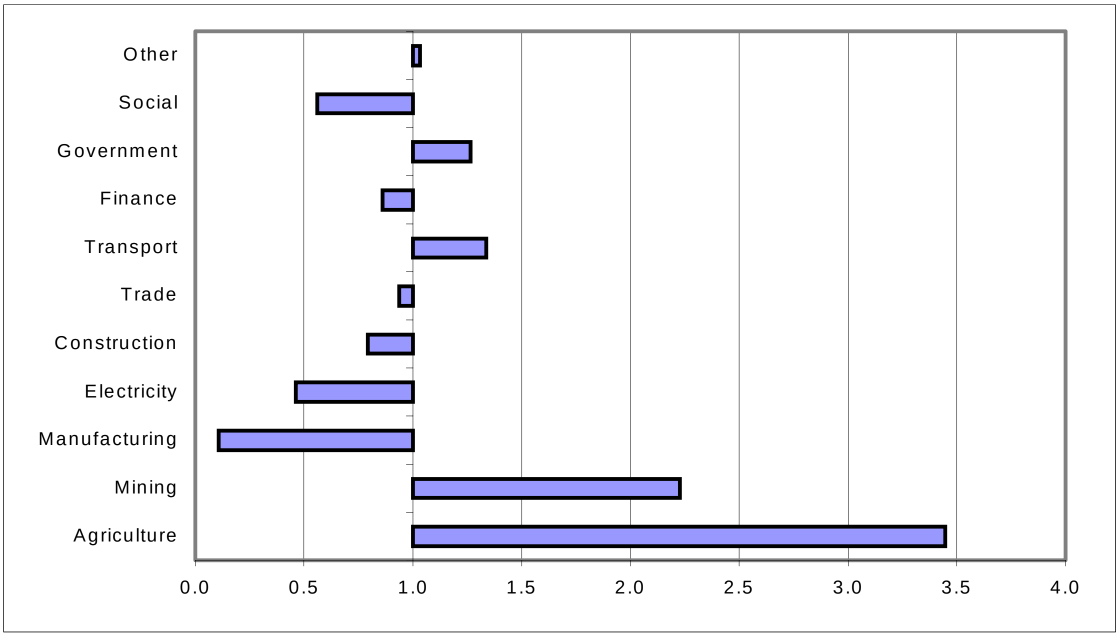
3.3.5 Comparative Advantages

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

Diagram 3.3.3 shows the location quotients for the LOWMA. The Figure shows that, based on the location quotients for 1997, the LOWMA economy is relatively more competitive than the remainder of South Africa in the following economic activities:

- Agriculture : 3.4
- Mining : 2.3
- Transport : 1.3
- Government : 1.3

Diagram 3.3.3: Lower Orange Gross Geographic Product Location Quotient by Sector, 1997



The comparative advantage of the agricultural sector of the LOWMA is attributable to the variety of agricultural products found in this area, many of which are characterised by high demand from international markets.

The mining sector in the LOWMA also has a comparative advantage in the national economy. This is due to the large variety of minerals and metals found in this region.

The comparative advantage of the transport sector can be attributed to import and export activities with regards to agricultural products as well as road and rail links leading into the area.

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 colonising 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 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, 1997 (Act 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, 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.

- 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 (NWRS) and the Catchment Management Strategy (CMS). The NWRS 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 CMS 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 NWRS 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 NWRS 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 108 of 1997).

Section 19 of the NWA provides *inter alia* that any person who is in control of land where 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 license.

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, and recharging of an aquifer with any waste or water containing waste are examples of activities that are already controlled activities. (See Section 37(1) of the National Water Act, 1998 (Act No. 36 of 1998)).

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

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

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

Compensation must be claimed from the Water Tribunal.

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

It is important to note that although the Water Services Act, 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 license.
- If a license is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a license for water under the NWA.
- 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 to achieve better inter-governmental co-ordination of coastal management.

This Act provides for the drafting up of environmental implementation plans by certain scheduled National Government Departments and the Provinces. In addition, environmental management plans are to be 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 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), one of which will be established in each of the Water Management Areas that have been promulgated by Government Notice 1160 of 1 October 1999 (19 in total). These will have various functions either delegated or assigned to them, thus bringing the management of water resources to the regional or catchment level. A CMA will operate via a board along the lines set out in Schedule 4 to the NWA. The composition of the board is recommended by an Advisory Committee that is established by the Minister and has the important task to recommend to the Minister proposed members who are racially, gender and community representative.

A second institution, is that of Water User Associations (WUA) that will operate on a restricted local level and are in effect cooperative associations of individual water uses who wish to undertake related water activities for a mutual benefit. Irrigation Boards established under the Water Act of 1956 had until 29 February 2000 to transform into a WUA. All WUAs 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 CMAs can be heard. The question of compensation for loss of entitlements to use water is also to be heard in this Tribunal. Appeals on questions of law from the Tribunal are heard in the High Court.

3.4.9 Institutional Arrangements

District Councils

There were five district councils within the Lower Orange Water Management Area in the year 1995. Each Council area in turn consisted of a number of magisterial districts. The district council boundaries have changed since 1995. **Figure 3.4.9.1** details the 1995 status, while **Figure 3.4.9.2** details the current status. **Table 3.4.9.1** is a summary of the year 1995 and current status.

Table 3.4.9.1: District Councils and Magisterial Districts in the LOWMA

DISTRICT COUNCIL	MAGISTERIAL DISTRICTS
Year 1995 Namaqualand	Namaqualand
Diamantveld	Hay, Herbert
Bo-Karoo	Prieska, Hopetown, Britstown, De Aar, Victoria West, Richmond, Hanover, Philipstown
Benede Oranje	Gordonia, Kenhardt
Hantam	Calvinia, Williston, Carnarvon, Fraserburg, Sutherland
Current*	
Namakwa	Namaqualand, Calvinia, Williston, Fraserburg, Sutherland (Springbok)
Siyanda	Kenhardt, Gordonia, Postmasburg (Upington)
Karoo	Kay, Prieska, Carnarvon, Victoria West, Britstown, Richmond, De Aar, Hanover (part), Hopetown (part) (De Aar)

* The current District Council seats are situated at De Aar, Upington and Springbok as shown in brackets above.

Irrigation Districts

An irrigation district may be constituted for a specific area. For each irrigation district there is at least one irrigation board, which is a body corporate. The Minister could assign various functions to the board, including among others the protection of the water, exercising supervision over the public streams, regulating the flow in the streams and the supervision and regulation of water distribution and its use.

Each irrigation board must compile a schedule of rateable areas setting out among others the area that might be irrigated from the public streams under the jurisdiction of the irrigation board. If the irrigation board's area of jurisdiction falls within a Government Water Control Area, then the schedule of rateable areas may not exceed the allocations made for the Government Water Control Area.

Irrigation boards will be transformed to water user associations in terms of the National Water Act of 1998. Some boards have done that already. **Appendix C.1** is a list of the irrigation boards in the LOWMA.

The irrigation districts in the LOWMA are:

- Middle Orange
- Boegoeberg Dam.
- Upington Islands.
- Kakamas.
- Vioolsdrift.

Water Boards

The Water Boards operational in the LOWMA are:

- Karos-Geelkoppen Water Board.
- Kalahari West Water Board.
- Pella Water Board.
- Namakwa Water Board.

Figure 3.4.1.0 shows the locality of the Transitional Local and Regional Councils as well as the Water Boards.

Water User Associations

The 1995 status as described above, is currently being amended. Most of the irrigation boards and water boards are being transformed into water user associations in accordance with the new National Water Act. In some cases a former water board is being incorporated into an irrigation district.

Appendix C.2 provides a listing of allocations to water users from government water works in terms of Section 56(3) of the water law. **Appendix C3** is a status report on the transformation of irrigation boards, water boards and the establishment of new water user associations as on 24 August 2001.

3.5 LAND-USE

3.5.1 Introduction

The climate and topography of the Lower Orange Water Management Area (LOWMA) does not lend itself to high density land-use. There are thousands of square kilometres of land which are used for livestock farming such as sheep and goats. The only high intensity land-use is irrigated crop farming, most of which is along the main stem of the Orange River. Dryland sugar cane, commercial forestry and dense indigenous forests are not found in this arid region there are however scatterings of local woodlands. Alien vegetation covers a considerable area, double that of any productive land-use. The urban coverage is almost insignificant to the area. **Table 3.5.1.1** is a summary of the land-use per drainage region (as indicated in **Figure 3.1.1**).

Table 3.5.1.1: Land-Use by Drainage Areas in km²

Catchment						Irrigation	Dryland Sugarcane	Other Dryland Crops	Afforestation	Alien Vegetation	Nature Reserves *	Urban	Rural Settlements	Other**	Total
Primary		**Secondary**		**Tertiary (Drainage Area)**											
No,	**Description**	**No,**	**Description**	**No,**	**Description**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**	**(km²)**
C D (Part)	Orange	D6	Ongers	D61 D62	Ongers (NC)	0,0	0,0	0,0	0,0	76,3	17,0	10,1	2,0	33 625	33 730
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	44,9	0,0	0,0	0,0	660,1	5,3	0,0	2,4	90 467	91 179
				D55	Sak-Hartbees (WC)	0,9	0,0	0,0	0,0	13,5	0,1	0,0	0,0	1 846	1 861
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	0,0	0,0	0,0	226,3	10 389,5	0,0	1,0	21 193	31 810
		C9 D7 D8	Orange	C92 D71 D72	Boegoeberg (NC)	208,4	0,0	0,0	0,0	161,2	23,6	0,0	2,1	15 695	16 090
				D73	Neusberg (NC)	248,0	0,0	0,0	0,0	8,4	53,5	14,3	10,5	17 395	17 730
				D81 D82	Vioolsdrift (NC)	118,4	0,0	0,0	0,0	45,8	44,1	0,0	2,4	27 299	27 510
				D82	Alexander Bay (NC)	13,6	0,0	0,0	0,0	0,1	1 622,8	0,0	0,4	3 874	5 511
	TOTAL IN NORTHERN CAPE PROVINCE					633,3	0,0	0,0	0,0	1 178,2	12 155,8	24,4	20,7	209 548	223 560
	TOTAL IN WESTERN CAPE PROVINCE					0,9	0,0	0,0	0,0	13,5	0,1	0,0	0,0	1 846	1 861
	TOTAL IN PRIMARY CATCHMENTS C + D					634,2	0,0	0,0	0,0	1 191,7	12 155,9	24,4	20,7	211 394	225 421
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0		0,0	0,0	136,8	42,1	0,0	1,9	24 358	24 539
				F50	Coastal (WC	0,0		0,0	0,0	7,2	2,2	0,0	0,1	1 282	1 292
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0	0,0	136,8	42,1	0,0	1,9	24 358	24 539
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0	0,0	7,2	2,2	0,0	0,1	1 282	1 292
	TOTAL IN PRIMARY CATCHMENT F					0,0	0,0	0,0	0,0	144,0	44,3	0,0	2,0	25 640	25 830
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						634,2	0,0	0,0	0,0	1 315,0	12 197,2	24,4	22,6	233 906	248 100
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,0	0,0	0,0	0,0	20,7	2,3	0,0	0,1	3 128	3 153
TOTAL IN LOWER ORANGE WMA						**634,2**	**0,0**	**0,0**	**0,0**	**1 336,0**	**12 200,2**	**24,4**	**22,7**	**237 034**	**251 253**
Z (Part)	Namibia	Z1 Z2	Namibia	Z10 Z20	Namibia	44,2	0,0	0,0	0,0	320,0	**0,0**	0,6	11,0	243 924	244 300
TOTAL IN REPORTING AREA						**678,4**	**0,0**	**0,0**	**0,0**	**1 656,0**	**12 200,2**	**25,0**	**33,7**	**480 958**	**495 553**

* Includes National Parks, wilderness areas, etc
** Balance of areas not otherwise defined, which could also include grazing and natural vegetation.

3.5.2 Irrigation

The total irrigated area and various crop areas for each sub-catchment are shown in **Table 3.5.2.1**. A map depicting the extent of the existing irrigation is shown in **Figure 3.5.1.1**. In the Lower Orange Water Management Area (LOWMA), the irrigation data along the Orange River was captured using the same methods as the Orange River Development Replanning Study (ORRS-BKS, 1997a). The latter study used scheduled areas and quotas, rather than theoretical crop requirements, due to the legal nature of the allocations. As a result, figures for irrigated areas along the Orange River represent scheduled areas, and not crop areas.

Scheduled areas along the Orange River were obtained from the ORRS (BKS, 1997a) and updated in accordance with “Orange River System 1999/2000 Operating Analysis” (BKS, 2000). The update incorporated areas previously excluded from the ORRS (BKS, 1997a) due to mismatched information from different inforamtion sources.

Information for Namibia was obtained from “Hydrology of the Fish River Catchment” (BKS, 1991), and the ORRS Report “Water Demands of the Orange River Basin” (BKS, 1997b). The latter was in turn based on "Namibian Water Requirements from the Orange River" (DWA Namibia, 1995).

In parts of the WMA remote from the Orange River, very little information on irrigation exists. WR90 (Midgley, et al 1994, Volume III, Appendix 8) was used as a basis in these areas, assuming lucerne as the dominant crop for animal feeds, and also being conservative in terms of water requirement relative to undifferentiated crops.

Areas of low assurance opportunistic irrigation have been excluded due to a lack of information on these practices. This information may become available in the near future through the licensing process currently underway.

Grapes occupy approximately half the irrigated area, while the other half is shared mainly between wheat, cotton, maize and lucerne. Other crops occurring in the area appear in **Table 3.5.2.2**. The crop distributions presented in the ORRS (BKS, 1997a) cannot be applied directly in this study as they are not compatible with the updated scheduled areas. In addition, scheduled areas and quotas are independant of farming practices such as double cropping, and therefore do not relate directly to crop distributions.

The quota is independant of irrigation practices. The ORRS (BKS, 1997b) assigned irrigation efficiencies to various river reaches for the purposes of estimating return flows only. Therefore, no specific information is available on the irrigation methods for the various crops. However, flood irrigation, sprinkler systems, mechanical systems, micro systems and drip systems all occur at various locations along the Orange River. Centre pivot sprinkler systems are most common between Douglas and Prieska, while flood irrigation tends to dominate most of the reaches downstream of Boegoeberg Dam.

It is generally recognised that future growth in irrigation will be severely limited by the availability of water. In more water scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use. In order to do this it will be necessary to base such decisions on sound economic principles that include the economic return per unit of water. Although acknowledged to be fairly generalised, only three income categories of irrigated crops have been used to represent an appropriate grouping for the purpose of assurance of irrigation water supply. Due to the use of scheduled areas along the Orange River, no direct correlation to income or assurance category exists. Crop distributions were therefore used to divide the scheduled areas proportionally into the three categories. **Table 3.5.2.2** shows the typical crops within each category.

Table 3.5.2.1: Irrigation Land-Use

Catchment						Perennial	Summer	Winter	Undifferen-tiated	Total
Primary		Secondary		Tertiary (Drainage Area)						
No,	Description	No,	Description	No,	Description	(km²)	(km²)	(km²)	(km²)	(km²)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,0	0,0	0,0	0,0	0,0
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,0	0,0	0,0	44,9	44,9
				D55	Sak-Hartbees (WC)	0,0	0,0	0,0	0,9	0,9
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	0,0	0,0	0,0	0,0
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,0	0,0	0,0	208,4	208,4
				D73	Neusberg (NC)	0,0	0,0	0,0	248,0	248,0
				D81, D82	Vioolsdrift (NC)	0,0	0,0	0,0	118,4	118,4
				D82	AlexanderBay (NC)	0,0	0,0	0,0	13,6	13,6
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0	633,3	633,3
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0	0,9	0,9
	TOTAL IN PRIMARY CATCHMENTS C + D					0,0	0,0	0,0	634,2	634,2
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0	0,0	0,0	0,0	0,0
				F50	Coastal (WC)	0,0	0,0	0,0	0,0	0,0
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0	0,0	0,0
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0	0,0	0,0
	TOTAL IN PRIMARY CATCHMENT F					0,0	0,0	0,0	0,0	0,0
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						0,0	0,0	0,0	633,3	633,3
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,0	0,0	0,0	0,9	0,9
TOTAL IN LOWER ORANGE WMA						**0,0**	**0,0**	**0,0**	**634,2**	**634,2**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	0,0	0,0	0,0	44,2	44,2
TOTAL IN REPORTING AREA						**0,0**	**0,0**	**0,0**	**678,4**	**678,4**

* Irrigation methods mixed or not available, due to use of scheduled areas.

Table 3.5.2.2: Assurance Categories for Irrigated Crops

CATEGORY	CROP EXAMPLES
Low	Maize, wheat, soya bean, dry bean, groundnut, lucerne and pasture.
Medium	Vegetables, potatoes, cotton.
High	Citrus, deciduous fruit and nuts, sub-tropical fruit and nuts, grapes and dates.

Due to the low resolution of available information, distinction was not made between pasture for small stock as opposed to dairy and ostrich. Regional experts questioned the relationship between annual enterprise returns and assurance categories for the various crops. A more thorough economic basis for assurance categorisation should therefore be sought in the future.

3.5.3 Dryland Agriculture

Dryland agriculture is generally used to refer to dryland sugarcane, although other types can also occur.

Except for sugar cane, all the dryland crops produced in South Africa are generally assumed to practically use the same water as that of the natural vegetation they replace. This implies that the water use of dryland crops is already accounted for in the surface water hydrology.

There is no dryland sugarcane production in the LOWMA.

The climate and low annual rainfall of the water management area is not suitable for dryland sugarcane production. No future introduction of dryland sugarcane is therefore foreseen.

3.5.4 Livestock and Game Farming

Figure 3.5.4.1 present livestock and game per drainage area.

The livestock and game data from the magisterial district surveys in 1990 were used for the 1995 base year. The reason being that there is a general consensus that this sector has reached a threshold and that numbers are unlikely to change much at present. The 1990 data represents mature and immature livestock and game, these numbers were accepted as the mature livestock and game for 1995 in order to convert these to equivalent large stock units.

The available data was in a magisterial district grouping and not an a quaternary breakdown as required for this study. The data was therefore reworked with the livestock and game being apportioned to each quaternary on a pro- rata basis according to the surface area of each quaternary catchment and its relationship to the magisterial district.

The livestock generally found throughout the Lower Orange Water Management Area (LOWMA) is:

- Sheep (wool/meat).
- Anghora goats (wool).
- Cattle (meat/dairy).

Springbok, Gemsbok, Eland, Kudu and Rooibok are found in the LOWMA. The Springbok is by far the dominant game animal.

All livestock was converted to a “large stock unit” through various factors to standardise the water consumption equivalent to a horse or eland. The list of conversion factors is given in **Appendix D.4. Table 3.5.4.1** indicates the census numbers which have been reworked to display the data on a drainage area basis. See **Appendix D.5** for a detailed listing.

Table 3.5.4.1: Livestock and Game Farming

Catchment						Number Of Livestock And Game							
Primary		Secondary		Tertiary (Drainage Area)		Cattle & Horses	Small Livestock	*Big Game	Large Antelope	Small Antelope	Ostrich	Other	Equivalent Large Stock Units
No,	Description	No,	Description	No,	Description	(Number)	(Number)	(Number)	(Number)	(Number)	(Number)	(Number)	(Number)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	12 793	1 472 928	0	0	28 924	0	0	151 500
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	3 148	1 603 229	0	0	5 890	0	0	230 130
				D55	Sak-Hartbees (WC)	47	13 847	0	0	144	0	0	1 890
		D4	Molopo	D42	Nossob-Molo (NC)	10 831	408 992	0	159	1 979	147	0	74 100
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	18 787	550 917	0	83	4 910	66	0	65 980
				D73	Neusberg (NC)	14 546	269 000	0	65	735	52	0	49 960
				D81, D82	Vioolsdrift (NC)	3 264	359 380	0	19	242	18	0	60 410
				D82	AlexanderBay (NC)	621	69 328	0	0	0	0	0	11 630
	TOTAL IN NORTHERN CAPE PROVINCE					63 990	4 733 774	0	326	42 680	283	0	643 710
	TOTAL IN WESTERN CAPE PROVINCE					47	13 847	0	0	144	0	0	1 890
	TOTAL IN PRIMARY CATCHMENTS C + D					64 037	4 747 621	0	326	42 824	283	0	645 600
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	3 812	430 671	0	0	0	0	0	72 270
				F50	Coastal (WC)	97	10 953	0	0	0	0	0	1 840
	TOTAL IN NORTHERN CAPE PROVINCE					3 812	430 671	0	0	0	0	0	72 270
	TOTAL IN WESTERN CAPE PROVINCE					97	10 953	0	0	0	0	0	1 840
	TOTAL IN PRIMARY CATCHMENT F					3 909	441 624	0	0	0	0	0	74 110
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						67 802	5 164 445	0	326	42 680	283	0	715 980
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						144	24 800	0	0	144	0	0	3 730
TOTAL IN LOWER ORANGE WMA						**67 946**	**5 189 245**	**0**	**326**	**42 824**	**283**	**0**	**719 710**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	-	-	-	-	-			*914 600
TOTAL IN REPORTING AREA						-	-	-	-	-			**1 634 310**

* The Namibian equivalent large stock units were estimated on the total equivalent large stock units of its apposing South African quarternaries. No breakdown per live stock unit was considered.

3.5.5 Afforestation

There are no plantations in the LOWMA. There are however some arid woodlands, for example:

- Camel Thron (Acacia erioloba) forest at Kathu
- Woodlands of the Kuruman, Molopo and Gamagara Rivers
- Smitsdrift
- Quiver Tree (Aloe dichotoma) forest near Kenhardt and Klein Pella.

3.5.6 Alien Vegetation

The impacts of the widespread infestations by alien plants in South Africa are increasingly recognised. The total incremental water use of invading alien plants was estimated at 3 300 million m^3/a by Le Matre et al. (1999) but this estimate is not widely recognised by the water resources planning community. This estimate is almost twice as high as the estimate for stream flow reduction resulting from commercial afforestation. Le Matre et al. (1999) estimate that the impact will increase significantly in the next 5 to10 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 independant 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 independant 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.

Table 3.5.6.1 indicates the condensed areas of alien vegetation in the LOWMA according to the drainage area breakdown. See **Figure 3.5.6.1** for distribution of alien vegetation per drainage area. Detailed results of the alien vegetation invasion impacts are given in Chapter 5.

Table 3.5.6.1: Infestation by Alien Vegetation

Catchment						Condensed Areas
Primary		Secondary		Tertiary (Drainage Area)		
No,	Description	No,	Description	No,	Description	(km²)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	76,3
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	660,1
				D55	Sak-Hartbees (WC)	13,5
		D4	Molopo	D42	Nossob-Molo (NC)	226,3
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	161,2
				D73	Neusberg (NC)	8,4
				D81, D82	Vioolsdrift (NC)	45,8
				D82	AlexanderBay (NC)	0,1
	TOTAL IN NORTHERN CAPE PROVINCE					1 178,2
	TOTAL IN WESTERN CAPE PROVINCE					13,5
	TOTAL IN PRIMARY CATCHMENTS C + D					1 191,7
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	136,8
				F50	Coastal (WC)	7,2
	TOTAL IN NORTHERN CAPE PROVINCE					136,8
	TOTAL IN WESTERN CAPE PROVINCE					7,2
	TOTAL IN PRIMARY CATCHMENT F					144,0
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						1 315,0
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						20,7
TOTAL IN LOWER ORANGE WMA						**1 335,7**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	320,0
TOTAL IN REPORTING AREA						**1 655,7**

3.5.7 Urban Areas

The settlement pattern of the Northern Cape Province has been determined by the irrigation and mining activities of the area. In Namaqualand, the mines are often far from existing nodes. This resulted in a fast initial growth phase for many towns, which stabalised thereafter. Often critical mass is not achieved to provide diversified municipal town services.

There are very few urban areas in the WMA. Their combined footprint is almost negligible in relation to the surface area of the WMA.

The type of urbanisation could best be described as service centres to the surrounding farm lands or mines. The population distribution is heavily concentrated at the urban nodes with Upington being the most dominant centre.

The urban areas are shown in **Figure 3.5.1.1.**

3.5.8 Rural Areas

A very basic estimate of the land use by rural areas was calculated using the person per square kilometre density of Upington and the respective rural population figures.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

There are no major industries in the Lower Orange Water Management Area (LOWMA). There are however a number of abbattoirs of various sizes as well as the wine cellars in the Upington and Douglas areas. Export raisin factories can also be found at Upington and Marchand, between Kakamas and Augrabies.

There are no power stations in the LOWMA. The influence of hydropower releases from Van der Kloof Dam on users in the LOWMA will be discussed later in the report.

3.7 MINES

3.7.1 Introduction

Mining operations in South Africa encompass a wide range of activities, which include the dressing and beneficiation of naturally occurring minerals, whether in solid, liquid or gaseous form to render the material marketable or to enhance the market value of the material. Mining operations include underground and surface mines as well as quarries.

Products of the mining industry in the Lower Orange Water Management Area (LOWMA) are predominantly alluvial diamonds, copper and salt. Base metals are also mined. There are a few quarries providing stone aggregate and gravel.

All known operating mines in the LOWMA, as per the DWAF data base, are shown on **Figure 3.7.1** and listed in **Appendix D.6**. Mines that impact significantly on the economy of a region or town are highlighted. Wastewater from the mines is evaporated through evaporation ponds and is not returned directly into the river systems.

The impact of mining activities on water resources and water quality is described in general terms for the WMA within the drainage areas listed, together with quantitative information, in Chapter 5.

3.8 WATER RELATED INFRASTRUCTURE

The water related infrastructure of the LOWMA consists predominantly of transfer schemes to mining, urban or irrigation areas. Apart from the Karos Geelkoppen and Kalahari-West Rural Water Supply Schemes, most of the rural areas are highly dependant on isolated boreholes.

The supply infrastructure is sparsely located and is predominantly along the main stem of the Orange River. There is effectively no reservoir storage in the WMA. The existing water related infrastructure is described in detail in Chapter 4.

CHAPTER 4: EXISTING WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The Lower Orange Water Management Area (LOWMA) is the largest WMA in the country, yet due to its harsh climate it has a sparse and widely distributed population. The major towns in the WMA are relatively small and therefore have a fairly small water requirement. Groundwater is the dominant source for municipal supply of the smaller centres, away from the Orange River while surface water from the Orange River is used for irrigation and mining purposes. The towns situated alongside the Orange River naturally draw their municipal supply from the river.

This chapter describes the water related infrastructure (potable supply, sewerage and irrigation supply) that currently exists within the LOWMA. **Figure 4.1.1** provides an overall picture of the current situation.

Several Government Water Schemes (GWS) and Irrigation Districts exist in the area. There are a number of small dams/weirs, on the Orange River such as the Boegoeberg Dam and Neusberg weirs. A few small dams have been built on the tributaries such as the Smartt Syndicate Dam on the Ongers River, as well as the Van Wyksvlei Dam on the Carnarvonleegte River. No hydro-power is generated within the LOWMA. A few transfer schemes provide water for irrigation, municipal and mining purposes. In all cases water is sourced from the Orange River.

The Orange River Development Replanning Study Report "Existing Water Infrastructure in the Orange River Basin" (BKS, 1997) is the main data source for this chapter.

Detailed information on the relevant components of the existing infrastructure is included in **Appendix E.**

The LOWMA has been divided into a number of drainage areas (key areas) to reflect the infrastructure status on a comparable base to the output from the Water Situation Assessment Model. Refer to **Figure 3.1.1** for details the relevant drainage areas.

The number of people supplied via the individual town and regional potable water supply schemes, per drainage area, are given in **Table 4.1.1.**

Table 4.1.1: Combined capacities of Individual Town and Regional Potable Water Supply Schemes by Drainage Area

Catchment						Area	Population	Town and Regional Water Supply Schemes		
Primary		Secondary		Tertiary (Drainage Area)						
No,	Description	No,	Description	No,	Description	Area	Population	Number of people supplied	% of Drainage Area Population	* Capacity
						(km²)	(Number)	(Number)	(%)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	33 730	75 086	65 300	87	4,15
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	91 197	32 072	20 094	62	1,63
				D55	Sak-Hartbees (WC)	1 843	648	406	62	0,3
		D4	Molopo	D42	Nossob-Molo (NC)	31 810	11 296	6 353	56	0,15
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	16 090	47 010	36 750	78	5,48
				D73	Neusberg (NC)	17 730	122 720	71 006	58	20,34
				D81, D82	Vioolsdrift (NC)	27 510	24 230	12 150	50	9,17
				D82	AlexanderBay (NC)	5 511	5 897	4 000	68	4,52
	TOTAL IN NORTHERN CAPE PROVINCE					223 578	318 311	215 653	66	45,44
	TOTAL IN WESTERN CAPE PROVINCE					1 843	648	406	62	0,3
	TOTAL IN PRIMARY CATCHMENTS C + D					225 421	318 959	216 059	66	45,74
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	24 552	56 175	46 812	83	0,67
				F50	Coastal (WC)	1 278	2 925	2 438	83	0
	TOTAL IN NORTHERN CAPE PROVINCE					24 552	56 175	46 812	83	0,67
	TOTAL IN WESTERN CAPE PROVINCE					1 278	2 925	2 438	83	0
	TOTAL IN PRIMARY CATCHMENT F					25 830	59 100	49 250	83	0,67
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						248 130	374 486	262 465	70	46,11
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						3 121	3 573	2 844	80	0,3
TOTAL IN LOWER ORANGE WMA						**251 251**	**378 059**	**265 309**	**70**	**46,41**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	-	-	-	-	9,2
TOTAL IN REPORTING AREA						**251 251**	**378 059**	**265 309**	**70**	**55,31**

* Where data is not available, the capacity of the individual town systems is assumed to be equivalent to the 1995 urban/municipal water demand and any transfers out.

4.2 REGIONAL WATER SUPPLY SCHEMES

The reader is referred back to **Figure 4.1.1** for the location of the schemes listed below.

The detail in this chapter refers to the development status in the year 1995. The authors are aware of the DWAF's Regional Office registration programme and the status reports that are being produced. It is expected that the latest information will be incorporated in the follow-up action that is being planned by DWAF : Water Resources Planning.

An area of 4 000 ha has been allocated to emerging farmers at places such as Riemvasmaak (Vredesvallei), Witbank and Sanddrift. These are also post 1995 developments.

The status report as at 24 August 2001 is included in **Appendix C.3.**

4.2.1 Douglas Irrigation Area

Douglas Irrigation Area is supplied with Orange River water from a pump station on the right bank of the Orange River at Marksdrift, just upstream of the Vaal River Confluence. The water is discharged into the Orange Vaal canal, which runs by gravity to Douglas Weir. From Douglas Weir, approximately 7 200 ha is irrigated.

4.2.2 Middle Orange Irrigation Area

The Middle Orange Irrigation Area comprises riparian irrigators from Hopetown to Boegoeberg Dam. Approximately 13 640 ha falls within the portion from the Vaal confluence to Boegoeberg Dam i.e. within the LOWMA.

4.2.3 Boegoeberg Irrigation Scheme

Boegoeberg Dam, a 9 m-high concrete gravity structure built in 1931 some 150 km upstream of Upington in the Orange River, is the major structure supporting the releases to the Boegoeberg irrigation area. Due to sedimentation, the capacity of the reservoir has decreased from its original 34,7 million m³ to only 20,7 million m³.

The Boegoeberg Canal comprises the 172 km long main canal on the left bank with a current capacity of 9,76 m³/s. A syphon and branch canal on the right bank of the Orange River (the Noord-Oranje Canal) conveys water to the area controlled by the Noord-Oranje Irrigation Board. Further downstream, another syphon and canal on the right bank supplies water to the Gariep Settlement. The schematic layout of the Boegoeberg-Karos Government Water Scheme (GWS) is shown in **Appendix E.2** together with details of the Noord-Oranje Canal. The scheduled irrigation area of the Boegoeberg and Noord-Oranje Irrigation Boards total 7 558 ha, while 1 065 ha is irrigated from river abstractions between Boegoeberg Dam and the Gifkloof weir upstream of Upington in the Orange River.

The Boegoeberg Canal on the left bank also supplies water to the Rouxville West scheme. This former irrigation board canal scheme now forms part of the Boegoeberg GWS. The Karos Weir in the Orange River upstream of the Rouxville West Island Group is no longer functional.

4.2.4 Karos Geelkoppen Rural Water Supply Scheme

This scheme abstracts water, via a pump station, from the Orange River upstream of Upington to supply a large area north of Upington for stock watering purposes.

4.2.5 Gifkloof Weir (Upington Islands GWS and Upington Irrigation Board Canal)

There are many islands in the Orange River, in the vicinity of Upington, where irrigation has been practiced as far back as 1883, when the first canal was constructed and is now controlled by the Upington Irrigation Board. The upstream intake for the Upington Irrigation Board Canal is on the right bank of the Gifkloof Weir at the Rouxville West Island Group.

Gifkloof Weir also diverts water to the left bank of the Orange River into the Upington Islands GWS. Both banks of the river and the islands are irrigated and water is supplied via a network of secondary canals and syphons (see **Appendix E.2**). The left bank canal has an initial capacity of approximately 10 m³/s and supplies water to the Upington Islands Government Water Scheme. A series of secondary canals and syphons supply water to irrigation land on the left and right banks of the river and to the islands in the river. The total length of the main canal is 58,5 km. The subdivision of the canal is given in **Appendix E.2.**

Steynsvoor canal, which supplies water to the Steynsvoor Irrigation Board, branches from the end of reach 5 of the Upington Island Canal. Water is transferred to this canal on the right bank of the river by means of the Steynsvoor syphon. Details of the Irrigation Boards in the Upington Islands GWS are listed in **Appendix E.2**. The scheduled area for irrigation from the Upington Main Board canals is 5 846 ha, while 407 ha is scheduled with water abstraction from the river.

In the vicinity of Keimoes there are various Irrigation Boards with their own diversions. The scheduled area for the Boards abstracting water from canals is 5 089 ha and 296 ha is scheduled with water abstraction from the river. A further 733 ha of irrigation land is scheduled between Gifkloof Weir and Neusberg Weir to abstract water from the river.

4.2.6 Kalahari-West Rural Water Supply Scheme

This water supply scheme northwest of Upington, was initiated following several years of critical drought in this part of the catchment. The scheme consists of a 51 ℓ/s main pump station at the Upington municipal reservoir, which conveys water through a 250 mm diameter pipeline 20 km long to the main reservoir (2 500 m^3 capacity) near Spitskop. From there, the water flows through a 250 mm diameter gravity pipeline to a balancing reservoir of 100 m^3 . A 22,5 ℓ/s booster pump station supplies water beyond this point to the primary distribution system. This distribution system consists of 9 reservoirs with capacities ranging from 100 m^3 to 730 m^3 and pipelines with a total length of 330 km with diameters ranging from 110 mm to 250 mm. A second booster pump station delivers the water to the remainder of the area at a maximum capacity of 16,4 ℓ/s. A secondary distribution system consists of 105 km of pipelines, with diameters between 50 mm and 110 mm, as well as three 80 m^3 reservoirs.

4.2.7 Neusberg Weir (Kakamas GWS)

The Neusberg Weir supplies water to the Kakamas Government Water Scheme area. The schematic layout of this scheme is shown in **Appendix E.2**. Irrigation in the Kakamas area already started in the late nineteenth century and the irrigated areas are on various islands in the Orange River as well as on the alluvial flood plains on both banks of the river. The construction of the South-Furrow and the North-Furrow canal schemes commenced in 1898 and 1908 respectively. Both canals were recently enlarged and upgraded. Water for both canals is abstracted at the Neusberg Weir, completed in 1993, in the Orange River near Kakamas. The scheduled area for the Kakamas North and South Schemes is 4 317 ha.

Details of the canal systems of the Kakamas GWS are summarised in **Appendix E.2**.

Between Neusberg and Augrabies 2 650 ha of land is scheduled with rights to abstract water from the Orange River.

4.2.8 Rhenosterkop Weir (Kakamas GWS)

The Rhenosterkop Canal diverts water below the end of the Kakamas South Furrow by means of a concrete weir, the Rhenosterkop Weir, which is built between the left bank and Paarden Island, and has an intake capacity of 7,85 m^3/s. The Rhenosterkop Canal leads into the Augrabies Canal, which in turn leads into the Noudonzies Canal. An area of 1 712 ha is scheduled for water supply through the Augrabies canal. Between Augrabies and the Namibian border, 662 ha of irrigation land has scheduled water rights for abstraction from the Orange River.

4.2.9 Onseepkans Irrigation Area

Onseepkans irrigation area is supplied through a canal on the left bank of the Orange River. The capacity of this canal could not be established within the scope of this study, but it supplies water to 314 ha of irrigation land.

4.2.10 Namakwaland Irrigation Area

The water for the Namakwaland Irrigation Area is abstracted from the Orange River. Water is released from Van der Kloof Dam to supply users in this area. The current scheduled area is 2 058 ha.

4.2.11 Pelladrift Water Supply Scheme

The Pelladrift Water Supply Scheme supplies water to Pofadder, Aggenys and Pella Mission. The current water supply amounts to 5,16 million m³/annum. This scheme is owned and operated by Pelladrift Water.

4.2.12 Springbok Regional Water Supply Scheme

This scheme was constructed due to insufficient water resources from boreholes. The works comprise of abstraction works on the Orange River at Henkriesmond, the purification works at Henkries, several pump stations as well as pipelines to reservoirs at the bulk consumers. Springbok, Okiep, Nababeep, Steinkopf, Concordia, Carolusburg and Kleinsee are supplied with purified water from this scheme.

The scheme consists of an inlet plus pump station in the Orange River, supplying water to a sedimentation dam. From this dam water is pumped through a 475 mm rising main of 9 500 m length to Henkries, where the water is treated and pumped over a distance of 35 200 m through a 419 mm pipeline. A booster pump has been installed to help supply the water to a reservoir of 6 800 m³ at Eenrietberg.

From this reservoir at Eenrietberg water is released, under gravity over a distance of 54 500 m, to supply water to the users at Concordia, Okiep reservoir (11 200 m³), Springbok and Nababeep. Kleinsee is supplied via a pipeline from the Springbok reservoir. The current water supply is 4,08 million m³/annum. This scheme is owned and operated by Namakwa Water.

4.2.13 Vioolsdrift and Noordoewer Irrigation Area

Vioolsdrift and Noordoewer irrigation areas are supplied through a canal system fed by the Vioolsdrift Weir on the Orange River. The canal originates on the left bank. All land on the northern (right) bank is inside Namibia. The schematic layout of the irrigation scheme is shown in **Appendix E.2.**

The capacity of the first reach of 13 km of the canal is 1,28 m³/s. This canal is also referred to as the Vioolsdrift canal. Within this reach a syphon feeds some water to the Noupoort Canal on the north (right) bank, supplying water to three plots. The water is then fed through the Vioolsdrift syphon to the right bank. The length of reach 2 (called the Noordoewer Canal), is 8 km with a capacity of 0,99 m³/s. At the Rooiwal syphon, water is transferred to the left bank canal, called the Rooiwal Canal. At the end of the Noordoewer Canal, after the syphon, the canal extends a further 4 km with a capacity of 0,09 m³/s. This canal is referred to as the Duifieloop Canal.

The Rooiwal Canal has a capacity of 0,71 m³/s and is 1,7 km long. The Rooiwal Canal splits into two canals: the Duin Canal, 2,5 km in length with a capacity of 0,26 m³/s, and the Swartbas Canal, 2,5 km long with a capacity of 0,45 m³/s.

The Swartbas syphon transfers water to the Modderdrift main canal on the right bank, 2,5 km in length with a capacity of 0,26 m³/s. At the end of the Modderdrift main canal, the capacity of the canal reduces to 0,09 m³/s for 2,4 km. This canal is called the Modderdrift North Branch Canal. At the point where the Modderdrift main canal reduces in capacity, some water is transferred to the left bank through the Modderdrift syphon. This left bank canal, the Modderdrift South Branch Canal, is 3,1 km long with a capacity of 0,40 m³/s.

The scheduled area for Vioolsdrift (RSA) amounts to 600 ha and for the Noordoewer (Namibia) area 284 ha. This scheme has been transferred to, and is operated by, the Vioolsdrift and Noordoewer Joint Water Authority.

4.2.14 Sendelingsdrift

Sendelingsdrift is a mining town on the left bank of the Orange River, with a low water causeway across the river. A few hundred metres upstream of the causeway on the right bank is the abstraction point for Rosh Pinah Mine.

4.2.15 Alexander Bay

Well points in the Orange River near Oppenheimer Bridge are used to supply the domestic and mining water requirements of Oranjemund and Alexander Bay, as well as Port Nolloth to the south. There is also 1 360 ha of irrigated land on the left bank upstream of Oppenheimer bridge.

4.2.16 Namibian Irrigation from Orange River

Approximately 1 800 ha (excluding Noordoewer) are irrigated by riparian abstraction on the right bank of the Orange River. The largest development of this type is at Aussenkjer, between Noordoewer and the Fish River Confluence.

4.2.17 Irrigation in the Fish River Catchment

Approximately 2 150 ha of irrigation takes place in the Fish River catchment, mainly in the vicinity of Hardap and Naute Dams.

4.3 DRAINAGE AREA BREAKDOWN

Due to the nature of the LOWMA, a brief description of each drainage area/catchment as shown on **Figure 4.1.1** is given below. Summary tables of the relevant dams, regional supply schemes, potable water supply and controlled irrigation areas are given in **Appendix E.**

4.3.1 Ongers Drainage Area

This catchment in the south eastern portion of the LOWMA has a population of 65 300 urban and 9 786 rural. The major towns are De Aar, Richmond, Victoria West, Britstown and Strydenburg. The Smartt Syndicate and Victoria West Dams are in this catchment. The towns are reliant on groundwater supplied by their own local systems. Approximately 87% of the population in the drainage area receives water from the individual town supply systems.

4.3.2 Boegoeberg Drainage Area

The Boegoeberg Catchment is the portion between the Vaal/Orange River Confluence at Douglas and Boegoeberg Dam. The population figures for this catchment are 36 750 urban and 10 260 rural. Water for irrigation along the Orange River is supplied via releases from the Douglas weir and also directly from the Orange River. Major towns include Marydale, Prieska, Niekerkshoop, Griekwastad and Douglas. Except for Douglas and Prieska, which draw their municipal supply from the Orange River, all the other towns in the drainage area are reliant on small individual wellfield systems. Approximately 78% of the population is supplied via these systems.

4.3.3 Neusberg Drainage Area

The Neusberg Catchment has the highest water requirement of all the catchments in the LOWMA. The towns of Groblershoop, Upington, Keimoes and Kakamas account for the majority of the urban population of 70 400. The rural population is estimated as 52 320. There is considerable irrigation within this catchment which includes the Boegoeberg Dam and Uppington Irrigation areas.

There are numerous diversion weirs in the Orange River downstream of Boegoeberg Dam, such as the Gifkloof and Neusberg weirs which supply water for irrigation.

Major potable water infrastructure in the area includes the Karos-Geelkoppen Rural Water Supply Scheme, a portion of the Kalahari West Rural Supply Scheme as well as the municipal system supplying the town of Upington.

4.3.4 Nossob-Molopo Drainage Area

This catchment extends into the wedge between Nambia and Botswana and is predominately an endoreic area. Eksteenskuil and Mier have been classified as urban centres which together with the rural population rely heavily on groundwater with the exception of those areas supplied by the Kalahari West Rural Water Supply Scheme. The population for this catchment is estimated at 6 600 urban and 55 749 rural. There is no irrigation in this catchment, livestock watering does however exist and is dependant on the Kalahari West Rural Water Supply Scheme.

4.3.5 Sak-Hartbees Drainage Area

The Sak Catchment is the largest catchment in the LOWMA, extending from south of Kakamas on the Orange River to the southern boundary at Sutherland. The population figures are in the order of 20 500 urban and 14 669 rural, with the urban centres being Kenhardt, Van Wyksvlei, Carnarvon, Fraserburg, Sutherland, Williston and Brandvlei. The Rooiberg, Van Wyksvlei, Modderpoort and Ratelfontein Dams are the only dams of any significance in the catchment. There are no elaborate transfer schemes in this catchment. Water is sourced from the above mentioned dams, but primarily from underground resources. Each town supplies its own requirements via surrounding wellfields.

4.3.6 Vioolsdrift Drainage Area

This catchment extends from Vioolsdrift upstream to Neusberg. The main towns include Aggeneys, Pella, Pofadder, Onseepkans and Augrabies. The population split is approximately 12 150 urban and 9 825 rural.

The Pelladrift Regional Water Supply Scheme is the only potable supply scheme providing surface water to Pofadder, Aggeneys and some mines in the area. There is considerable irrigation in the catchment, notably from Neusberg to Augrabies, Augrabies to the Namibian border and Onseepkans.

The abstraction point, Henkriesmond, for the Springbok regional water supply scheme lies within this drainage area.

4.3.7 Alexander Bay Drainage Area

The Alexander Bay drainage area has an estimated population of 4 000 urban and 1 595 rural. The main towns in the catchment are Vioolsdrift, Eksteenfontein and Alexander Bay. Raw water is abstracted near Sendelingsdrift for the mine at Rosh Pinah (Namibia). Alexander Bay draws water from well points along the Orange River near the Oppenheimer bridge. All other settlements in this area rely on groundwater. The Vioolsdrift and Noordoewer Irrigation Schemes fall within this drainage area. There are no major dams in the area.

4.3.8 Coastal Drainage Area

This catchment covers the entire coastal belt as far inland as Springbok. The estimated population is 49 250 urban and 9 850 rural. The major towns are Port Nolloth, Steinkopf, Springbok, Okiep, Nababeep, Concordia, Carolusburg, Kleinsee, Kamieskroon, Koningnaas and Hondeklipbaai. The Springbok Regional Water Supply Scheme draws water from Henkriesmond on the Orange River, it is purified at Henkries and pumped to Springbok and the surrounding copper mines via Steinkopf. Kleinsee also receives water from this scheme via Springbok. Port Nolloth receives Orange River Water from Alexander Bay. The other towns and rural areas rely on groundwater.

4.3.9 Dams and Water Supply Schemes

There are very few dams of substance in the LOWMA, **Table 4.3.1** lists those with a capacity above 3 million m^3. The smaller dams, as listed in Volume III of WR90 (Midgley, et al, 1994), were also captured into the WSAM database. **Table 4.3.2** summarises the water supply schemes, while **Table 4.3.3** details the controlled irrigation areas.

Table 4.3.1: Main Dams in the LOWMA

NAME OF DAM	DRAINAGE AREA	CATCHMENT	GROSS STORAGE CAPACITY (10^6 m³/a)
Boegoeberg	Boegoeberg	D72C	20,29
Modderpoort	Sak-Hartbees	D55A	10,00
Ratelfontein	Sak-Hartbees	D52F	6,91
Rooiberg	Sak-Hartbees	D53A	3,65
Smartt Syndicate	Ongers	D61M	101,12
Van Wyksvlei	Sak-Hartbees	D54C	143,08
Victoria West	Ongers	D61E	3,66

4.4 HYDROPOWER AND PUMPED STORAGE

There is no hydropower or pumped storage infrastructure in the Lower Orange Water Management Area.

Table 4.3.2: Potable Water Supply Schemes in the LOWMA

SCHEME NAME	DRAINAGE AREA	RAW WATER SOURCE	POPU-LATION SUPPLIED	TREATMENT WORKS			SUPPLY SCHEME		
				NAME	CAPA-CITY (Mℓ/d)	OWNER/ OPERATOR	CAPA-CITY (Mℓ/d)	OWNER/ OPERA-TOR	LIMI-TING FACTOR (*)
Kalahari-West, Rural Water Supply Scheme	Neusberg	Orange River	Unknown	Upington Munici-pality	55**	Kharahais Waterboard	1,340	Kharahais Water-board	
Upington Municipal Supply	Neusberg	Orange River	52 850						Currently none
Pelladrift Water Supply Scheme	Vioolsdrift	Orange River	7 150		Unknown (assumed 5.16)	Pella Water Board	5.16	Pella Water Board	
Springbok Regional Water Supply Scheme	Vioolsdrift/Coastal	Orange River	35 350	Henkries	10	Namakwa Water	4.745	Namakwa Water	Old pipelines
Sendelingsdrift	Namibia	Orange River	7 100	Unkown	Unknown (assumed 9.2)	Unknown	9,2	Rosh Pinah mine	Unkown
Karos Geelkoppen Water Supply Scheme	Neusberg/Nossob-Molopo	Orange River	Stock watering	No treatment works, filters only	-	Karos Geelkoppen Water Board		Karos Geelkoppen Water Board, users help with maintenance	
Prieska Municipal Supply	Boegoeberg	Orange River	11 000	Prieska	15,0	Siyathemba Municipality	8,65	Siyathemba Municipality	Demand > Permit (15Mℓ/d vs 3,8Mℓ/d)
Alexander Bay to Port Nolloth	Coastal	Orange River	4 650	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

* Typically treatment capacity or raw water source or raw water conveyance capacity.
** Upington treatment works expanded to 60 Mℓ/d in 2000

Additional information on the existing infrastructure in the LOWMA is provided in **Appendix E.**

Table 4.3.3: Controlled Irrigation by Drainage Area

DRAINAGE AREA	SCHEDULED AREA (km²)	CURRENT AREA* (km²)	DOMINANT PRODUCE	SUPPLY SOURCE	QUOTA ($m^3/ha/a$)	ALLOCATION ($10^6\ m^3/a$)	THEORETICAL REQUIREMENT** ($m^3/ha/a$)
Boegoeberg	208,4	N/A	Wheat	Orange	10 000	208,4	±13 000
Neusberg	248,0	N/A	Grapes	Orange	15 000	372,0	±18 500
Vioolsdrif	118,4	N/A	Grapes	Orange	15 000	177,6	±18 500
Namibia	44,2	N/A	Wheat	Orange & Fish	20 000	88,3	N/A
Alexander Bay	13,6	N/A	Wheat & Maize	Orange	15 000	20,4	± 14 800

* Current areas not available (see section 3.5.2.)

** Estimated theoretical requirement from ORRS CROPWAT estimates, although ORRS crop distributions no longer applicable.

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

Apart from the ecological Reserve, the two largest water requirement sectors in the Lower Orange Water Management Area (LOWMA) are irrigation and river losses. Due to the large cummulative natural runoff of the Orange River, it is to be expected that the ecological Reserve will represent a major water requirement. The impact of the ecological Reserve on yield is calculated based on available information. Other water requirement sectors in order of decreasing impact on yield, are urban, rural, mining and alien vegetation.

The water requirements for the aquatic ecosystems (ecological requirement) are considered at the outlet to the WMA. The instream flow requirement was used for the coastal catchments as fresh water requirements at the river mouths are unknown.

There is no hydropower in the WMA, therefore water consumption as a result of hydropower releases is not applicable. The impact of hydropower releases from upstream on users in the LOWMA is discussed later in this chapter.

Water allocations and consumption patterns occur at varying levels of assurance of supply. The ecological and human Reserve components are provided for at a high level of assurance (low risk of failure/non-supply). The agricultural sector on the other hand is supplied at a much lower level of assurance. The water requirements for the different user sectors were all related to one another at a 1:50 year level of assurance, which is generally the norm for urban/industrial use.

Distribution losses and conveyance losses are included in the water requirements. A separate figure is provided for water transfers out of the WMA. **Tables 5.1.1 and 5.1.2** provide a breakdown per user group on a WMA and a provincial basis respectively.

Table 5.1.1: Water Requirements per User Group in 1995

USER GROUP		ESTIMATED WATER REQUIREMENT (10^6 m³/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m³/a)
Urban		23,87	24,13
Rural		17,32	18,80
Bulk Use	Strategic	0,0	0,0
	Mining	8,64	9,11
	Other	0,0	0,0
Agriculture	Irrigation	901,40	774,50
Afforestation		0,0	0,0
Alien Vegetation		16,93	4,42
Water Transfers out		6,69	6,69
Hydropower		0,0	0,0
River Losses		527,3*	527,3*
TOTAL (LOWMA)		**1 502,15****	**1 364,95****
Ecological Reserve		65,16	65,16

* The impact of the ecological Reserve and river losses on yield have not been finalised.
** Excludes ecological Reserve

The Figures in the above table are for the Lower Orange Water Management Area (LOWMA) only and do not include the entire reporting area.

Table 5.1.2: Water Requirements per Province in 1995 at 1:50 Year Assurance

USER GROUP		NORTHERN CAPE PROVINCE (10^6 m³/a)	WESTERN CAPE PROVINCE (10^6 m³/a)
Urban		24,13	0,00
Rural		18,69	0,11
Bulk Use	Strategic	0,00	0,00
	Mining	9,11	0,00
	Other	0,00	0,00
Agriculture	Irrigation	774,50	0,00
	Dry-land Crops	0,00	0,00
Afforestation		0,00	0,00
Alien Vegetation		4,42	0,00
Water Transfers Out		6,69	0,00
Hydropower		0,00	0,00
River Losses		527,30	0,00
TOTALS		**1 364,84**	**0,11**

1) The water requirement is assigned to the province where it arises, irrespective of transfers.
2) The ecological Reserve is associated with water resources, and is not available by province.

Table 5.1.3: Water Requirements per Drainage Area in 1995 at 1:50 year Assurance

Primary		Secondary		Tertiary (Drainage Area)		Urban	Rural	Bulk	Irrigation	Dryland Crops	Affore-station	Alien Vegetation	Transfers (Out)	River Losses	Total
No,	**Description**	**No,**	**Description**	**No,**	**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)**	**(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)**
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	4,15	3,62	0,00	0,00	0,00	0,00	0,60	0,00	0,00	8,4
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	1,63	5,42	0,00	11,41	0,00	0,00	3,67	0,00	0,00	22,1
				D55	Sak-Hartbees (WC)	0,03	0,11	0,00	0,23	0,00	0,00	0,07	0,00	0,00	0,5
		D4	Molopo	D42	Nossob-Molo (NC)	0,15	1,81	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,0
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	3,45	1,63	0,00	199,20	0,00	0,00	0,00	0,00	119,30	323,6
				D73	Neusberg (NC)	9,00	2,36	0,00	383,20	0,00	0,00	0,05	0,46	131,00	526,1
				D81, D82	Vioolsdrift (NC)	1,19	1,63	3,52	162,00	0,00	0,00	0,00	5,56	163,00	336,9
				D82	AlexanderBay (NC)	0,42	0,30	3,43	18,46	0,00	0,00	0,00	0,67	114,00	137,3
	TOTAL IN NORTHERN CAPE PROVINCE					19,99	16,77	6,95	774,27	0,00	0,00	4,33	6,69	527,30	1 356,3
	TOTAL IN WESTERN CAPE PROVINCE					0,03	0,11	0,00	0,23	0,00	0,00	0,07	0,00	0,00	0,5
	TOTAL IN PRIMARY CATCHMENTS C + D					20,02	16,88	6,95	774,50	0,00	0,00	4,40	6,69	527,30	1 356,7
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	3,90	1,82	2,05	0,00	0,00	0,00	0,02	0,00	0,00	7,8
				F50	Coastal (WC)	0,21	0,10	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,4
	TOTAL IN NORTHERN CAPE PROVINCE					3,90	1,82	2,05	0,00	0,00	0,00	0,02	0,00	0,00	7,8
	TOTAL IN WESTERN CAPE PROVINCE					0,21	0,10	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,4
	TOTAL IN PRIMARY CATCHMENT F					4,11	1,92	2,16	0,00	0,00	0,00	0,02	0,00	0,00	8,2
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						23,89	18,59	9,00	774,50	0,00	0,00	4,35	6,69	527,30	1 364,1
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,24	0,21	0,11	0,00	0,00	0,00	0,07	0,00	0,00	0,9
TOTAL IN LOWER ORANGE WMA						**24,13**	**18,80**	**9,11**	**774,50**	**0,00**	**0,00**	**4,42**	**6,69**	**527,30**	**1 364,95**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	2,43	21,62	10,51	68,11	0,00	0,00	0,00	0,00	0,00	102,7
TOTAL IN REPORTING AREA						**26,56**	**40,42**	**19,61**	**842,60**	**0,00**	**0,00**	**4,42**	**6,69**	**527,30**	**1 467,65**

* Rounding errors do occur.

Figures 5.1.1 and 5.1.2 show the total and sectoral water requirements per drainage area.

5.2 ECOLOGICAL COMPONENT OF THE RESERVE

5.2.1 Introduction

The classification of the main stem rivers in the vicinity of the outlets of the quaternary catchments is described in Section 2.6.3. On the basis of this classification, a so-called desktop method has been developed (Hughes and Munster, 1999) to provide a low-confidence estimate of the water required for the ecological component of the Reserve, which is suitable for use in this water resources situation assessment.

The method involves the extrapolation of high confidence results of previous instream flow requirement (IFR) workshops, the use of a reference time series of monthly runoff at the outlet of the quaternary catchment, and a number of hydrological indices or parameters that have been defined for 21 desktop Reserve parameter regions in South Africa. These desktop Reserve parameter regions are described and shown in **Figure 5.2.1.1.** The instream flow requirements that were previously determined, 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. Likewise, the water requirement will decrease as the ecological status is decreased.

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

- The extrapolations from past IFR workshops are based on a very limited data set, which does not cover the whole of the country. While some development work has been completed to try and extend the extrapolations and has improved the high flow estimations for dry and variable rivers, this has been quite limited.

- The extrapolations are based on a hydrological index and no allowance (in the desktop method adopted for this water resources situation assessment) has been made for regional, or site specific ecological factors. It is unlikely that an index based purely on hydrological characteristics can be considered satisfactory, but it represents a pragmatic solution in the absence of sufficient ecological data.

- The method assumes that the monthly time series of natural flows are representative of real natural flow regimes and many of the algorithms rely upon the flow characteristics being accurately represented. Should the data indicate more extended base flows than actually occur, the hydrological index of flow variability would be underestimated 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 Munster, 1999).

The simulation model provides annual maintenance and drought low-flows and maintenance high-flows (expressed as a proportion of the mean annual runoff). The model also provides for the seasonal distribution and assurances associated with the monthly flows on the basis of a set of default parameters that has been developed for each of the 21 desktop Reserve parameter regions of South Africa referred to in Section 5.2.1. The quaternary catchments in this Lower Orange Water Management Area fall within the so-called Western Karoo, Eastern Karoo, Lowveld and Vaal regions, as indicated in **Figure 5.2.1.1** by the numbers 3, 4, 18 and 20 respectively.

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 Situation Assessment Model (WSAM), 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 least average flow for all periods in the monthly time series of water requirements for the ecological component of the Reserve that are as long as the critical drought period.

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

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

- The seasonal distributions of the annual estimates of water requirements are based on analyses of the base flow characteristics of some 70 rivers using daily data, the results of which were then regionalised. Some individual quaternary catchments that have been allocated to a specific region may, however, have somewhat different characteristics.

- Similarly, the regional parameters for the assurance rule curves have been based on the duration curve characteristics of the natural flow regimes represented by the monthly time series of flow 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

Little is known about the aquatic biota of the Lower Orange Water Management Area (LOWMA), with the notable exception of the Orange River, which has been studied in reasonable detail. The assessment of catchments that included the Orange River focused on fishes and aquatic invertebrates, and the results may be considered as reasonably reliable. The riparian vegetation along the middle and lower Orange River is neither diverse nor botanically interesting, and for this reason, little information is available.

A first assessment of the environmental flow requirements of the Orange River estuary was undertaken in the year 1985 (CSIR, 1985). This assessment was superseded in the year 1989, when the Orange River Environmental Task Group met in Oranjemund to discuss the flow requirements of the estuary. The group recommended a minimum of 100 million m³ per annum during drought years, and a minimum of 244 million m³ per annum during normal years (ORETG, 1989). High-flows in summer were recommended to inundate the salt marsh.

The first assessment of environmental flow requirements in the Orange River downstream of the Van der Kloof Dam was conducted in the year 1990 (ORETG, 1990). The assessment recommended a minimum of 200 million m³ per annum.

In 1996 the environmental flow requirements of both the river and estuary were reassessed as part of the Orange River Replanning Study (Venter and van Veelen, 1996). The assessment recommended low-flows in winter, not exceeding 5 m³/s, intended to close the mouth, and so inundate the salt marsh. In summer, the recommended minimum flow required to keep the mouth open was 12 m³/s. Between these flows, the dynamics of the system are not well known, and more research would be required to provide a more accurate flow recommendation. The assessment recommended a minimum of 197 million m³ per annum during drought years, and a minimum of 294 million m³ per annum during normal years for both the river and the estuary.

The environmental flow requirements for the river were slightly higher than the estuary during December and February because of the need to stimulate the spawning of *Barbus kimberleyenis* and *Barbus hospes*. In winter (July to September) the environmental flow requirements for the estuary were lower than the river because of the need to close the river mouth and inundate the salt marsh. This was not considered detrimental for the river because the cool temperatures at this time of the year would not cause undue stress.

For the rest of the study area, information on aquatic ecosystems is almost non-existent. This is not surprising considering that most of the area is desert, semi-desert or Karoo. The scarcity of permanent water meant that the study could not rely on the same criteria as used for perennial rivers. The information for arid areas was therefore based mainly on the composition, distribution and status of birds, particularly raptors that use riparian trees for nesting. Despite the lack of information, the confidence in many scores was high because it is reasonably safe to assume that few species found in arid areas will be sensitive to changes in flow or water quality. It is also probable that species richness is low, although aquatic invertebrates in temporary streams may challenge this assumption. Habitat diversity was assumed to be low, and the area was, in general, not considered important for refugia for aquatic biota.

5.2.4 Presentation of Results

Summary results for the desktop classification of quaternary catchments are presented in **Appendix F.1. Table 5.2.4.1** and **Figure 5.2.4.1** detail the requirements per drainage area.

Key points considered coincide with catchment outlets, or with existing or proposed dam sites

In terms of the **Default Ecological Management Class (DEMC)**, the majority (80%) of quaternary catchments in the LOWMA were rated as Class D Eighteen catchments (12%) were rated as Class B, all of which were situated along the Orange River. Eleven catchments (7%) were rated as Class C. No areas were rated as Class A.

In general, the diversity of aquatic biota was considered low, and the area was not considered highly sensitive to water quality changes. Likewise, the diversity of riverine habitats was considered low. Notable exceptions were the anastomosed areas of the Orange River in the vicinity of Neusberg (D73) and Onseepkans (D81E, D81F), and the mountainous region in the Richtersveld (e.g. F10A).

Table 5.2.4.1: Water Requirement of Aquatic Ecosystems

DRAINAGE AREA OUTLET	PRESENT ECOLOGICAL STATUS CLASS	RIVERINE ECOLOGICAL WATER REQUIREMENTS		
		% VIRGIN MAR	*** VALUE	IMPACT ON 1:50 YEAR YIELD **
	(PESC)	(%)	(10^6 m³/a)	(10^6 m³/a)
Ongers	B	13,5	11,42	0,0
Sak-Hartbees	B	11,9	23,3	0,0
Nossob-Molopo	C	3,6	0,25	0,0
Boegoeberg	B	20,9	15,07	-131,5
Neusberg	C	13,9	9,92	5,5
Vioolsdrift	B	19,1	2,83	0,0
Alexander Bay	C	13,2	0,16	0,0
Coastal	C	9,1	2,2*	0,0
TOTAL LOWMA *			**65,16**	**-126,0**
Namibia	C	2,7	13,1	0,00
TOTAL REPORTING AREA		**-**	**78,26**	**-126,0**

* Sum of values for quaternaries discharging into the sea. Value of lower most quarternary where it is the only exit point.

** Estimated values for quarternary at drainage area outlet.

*** The values have been determined by multiply the % MAR figure by the drainage areas MAR.

In terms of the **Present Ecological Status Class (PESC)**, the majority, (85%) of quaternary catchments were rated as Class B **(Appendix F.1)**. The remaining catchments (15%) were rated as Class C. These were mostly situated along the middle reaches of the Orange River, where the construction of artificial levees have had major ecological impacts, and discharges from the Van der Kloof Dam have altered water temperatures, increased daily flow variance and reduced seasonal flow variance (Palmer, 1997).

Fish kills have been recorded in the Orange River, downstream of Boegoeberg Dam. (5 – 12 April 1993, 10 May 1996, Palmer pers obs.) This is due to draining of the Boegoeberg Dam and the consequent release of silt-laden water.

Other areas that were considered moderately modified (Class C) included the Orange River downstream of Vioolsdrift (D82J), where the activities of alluvial diamond mining have impacted on the river, as well as the mining areas in the vicinity of Springbok.

Another concern is the ecological impacts of the Kalahari West Rural Water Supply Scheme which abstracts water from the Orange River at Upington (S. Esterhuizen, pers. comm. 1999). The scheme distributes water to stock and rural communities over large areas in the Kalahari. The impacts of these pipelines are related to the destabilisation of dunes through excessive trampling by stock. This occurs where the stocking rates exceed that recommended for the number of watering points (A. van Rooyen, pers. comm. 1999). Dunes that are destabilised through trampling lose their nutrients and are colonised by the indigenous Driedoring, *Rhigozum trichotonum* (A. Palmer, pers. comm. 1999). The nutrients end up in the inter-dune slacks, which become colonised by the

Kalahari sour grass, *Schmidtia kalahariensis*. Both species are unpalatable to stock, and are a major agricultural problem in the northern Cape (A Palmer, pers. comm. 1999).

Herbivory by cattle associated with these water schemes has been shown to have a negative impact on the vegetation in the vicinity of the watering points (Perkins and Thomas 1993). This topic has been the subject of a PhD thesis, which describes in detail the degradation of rangelands associated with the water schemes (van Rooyen 2000). Examination of Landsat TM imagery confirms that major changes have taken place in vegetation in these areas between 1989 and 1995 (Palmer & van Rooyen 1998).

Additional factors that may affect the present ecological status of the area include:

- The abundance of windmills along the dry riverbeds, particularly in the Auob, Nossob and Molopo Rivers. Windmills tend to attract and concentrate game and large stock, and this leads to trampling, soil compaction, and general deterioration of vegetation in the surrounding vicinity.
- Open cast mining at various localities.
- Grazing by goats and other large stock.

In terms of the **Suggested Future Ecological Management Class (AEMC)**, the majority of quaternary catchments were rated as Class B (88%) **(Appendix F.1)**. Values ranged from Class B to Class D.

5.2.5 Discussion and Conclusions

Reliability of Results

The desktop method for assessing ecological management classes (Kleynhans, 1999) is based on available information only. Although there was a considerable amount of ecological information available for the Lower Orange Water Management Area (LOWMA), most of this information was highly scattered and not in a format that could be readily used for the present assessment. The assessment was therefore based largely on professional judgement, with little or no reference to published studies. This makes the assessment difficult, if not impossible, to verify.

Given the importance of professional judgement in deriving the classifications for this study, it is inevitable that the results were skewed by the fields of expertise and geographic locations in which the professionals involved in the study were most familiar. This unavoidable bias should be borne in mind when the results of this study are interpreted and used.

Major Impacts

Dry streambeds in arid areas provide important migration corridors for fauna, flora and humans alike. The fact that most developments in arid areas take place within or close to river courses, highlights the importance (and vulnerability) of these areas to the ecology (and economy) of arid areas.

Assumption and Limitations

The classification method used in this study considered the importance of rare, endangered and endemic species. These criteria have been accepted internationally as indicators of ecological sensitivity. The main problem with Red Data Books is that very little information is available on the vast majority of species, particularly plants and invertebrates. Red Data Books therefore tend to emphasise the larger, well-known species at the expense of the smaller, lesser-known species.

The assessment was restricted to biota that are dependant on the mainstream and its riparian zone for part or all of their life. This meant that in some quaternaries, the presence of rare and endangered species, or other criteria, were not recorded, despite their presence or importance within the quaternary. The results of this study should therefore not be used for Impact Assessments, even at Scoping level.

The scale or resolution of this investigation has a major impact on the reliability of the results. For example, many species, particularly plants, have distributions restricted to a few hectares. This level of detail was not included in this study, and is not usually presented in Red Data Books even if it is known, mainly to protect the confidentiality of the site (Ferrar, 1989). Catchments that were considered ecologically sensitive or important are almost certain to be so. However, catchments that were not considered ecologically sensitive or important are not necessarily unsensitive or unimportant.

It should be noted that the chosen method rated quaternary catchments in arid areas with a low ecological significance and importance, despite the fact that many of these catchments are important nodes of biodiversity (e.g. the Richtersveld). This reflects the nature of this assessment, which focuses on aquatic systems, particularly those that are perennial. Arid areas, such as the Northern Cape Province, tend to recover more slowly from the impacts of disturbance compared to wet areas. Arid areas may therefore be considered more sensitive to disturbance than wet areas. This highlights the importance that the results of this assessment should be used only within the context for which they were intended.

Several quaternary catchments within the study area were endoreic, and as such, did not have a mainstream (e.g. D73A, D82B, F20E, F40A). Data for these quaternaries were entered, but the results should be interpreted with caution.

Lastly, it should be noted that the database explicitly excluded estuaries. In the case of the Orange River, whose estuary is of major ecological significance and listed as a RAMSAR site, this omission has significant implications for the ecological management of the middle and lower Orange River.

5.3 URBAN AND RURAL

5.3.1 Introduction

The urban and rural water requirements in the Lower Orange Water Management Area (LOWMA) are almost insignificant in relation to the ecological Reserve, irrigation and river loss components (see **Figure 5.3.1.1**). The climate and topography of the WMA has not encouraged widespread development, with the result that the urban and rural water requirements are sparsley scattered around the WMA. The urban demand is generally concentrated along the main stem Orange River as a result of agriculture developments, or at places such as Springbok, Aggeneys and Port Nolloth due to mining activities. Smaller farming communities in the south also account for a small urban demand. Upington is by far the dominant and most developed urban centre in the WMA.

The rural communities are widespread across the WMA, with most areas reliant on groundwater.

The human Reserve is the basic constitutional right that each citizen be provided with an acceptable quantity of water on a daily basis. This study has accepted an amount of 25ℓ/c/d as the basic requirement that must be provided before water can be used by any other sector.

Table 5.3.1.1: Urban and Rural Domestic Water Requirements in 1995

Catchment						Urban Domestic Requirements	Rural Domestic Requirements	Combined Urban And Rural Domestic Requirement	Requirements At 1:50 Year Assurance	Human Reserve
Primary		Secondary		Tertiary (Drainage Area)						
No,	**Description**	**No,**	**Description**	**No,**	**Description**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**	**(10^6 m³/a)**
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	2,00	0,16	2,16	2,21	0,69
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,87	0,20	1,06	1,11	0,29
				D55	Sak-Hartbees (WC)	0,02	0,00	0,02	0,02	0,01
		D4	Molopo	D42	Nossob-Molo (NC)	0,08	0,08	0,15	0,17	0,10
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	1,82	0,16	1,98	1,99	0,43
				D73	Neusberg (NC)	4,06	0,74	4,80	4,84	1,12
				D81, D82	Vioolsdrift (NC)	0,65	0,20	0,84	0,86	0,22
				D82	AlexanderBay (NC)	0,19	0,03	0,22	0,23	0,05
	TOTAL IN NORTHERN CAPE PROVINCE					11,74	1,71	13,45	13,68	2,90
	TOTAL IN WESTERN CAPE PROVINCE					0,02	0,00	0,02	0,02	0,01
	TOTAL IN PRIMARY CATCHMENTS C + D					9,67	1,56	11,23	11,43	2,91
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	2,09	0,15	2,24	2,28	0,51
				F50	Coastal (WC)	0,11	0,01	0,12	0,12	0,03
	TOTAL IN NORTHERN CAPE PROVINCE					2,09	0,15	2,24	2,28	0,51
	TOTAL IN WESTERN CAPE PROVINCE					0,11	0,01	0,12	0,12	0,03
	TOTAL IN PRIMARY CATCHMENT F					2,20	0,16	2,36	2,40	0,54
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						11,74	1,71	13,45	13,68	3,41
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,13	0,01	0,14	0,14	0,04
TOTAL IN LOWER ORANGE WMA						**11,87**	**1,72**	**13,59**	**13,82**	**3,45**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	1,88	0,57	2,45	2,47	0,79
TOTAL IN REPORTING AREA						**13,75**	**2,29**	**16,04**	**16,29**	**4,24**

All figures in the above table exclude losses.

5.3.2 Urban

Introduction

A study by Schlemmer *et al* (2001), in support of the development of the National Water Resource Strategy, developed a methodology to provide a framework for estimation of both direct (domestic) and indirect (commercial and industrial) 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 as part of the Water Resources Situation Assessments was used to refine the analysis.

Methodology

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

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

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

It was recognised that a critical factor to be considered was the dependence on data that was required from Local and Water Service Authorities. Generally many authorities have records of water supplied to different users; individual households, and at times to flats and multi-household complexes.

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

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 unavailable, an estimation procedure was followed. The categories defined were associated with default unit water uses to generate overall water use estimates where hard data was not available. These categories and default unit water uses are listed in **Table 5.3.2.1.**

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

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

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

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

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

CLASSIFI-CATION	TYPE OF CENTRE	PERCEPTION
1.	Long Established Metropolitan Centres (M)	Large conurbation of a number of largely independant 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.
7.	New Centres 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 on the basis of available information for these classes, and are given in the **Table 5.3.2.3**.

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

<table>
<tr><th>URBAN CENTRE

CLASSIFICATION</th><th>COMMER-
CIAL</th><th>INDUSTRIAL</th><th>INSTITU-
TIONAL</th><th>MUNICIPAL</th></tr>
<tr><td>Metropolitan</td><td rowspan="4">0,2</td><td rowspan="4">0,3</td><td rowspan="4">0,15</td><td rowspan="4">0,08</td></tr>
<tr><td>Cities</td></tr>
<tr><td>Towns : Industrial</td></tr>
<tr><td>Towns : Isolated</td></tr>
<tr><td>Towns : Special</td><td>0,30</td><td>0,15</td><td>0,08</td><td>0,03</td></tr>
<tr><td>Towns : Country</td><td>0,10</td><td>0,15</td><td>0,03</td><td>0,10</td></tr>
<tr><td>New Centres</td><td>0,15</td><td>0,08</td><td>0,08</td><td>0,08</td></tr>
</table>

Where detailed data was unavailable, **Table 5.3.2.3** was used as a basis for estimating the indirect water use.

The urban centres within the WMA were evaluated to determine their 1995 consumption figures. Where available, information from the water service provider was reconciled with the approach provided by Schlemmer *et al*, as a cross check. In many cases, information was not forthcoming from the service provider and the above listed approach was therefore used.

The largest urban water demands are in the Neusberg catchment and is predominately driven by Upington’s requirements.

Bulk conveyance and network distributon losses of 5% and 20% respectively have been assumed, which are in line with current operating practicies.

Drought periods automatically install a greater awareness to conserve water albeit through a process of implementing water restrictions. It is however very difficult to quantify the potential reduction in water consumption during a drought period. Previous demand management actions during drought periods introduced penalty tariffs for household consumptions greater than (approximately) 50% of the normal consumption. Based on this practice it can be assumed that reasonable curtailment of average water use could be in the order of 20 to 35%.

Return flows back into the river course/s were also taken into consideration. In many cases there are no return flows as water is fed into evaporation ponds. Upington is the only source of significant return flows.

Table 5.3.2.4 is a summary of the urban water requirements by drainage area for the base year 1995.

Table 5.3.2.4: Urban Water Requirements by Drainage Area in 1995

Catchment						Urban Water Requirements								Return Flows			
Primary		Secondary		Tertiary (Drainage Area)		Direct	Indirect	Bulk Conveyance Losses		Distribution Losses		Total	Total At 1:50 Yr Assurance	Effluent	Impervious Urban Areas	Total Return Flow	Total At 1:50 Yr Assurance
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(%)	(10^6 m³/a)	(%)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	2,00	1,05	0,20	5,0	0,81	20,0	4,07	4,15	0,00	0,30	0,30	0,30
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,87	0,33	0,08	5,0	0,32	20,0	1,59	1,63	0,00	0,00	0,00	0,00
				D55	Sak-Hartbees (WC)	0,02	0,01	0,00	5,0	0,01	20,0	0,03	0,03	0,00	0,00	0,00	0,00
		D4	Molopo	D42	Nossob-Molo (NC)	0,08	0,03	0,01	5,0	0,03	20,0	0,14	0,15	0,00	0,00	0,00	0,00
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	1,82	0,69	0,24	7,0	0,69	20,0	3,43	3,45	0,00	0,00	0,00	0,00
				D73	Neusberg (NC)	4,06	2,66	0,45	5,0	1,79	20,0	8,95	9,00	0,49	0,25	0,75	0,75
				D81, D82	Vioolsdrift (NC)	0,65	0,24	0,06	5,0	0,24	20,0	1,19	1,19	0,00	0,00	0,00	0,00
				D82	AlexanderBay (NC)	0,19	0,12	0,02	5,0	0,08	20,0	0,41	0,42	0,00	0,00	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					9,65	5,12	1,06	5,3	3,96	20,0	19,79	19,99	0,49	0,55	1,05	1,05
	TOTAL IN WESTERN CAPE PROVINCE					0,02	0,01	0,00	5,0	0,01	20,0	0,03	0,03	0,00	0,00	0,00	0,00
	TOTAL IN PRIMARY CATCHMENTS C + D					9,67	5,13	1,06	5,3	3,96	20,0	19,82	20,02	0,49	0,55	1,05	1,05
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	2,09	0,79	0,19	5,0	0,77	20,0	3,85	3,90	0,00	0,00	0,00	0,00
				F50	Coastal (WC)	0,11	0,04	0,01	5,0	0,04	20,0	0,20	0,21	0,00	0,00	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					2,09	0,79	0,19	5,0	0,77	20,0	3,85	3,90	0,00	0,00	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,11	0,04	0,01	5,0	0,04	20,0	0,20	0,21	0,00	0,00	0,00	0,00
	TOTAL IN PRIMARY CATCHMENT F					2,20	0,84	0,20	5,0	0,81	20,0	4,05	4,11	0,00	0,00	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						11,74	5,91	1,25	5,3	4,73	20,0	23,64	23,89	0,49	0,55	1,05	1,05
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,13	0,05	0,01	5,0	0,05	20,0	0,23	0,24	0,00	0,00	0,00	0,00
TOTAL IN LOWER ORANGE WMA						**11,87**	**5,97**	**1,26**	**5,3**	**4,77**	**20,0**	**23,87**	**24,13**	**0,49**	**0,55**	**1,05**	**1,05**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	1,88	0,00	0,13	5,0	0,50	20,0	2,50	2,43	0,00	0,00	0,00	0,00
TOTAL IN REPORTING AREA						**13,75**	**5,97**	**1,39**	**5,3**	**5,27**	**20,0**	**26,38**	**26,56**	**0,49**	**0,56**	**1,05**	**1,05**

* A factor of 20% for distribution losses has been included uniformily across all the drainage areas for modelling purposes (WSAM).

Water Losses

Water losses in urban areas can be broken down into two components:

- Losses in the bulk supply system to an urban area typically range from 0.03 to 0.07 of the urban water use, and include losses at purification works due to backwashing of sand filters. The portion of urban water use lost in the bulk supply system is assumed to be 5% of the urban use within the WMA, which implies a total loss of 1,39 million m³/a for the WMA. There are a number of small communities in Namaqualand and along the Sishen-Saldanha railway line who make use of desalination plants to produce potable water. The brine is evaporated. Such losses are considered as "purification losses" and fall within the estimated 5%.

- Losses in the water distribution system, which include losses due to leaking pipes and reservoirs. Distribution losses can range from 10% of the urban water use to as high as 30% of the urban water use in places where proper maintenance is not done. Total losses in the distribution system in the WMA were assumed as 20% due to a lack of better information. This equates to 5,27 million m³/a.

Return Flows

Return flows from urban areas can be broken down into two categories:

- Effluent generated from residential and industrial areas is directly proportional to the water used. The water use is further dependant on the standard of living and type of industries. These return flows also include that which is generated by irrigation municipal areas such as sports fields and gardens. All of these factors have been taken into consideration when estimating the return flows. The total effluent return flow is estimated as 0,49 million m³/a, and is predominantly at Upington.

- Return flow due to impervious urban areas. This is additional rainfall runoff, which is created due to impervious areas created in urban areas. The impervious area within the LOWMA is almost negligible with an estimated return flow of 0,56 million m³/a. This represents the increase in runoff and not the increase in yield. The latter would be much smaller.

5.3.3 Rural

Water Requirements

The water requirements considered under the rural component include direct domestic use, subsistence irrigation and stock watering. Losses and return flows are also taken into account. The direct use is naturally linked to a per capita use based on the adopted population statistics for a given quaternary. The large stock/game watering was centred around the consumption of an equivalent large stock unit equal to 45ℓ/unit per day. Factors were adopted to convert the various large stock such as goats, chickens and Springbok into an equivalent large stock unit (equivalent to horse or eland). This table is included in **Appendix D.4**. The water requirement was also converted to a 1:50 assurance level so that it could be included in the overall assessment. **Tables 5.3.3.1** and **5.3.3.2** detail the rural water requirements and anticipated return flows.

Table 5.3.3.1: Per Capita Water Requirements in Rural Areas in 1995

Catchment						Unit Rural Water Requirements				
Primary		Secondary		Tertiary (Drainage Area)		Rural Per Capita (Direct)	Distribution Losses		Total	Total At 1:50 Yr Assurance
No,	Description	No,	Description	No,	Description	(l/c/d)	(l/c/d)	%	(l/c/d)	(l/c/d)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	45,0	9,0	20,0	54,0	59,7
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	45,0	9,0	20,0	54,0	60,4
				D55	Sak-Hartbees (WC)	45,0	9,0	20,0	54,0	60,4
		D4	Molopo	D42	Nossob-Molo (NC)	42,0	8,4	20,0	50,4	57,3
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	42,6	8,5	20,0	51,1	55,2
				D73	Neusberg (NC)	38,5	7,7	20,0	46,2	49,7
				D81, D82	Vioolsdrift (NC)	45,0	9,0	20,0	54,0	59,4
				D82	AlexanderBay (NC)	45,0	9,0	20,0	54,0	58,1
	TOTAL IN NORTHERN CAPE PROVINCE					43,8	8,8	20,0	52,6	58,4
	TOTAL IN WESTERN CAPE PROVINCE					45,0	9,0	20,0	54,0	60,4
	TOTAL IN PRIMARY CATCHMENTS C + D					44,0	8,8	20,0	52,8	58,7
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	45,0	9,0	20,0	54,0	60,8
				F50	Coastal (WC)	45,0	9,0	20,0	54,0	60,8
	TOTAL IN NORTHERN CAPE PROVINCE					45,0	9,0	20,0	54,0	60,8
	TOTAL IN WESTERN CAPE PROVINCE					45,0	9,0	20,0	54,0	60,8
	TOTAL IN PRIMARY CATCHMENT F					45,0	9,0	20,0	54,0	60,8
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						43,8	8,8	20,0	52,6	58,4
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						29,6	5,9	20,0	35,5	39,7
TOTAL IN LOWER ORANGE WMA						**44,0**	**8,8**	**20,0**	**52,8**	**58,7**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	28,3	5,7	20,0	33,9	38,7
TOTAL IN REPORTING AREA						**36,3**	**7,3**	**20,0**	**43,5**	**48,8**

* A factor of 20% for distribution losses has been included uniformly across all the drainage areas for modelling purposes (WSAM).

Table 5.3.3.2: Rural Water Requirements by Drainage Area in 1995

Catchment						Rural Water Requirements							Return Flows	
Primary		Secondary		Tertiary (Drainage Area)		Domestic	Subsitence Irrigation	Livestock & Game	Losses		Total	Total At 1:50 Yr Assurance	Normal	Total At 1:50 Yr Assurance
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(%)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,16	0,02	2,49	0,67	20,0	3,33	3,62	0,00	0,00
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,20	0,02	3,73	0,99	20,0	4,95	5,42	0,00	0,00
				D55	Sak-Hartbees (WC)	0,00	0,00	0,08	0,02	20,0	0,10	0,11	0,00	0,00
		D4	Molopo	D42	Nossob-Molo (NC)	0,08	0,01	1,14	0,41	20,0	1,64	1,81	0,00	0,00
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,16	0,01	1,08	0,28	20,0	1,53	1,63	0,00	0,00
				D73	Neusberg (NC)	0,74	0,10	0,70	0,69	20,0	2,23	2,36	0,00	0,00
				D81, D82	Vioolsdrift (NC)	0,20	0,02	0,99	0,30	20,0	1,52	1,63	0,00	0,00
				D82	AlexanderBay (NC)	0,03	0,00	0,19	0,06	20,0	0,28	0,30	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					1,56	0,18	10,33	3,41	20,0	15,48	16,77	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,00	0,00	0,08	0,02	20,0	0,10	0,11	0,00	0,00
	TOTAL IN PRIMARY CATCHMENTS C + D					1,56	0,18	10,40	3,43	20,0	15,58	16,88	0,00	0,00
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,15	0,01	1,16	0,33	20,0	1,65	1,82	0,00	0,00
				F50	Coastal (WC)	0,01	0,00	0,06	0,02	20,0	0,09	0,10	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					0,15	0,01	1,16	0,33	20,0	1,65	1,82	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,01	0,00	0,06	0,02	20,0	0,09	0,10	0,00	0,00
	TOTAL IN PRIMARY CATCHMENT F					0,16	0,01	1,22	0,35	20,0	1,74	1,92	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						1,71	0,20	11,49	3,74	20,0	17,13	18,59	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,01	0,00	0,14	0,05	20,0	0,19	0,21	0,00	0,00
TOTAL IN LOWER ORANGE WMA						**1,72**	**0,20**	**11,60**	**3,70**	**20,0**	**17,32**	**18,80**	**0,00**	**0,00**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	0,57	0,07	14,16	4,83	20,0	19,63	21,62	0,00	0,00
TOTAL IN REPORTING AREA						**2,29**	**0,27**	**25,83**	**8,62**	**20,0**	**36,95**	**40,42**	**0,00**	**0,00**

Water Losses

Rural water in the WMA is generally sourced from groundwater via hand pumps, wells or the like. As a result there is very little infrastructure. Spillage during container filling and taps not closed properly are generally the most common scenario. Losses of 20% have been assumed to occur throughout the WMA.

Return Flows

The return flow generated by rural consumers is minimal due to their low water usage. Zero return flows have been accepted for the LOWMA.

5.4 BULK WATER USE

5.4.1 Introduction

This section addresses industries, mines and thermal powerstations, which have their own bulk water supply or receive their supply from water boards or DWAF. Industries and other bulk users receiving water from a municipality are addressed in Section 5.3.2 as part of the urban requirement. The bulk water users are subdivided into three categories: strategic, mining, and other.

5.4.2 Strategic

There are no strategic water users in the Lower Orange Water Management Area (LOWMA).

5.4.3 Mining

The mining activities in the Lower Orange Water Management Area (LOWMA) have greatly reduced over the past decade. The drainage areas affected by mining are Vioolsdrift (Aggeneys and Pofadder area), Alexander Bay (Alexcor) and Coastal (Okiep/Nababeep, Kleinsee, Hondeklipbaai, and the coastal belt). **Table 5.4.3.1** indicates the mining water requirements for the various drainage areas. The return flows are listed as zero as they are not fed back into the river system. Losses are assumed to be 10%.

The reader’s attention is drawn to the fact that the Okiep Copper Company is likely to be down-scaling its mining operations in the very near future with the associated effect on the water requirement. The proposed mine at Ghaamsberg (Aggeneys), for which a water allocation has been long standing but never used, and the current developments for the Scorpion Mine in southern Namibia, may well influence the future water requirements of mines supplied from the Orange River.

Table 5.4.3.1: Water Requirements of Mines

Catchment						Mining Water Requirements					Return Flows	
Primary		Secondary		Tertiary (Drainage Area)		Mining On-Site	Losses		Total	Total At 1:50 Yr Assurance	Total	Total At 1:50 Yr Assurance
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(%)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
				D55	Sak-Hartbees (WC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
		D4	Molopo	D42	Nossob-Molo (NC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
				D73	Neusberg (NC)	0,00	0,00	10,0	0,00	0,00	0,00	0,00
				D81, D82	Vioolsdrift (NC)	3,00	0,30	10,0	3,30	3,52	0,00	0,00
				D82	AlexanderBay (NC)	3,00	0,30	10,0	3,30	3,43	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					6,00	0,60	10,0	6,60	6,95	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,00	0,00	10,0	0,00	0,00	0,00	0,00
	TOTAL IN PRIMARY CATCHMENTS C + D					6,00	0,60	10,0	6,60	6,95	0,00	0,00
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	1,76	0,18	10,0	1,93	2,05	0,00	0,00
				F50	Coastal (WC)	0,09	0,01	10,0	0,10	0,11	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					1,76	0,18	10,0	1,93	2,05	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,09	0,01	10,0	0,10	0,11	0,00	0,00
	TOTAL IN PRIMARY CATCHMENT F					1,85	0,19	10,0	2,04	2,16	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						7,76	0,78	10,0	8,53	9,00	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,09	0,01	10,0	0,10	0,11	0,00	0,00
TOTAL IN LOWER ORANGE WMA						**7,85**	**0,79**	**10,0**	**8,64**	**9,11**	**0,00**	**0,00**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	9,20	0,92	10,0	10,12	10,51	0,00	0,00
TOTAL IN REPORTING AREA						**17,05**	**1,71**	**10,0**	**18,76**	**19,61**	**0,00**	**0,00**

* A factor of 10% for water losses has been included uniformily, across all the drainage areas for modelling purposes (WSAM). It is possible that the small mines abstracting water directly from the river systems may already have included such losses in their annual requirements.

5.4.4 Other Bulk Users

There are no other bulk water users in the Lower Orange Water Management Area (LOWMA).

5.5 NEIGHBOURING STATES

The water requirements of the neighbouring states was very difficult to quantify because of the nature of the study (desktop) and the time constraints imposed. It was decided to address their requirements based on the same user sectors considered for the South African scenario. Only the neighbouring state catchment areas adjacent to the Nossob, Molopo and Orange Rivers were considered. The information was applied under the various water requirement sections as a separate region. The approach adopted was a very simplified one, whereby the land-use of the neighbouring state catchment was determined on a pro rata basis in relation to the land-use and surface area of the corresponding South African quaternary catchment. A water requirement was then determined using the same principles as that for the South African catchments. Better information was used as and where available.

5.6 IRRIGATION

5.6.1 General

Comprehensive detailed observed data on water use for irrigation is not generally available. In the Lower Orange Water Management Area (LOWMA), it was decided that irrigation water requirements along the Orange River be determined using the same methods as the Orange River Development Replanning Study (BKS, 1997a and BKS, 1997b). The latter study used scheduled areas and quotas, rather than theoretical crop requirements, due to the legal nature of the allocations. Scheduled areas along the Orange River were obtained from the ORRS. (BKS, 1997a) and updated in accordance with “Orange River System 1999/2000 Operating Analysis” (BKS, 2000). The update incorporated areas previously excluded from the ORRS due to mismatched information from different information sources. The crop distributions presented in the ORRS cannot be applied directly in this study as they are not compatible with the updated scheduled areas. In addition, scheduled areas and quotas are independant of farming practicies such as double cropping, and therefore do not relate directly to crop distributions.

The SAPWAT crop factors used in this study were therefore adjusted so that the resultant field requirement (excluding conveyance losses) was equal to the quota independant of crop distribution or farming practices. Other information such as irrigation efficiency and conveyance losses, was taken from the ORRS Report “Water Demands of the Orange River Basin” (BKS, 1997b). These factors are not reflected in the quota, which is regarded as the total (gross) irrigation requirement including all losses except for conveyance losses on major canal systems. Estimates of irrigation efficiency were captured for the purpose of estimating irrigation return flows.

Information for Namibia was obtained from “Hydrology of the Fish River Catchment” (BKS, 1991), and the ORRS Report “Water Demands of the Orange River Basin” (BKS, 1997b). The latter was, in turn, based on "Namibian Water Requirements from the Orange River" (DWA Namibia, 1995).

In parts of the LOWMA remote from the Orange River, very little information on irrigation exists. WR90 (Midgeley, et al, 1994, Volume III, Appendix 8) was used as a basis in these areas, assuming lucerne as the dominant crop for animal feeds, and also being conservative in terms of water requirement relative to undifferentiated crops.

5.6.2 Water Use Patterns

Moving from east to west across the WMA, there is a general increase in evaporation and decrease in rainfall, with consequent increases in unit irrigation requirements. The Quota ranges from 914 mm/a in C92C to 1 000 mm/a in D71 and D72, and 1 500 mm/a from D73 to D82. A quota of 2 000 mm/a was used for Namibian quaternaries, as quoted in the reports from which the information on irrigation was extracted (see Section 5.6.1). **Table 5.6.2.1** and **Figure 5.6.1** detail the 1995 irrigation water requirements.

Most of the irrigation in the WMA is supplied from the Orange River, with releases made from Van der Kloof Dam specifically for this purpose. This includes C92C, which is supplied with Orange River water via the Orange-Vaal Canal near Douglas. The only exceptions include irrigation in the Fish River Catchment (Z20A) supplied mainly from Hardap Dam, plus small amounts of irrigation in the Sutherland region supplied from small dams and groundwater. Small amounts of opportunistic irrigation using rainfall harvesting also takes place in the catchments away from the Orange River, but these have not been quantified due to inadequate information. It is hoped that the licensing process currently underway will improve information on these areas in the near future.

The vast size of the WMA relative to the amount of irrigation makes policing of water restrictions extremely difficult. Releases from Van der Kloof Dam flow approximately 1 400 km before reaching the river mouth, without any significant storage along the route. Shortages occurring due to over-abstraction during drought periods could therefore have a disastrous impact on the users and environment at the river mouth, as increased releases from Van der Kloof Dam could take up to eight weeks to relieve shortages at the river mouth. These factors make implementing restrictions very difficult, and further consideration should be given to the assurances at which irrigation requirements are modelled/supplied.

The DWAF Regional office at Kimberley is involved in a registration process which will provide updated information on the report's base data of 1995. This data should be addressed in any further work related to the LOWMA water use patterns.

5.6.3 Water Losses

There are two types of water losses associated with irrigation, namely conveyance losses to field edge, and losses due to inefficiencies in the application of water to the field. The former can be further broken down into conveyance losses from major communal canals, and on-farm distribution losses from rivers or communal canals to field edge.

Both on-farm distribution losses and application inefficiencies are allowed for within the quota. Only losses from major communal canals were therefore considered in this study, as indicated in **Table 5.6.2.1.** Losses from the Orange River between Van der Kloof Dam and the point of irrigation abstraction are discussed under Section 5.8 on "Water Losses From Rivers, Wetlands and Dams".

Table 5.6.2.1: Irrigation Water Requirements

Catchment						Irrigation Water Requirements							Return Flows	
Primary		Secondary		Tertiary (Drainage Area)		Field Edge Requirement	Canal Losses*		On Farm Distribution Losses **		Total Water Requirement	Total At 1:50 Yr Assurance	Total	Total At 1:50 Yr Assurance
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(%)	(10^6 m³/a)	(%)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	16,67	0,00	0,0	0,00	0,0	16,67	11,41	0,00	0,00
				D55	Sak-Hartbees (WC)	0,34	0,00	0,0	0,00	0,0	0,34	0,23	0,00	0,00
		D4	Molopo	D42	Nossob-Molo (NC)	0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	224,70	15,50	6,9	0,00	0,0	240,20	199,20	24,02	19,92
				D73	Neusberg (NC)	380,78	57,12	15,0	0,00	0,0	437,90	383,20	43,79	38,32
				D81, D82	Vioolsdrift (NC)	174,85	9,45	5,4	0,00	0,0	184,30	162,00	18,43	16,20
				D82	AlexanderBay (NC)	20,66	1,36	6,6	0,00	0,0	22,02	18,46	2,20	1,85
	TOTAL IN NORTHERN CAPE PROVINCE					817,66	83,43	9,1	0,00	0,0	901,09	774,27	88,44	76,29
	TOTAL IN WESTERN CAPE PROVINCE					0,34	0,00	0,0	0,00	0,0	0,34	0,23	0,00	0,00
	TOTAL IN PRIMARY CATCHMENTS C + D					818,00	83,43	9,1	0,00	0,0	901,43	774,50	88,44	76,29
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
				F50	Coastal (WC)	0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
	TOTAL IN WESTERN CAPE PROVINCE					0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
	TOTAL IN PRIMARY CATCHMENT F					0,00	0,00	0,0	0,00	0,0	0,00	0,00	0,00	0,00
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						817,66	83,43	9,1	0,00	0,0	901,09	774,27	88,44	76,29
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,34	0,00	0,0	0,00	0,0	0,34	0,23	0,00	0,00
TOTAL IN LOWER ORANGE WMA						**818,00**	**83,43**	**9,1**	**0,00**	**0,0**	**901,40**	**774,50**	**88,44**	**76,29**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	80,98	7,30	9,0	0,00	0,0	88,28	68,11	8,83	6,81
TOTAL IN REPORTING AREA						**898,98**	**90,73**	**9,1**	**0,00**	**0,0**	**989,70**	**842,60**	**97,27**	**83,1**

* Canal losses for major canal schemes only.

** On farm distribution losses assumed to be included in the quota for this study.

5.6.4 Return Flows

Return flows are those portions of abstracted water not taken up by the crop which return to the river and are available for use downstream. Return flows as a result of irrigation can be broken down primarily into two components, namely return flow due to leaching beyond the root zone, and additional return flow due to increased runoff.

Leaching water stems from applied irrigation water not used by the plant, and is returned to the groundwater or streams due to leaching and is largely dependant on the soil characteristics and water quality. This may also include a small portion of the conveyance losses which seep back to the river.

Additional return flow due to the increased rainfall runoff can result from the higher level of soil moisture when compared with the natural state. This quantity is however not quoted here. In any event, the rainfall is so low over most of the WMA that this contribution can safely be regarded as negligible.

Return flows were assumed to equal 10% of the 1:50 year irrigation requirement along the Orange River, and 0% in areas remote from the Orange River where any return flows are unlikely to become available for re-use. This assumption is coarse, as it does not make adjustment for return flows from conveyance losses or different irrigation efficiencies. The total return flows are presented in **Table 5.6.2.1**. The constituent parts are not given.

5.7 DRY LAND AGRICULTURE

Dryland agriculture is generally used to refer to dryland sugarcane, although other types can also occur.

However, in the Lower Orange Water Management Area, some low assurance opportunistic irrigation does take place using rainfall harvesting. While the runoff is already sporadic, these practices do impact on stream flow and could therefore be regarded as stream flow reduction processes. Furthermore, dryland (winter) wheat is planted in the Kamieskroon area. Due to the lack of information, these areas have not been presented here. The licensing process underway may provide such information in the future.

There is no dryland sugarcane production in the LOWMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

5.8.1 Rivers and Wetlands

Estimates of evaporative losses from river channels are given in WR90 (Mideley et al, 1994). Generally, it is advisable to use these values since they were used in calibrating the runoff from the surrounding regions. However, in the case of the lower Orange River, incremental runoff is low and sporadic, and small relative to evaporation losses in the Orange River. As a result, adjustments can be made to river loss estimates without significant adverse effects on the calibration of incremental runoff. Loss estimates were therefore based on information presented in the report “Evaporation Losses from South African Rivers” (BKS, 1999). The surface area of the river, and therefore also the evaporative losses, vary with flow in the river. The loss estimates captured represent the losses when releases from Van der Kloof Dam average approximately 50 m^3/s over the year. Finer adjustments to represent average annual or 1:50 year drought conditions at 1995 development levels have not been made. The river loss estimates captured also include an allowance for evapotranspiration from reeds and trees alongside the river. This could potentially represent double-accounting with respect to alien vegetation. However, detailed information on the distribution of the alien vegetation data between riparian and non-riparian zones is not available. It was therefore decided to retain the evapotranspiration losses in the river loss data, in order to be conservative, until improved information becomes available. Double accounting of river losses could also occur at Boegoeberg and Neusberg which have surface areas despite being in the river, and which therefore needs to be clarified. This is however, not a large portion of the estimated losses.

WR90 indicates wetland losses to the total of 27 million m^3/a in the Brandvlei area (D53F, D57C,D). It is estimated that there are no surpluses available from 1:50 year runoff river yield in these quaternary catchments, including the runoff from upstream catchments. These losses have therefore not been included into the database.

Another issue, although not directly related to river losses, is the operational losses incurred while supplying users with water over the 1 400 km of the Orange River below Van der Kloof Dam. Due to the length and associated lag times (four to eight weeks), it is almost impossible to release the amount needed for users downstream without some wastage. Currently an estimate of 10% of hydropower releases has been assumed lost to operational losses, which is excluded from figures in **Table 5.8.1**, which gives details of the other losses.

5.8.2 Dams

Evaporation losses from a reservoir surface depends on net evaporation rates and the surface area exposed. The critical evaporation losses occur during the critical period, which establishes the yield of the system. However, the surface area exposed to evaporation during the critical period may depend on many factors, especially operating rules and storage relative to inflows. Adjustments were therefore made to the proportion of full supply area exposed to evaporation over the critical period, based on the gross yield at major dam locations before the evaporation took place. This adjustment represents a very poor estimate, and can significantly influence the yield available from dams in these arid areas.

Table 5.8.1: Water Losses From Rivers, Wetlands and Dams

Catchment						Losses From Rivers And Wetlands*	Evaporation From Dams**	Total
Primary		Secondary		Tertiary (Drainage Area)				
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,0	22,1	22,1
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,0	29,1	29,1
				D55	Sak-Hartbees (WC)	0,0	0,6	0,6
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	0,1	0,1
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	119,3	8,8	128,1
				D73	Neusberg (NC)	131,0	1,5	132,5
				D81, D82	Vioolsdrift (NC)	163,0	0,0	163,0
				D82	AlexanderBay (NC)	114,0	0,0	114,0
	TOTAL IN NORTHERN CAPE PROVINCE					527,3	61,6	588,9
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,6	0,6
	TOTAL IN PRIMARY CATCHMENTS C + D					527,3	62,2	589,5
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0	0,0	0,0
				F50	Coastal (WC)	0,0	0,0	0,0
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0
	TOTAL IN PRIMARY CATCHMENT F					0,0	0,0	0,0
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						527,3	***61,6	588,9
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,0	***0,6	0,6
TOTAL IN LOWER ORANGE WMA						**527,3**	**62,2**	**589,5**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	0,0	62,6	62,6
TOTAL IN REPORTING AREA						**527,3**	**124,8**	**652,1**

* Excludes operational losses.
** Reservoir trajectories over critical period not available – these figures represent poor estimates.
*** The provincial apportionment of Modderpoort Dam in D55A, and the minor dams in D55D, are approximate.

5.9 AFFORESTATION

There is no forestry in the Lower Orange Water Management Area (LOWMA).

5.10 HYDROPOWER

There is no hydropower in the Lower Orange Water Management Area (LOWMA). Hydropower releases from Van der Kloof Dam in the Upper Orange WMA are used for peak power generation in the mornings and evenings. This causes uneven flow patterns in the Orange River. This factor, aggravated by the high sediment load in the river, makes river abstractions very difficult for riparian farmers. These impacts need to be managed, and possible remedial measures investigated. The interaction between hydropower releases and the ecological Reserve in the middle and lower Orange River also requires further investigation and careful management by DWAF and Eskom.

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). See **Figure 5.11.1.**

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 the Water Situation Assessment Model (WSAM) using the above assumptions. The impact of this reduction in runoff on catchment yield was determined in the same manner as for afforestation.

The following paragraphs from the afforestation section are included under alien vegetation as it was deemed superfluous in the afforestation section.

The water use by commercial afforestation is based on the so-called CSIR curves (CSIR, 1995) which have replaced the so-called Van der Zel curves that were used for the preparation of WR90 (Midgley, et al., 1994). The Van der Zel curves were considered to be too simplistic compared to the CSIR curves, which now take the species, age and site conditions into account in estimating the stream flow reductions. A study was undertaken (Ninham Shand, 1999) to provide adjusted naturalised flow sequences for the Water Situation Assessment Model (WSAM) (Department of Water Affairs and Forestry, 2000) based on the WR90 naturalised flow data. This now enables the CSIR curve-based stream flow reduction estimates to be used in the WSAM and these reduction estimates have been used in the WRSA reports. Details of the method of estimating the reduction in runoff by or water use of commercial afforestation are described in CSIR (1995).

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

The impact of alien vegetation on water resources is difficult to assess because of the lack of available information. A recent survey indicated that 16,56% of the Mean Annual Runoff in the Northern Cape Province is used by alien plants (Versveld *et al*, 1998).

The most important alien invader in the Northern Cape is Mesquite (*Prosopis spp.*), which has invaded about 1,8 million ha (equivalent condensed area 173 150 ha), most of which is situated along river courses *(Le Maitre, 1999)*. A review of the ecology and impacts of these trees shows that they are capable of developing extensive and deep root systems that can easily reach water tables at depths of 10-15 m and more *(Le Maitre, 1999)*. Their roots are generally longer than indigenous plant species, with a maximum recorded depth of 53 m *(Le Maitre, 1999)*. Water use per tree ranges from 1 to 108 litres per day during the growing season *(Le Maitre 1999)*. The main concentrations of this tree are in the Sak River system and the Van Wyksvlei and Britstown-De Aar area (D54, D57) and the Nossob, Auob and Molopo area (D42).

The total volume of water used by Mesquite in the country as a whole is estimated to be 192 million m^3 per year (Le Maitre, 1999). Catchment-scale studies have shown that clearing *Prosopis* can increase runoff in vegetation types where grass and herb cover does not increase and use all, or even more water 'released' by clearing. This is the case in most areas invaded by *Prosopis* in South Africa because the vegetation is mainly Karoo shrubland or sparse grassland. Groundwater recharge in these areas is roughly 8 mm-30 mm per year (4% of mean annual rainfall), so the probable water use rates are not sustainable *(Le Maitre, 1999)*. However, in areas where communities depend on groundwater, clearing of *Prosopis* in targeted areas is likely to significantly alleviate water shortages (Le Maitre, CSIR, pers. comm. 1999).

Another species of concern is the exotic Saltcedar, *Tamarix ramosissima*, which has invaded sandy riverbeds in the central, southern and succulent Karoo and the dryer parts of the grassland biome (Henderson 1995, Versfeld *et al*, 1998). This species is able to replace mixed riparian woodland, including *Prosopis pubescens* because it has greater drought tolerance and higher sap fluxes, and may have a greater impact on water resources per unit area than *Prosopis (Le Maitre, 1999)*. Invasions by *Tamarix* are still relatively sparse and limited in extent and could probably be controlled relatively easily. The use of biocontrol will be made more difficult because there is an indigenous species, *Tamarix usneoides*, which could severely limit the biocontrol options. Clearing of *Tramosissima* should be given a high priority to prevent it from becoming a significant problem *(Le Maitre, 1999)*.

Another important invasive plant species in the Northern Cape Province is Wild tobacco, *Nicotina glauca*, which is predicted to colonise all the river systems of the arid west coast and Karoo over the next 20 years (Versveld *et al*, 1998).

There is currently a monitoring programme underway to assess the effect of alien vegetation removal on groundwater in the Kenhardt area.

Table 5.11.1 indicates the water use by alien vegetation per drainage area.

Table 5.11.1: Water Use by Alien Vegetation in 1995

Catchment						Reduction In Runoff		Reduction In Yield
Primary		Secondary		Tertiary (Drainage Area)				
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(mm/a*)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	1,44	18,9	0,60
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	10,99	16,6	3,67
				D55	Sak-Hartbees (WC)	0,22	16,6	0,07
		D4	Molopo	D42	Nossob-Molo (NC)	0,45	2,0	0,00
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	2,48	15,4	0,00
				D73	Neusberg (NC)	0,13	15,3	0,05
				D81, D82	Vioolsdrift (NC)	0,29	6,4	0,00
				D82	AlexanderBay (NC)	0,00	6,0	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					15,78	12,7	4,33
	TOTAL IN WESTERN CAPE PROVINCE					0,22	16,6	0,07
	TOTAL IN PRIMARY CATCHMENTS C + D					16,00	12,7	4,40
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,88	6,4	0,02
				F50	Coastal (WC)	0,05	6,4	0,00
	TOTAL IN NORTHERN CAPE PROVINCE					0,88	6,4	0,02
	TOTAL IN WESTERN CAPE PROVINCE					0,05	6,4	0,00
	TOTAL IN PRIMARY CATCHMENT F					0,92	6,4	0,02
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						16,66	19,1	4,35
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,27	23	0,07
TOTAL IN LOWER ORANGE WMA						**16,93**	**42,1**	**4,42**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	3,29	10,3	0,00
TOTAL IN REPORTING AREA						**20,22**	**52,4**	**4,42**

* mm/a is quoted as equivalent unit runoff reduction after reducing consumption in the non-riparian zone (assumed 90%) to maximum of unit runoff. This differs from the input value of runoff reduction, as well as from the effective reduction in yield.

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 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 water 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 57% of total water use in the Lower Orange Water Management Area. Irrigation losses are often quite significant and it is estimated that often no more than 60% 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

Forestry accounts for an estimated 0% of total water use in the Lower Orange Water Management Area.

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 water 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 water 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 (bylaws). 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 water 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. Alien plants also use more water than indigenous plants, thereby reducing available runoff. The campaign also provides 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-1980s 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 and Water Demand Management in the Lower Orange Water Management Area

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

The Water Services Strategy in the Northern Cape Province has previously identified key issues to be addressed in terms of a water services awareness programme. The aim of the programme is to inform the communities on water conservation and matters such as rainfall harvesting, as well as awareness of polluting the groundwater resources through inadequate sanitation.

The per capita consumption in the rural areas is very low, due to the nature of the service (boreholes and hand pumps), and it is unlikley that there is much scope for decreasing the per capita demand.

Water conservation and water demand management and better maintenance of existing systems in the urban areas will provide scope for a reduced demand.

A pilot project in water conservation and water demand management is currently underway as part of the establishment of the Orange/Vaal water user association in the Douglas area.

Best Practice Management Guidelines and Water Conservation and Water Management Strategy content is included in comments on environmental management practice reports from the mines as well as individual water license applications.

The strategy is also included as part of the WINTECH research project looking at water generation and treatment of cellars.

5.13 WATER ALLOCATIONS

5.13.1 Introduction

Numerous allocations to use water were made in terms of the Water Act, 1956 (Act No 54 of 1956) and Special Water Acts. These Acts also regulated other water related matters. The Water Act of 1956 and the Special Acts were all repealed between 1 October 1998 and 1 October 1999 by the National Water Act, 1998 (Act No 36 of 1998). Water usage that has taken place lawfully at any time between 1 October 1996 and 30 September 1998 has been regarded as existing lawful use for the purposes of the National Water Act of 1998. Such usage will have certain preferences and protection when water is allocated in terms of the National Water Act of 1998.

This part of the report focuses on the Water Act of 1956 and the Special Acts as these Acts were the appropriate Acts regulating water use during 1995, the study base date.

The purpose of this part of the report is twofold:

- Firstly, it sets out certain relevant provisions of the Water Act of 1956 and the relevant Special Water Acts. This is needed to put the second purpose in perspective and to understand the framework under which the exercised rights will be regarded by existing lawful users.

- Secondly, it records the quantity of water allocated in terms of the Water Act of 1956 and the Special Water Acts.

Only relevant, readily available information was used to record the quantity of water that had been allocated. This was compared with the estimated requirements and available water resources as follows:

- Conversations and written communications were held with other team members and officials of DWAF to determine the scope and locations of the different water usages.

- The information obtained from questionnaires sent out for the purpose of the study were analysed to determine by whom and the manner in which water was used.

- Notices issued due to the declaration of Government Water Control Areas, as well as permits and scheduled lists were reviewed to quantify the different water uses.

- Telephonic conversations were held with water users to obtain further information, as well as to verify information obtained.

5.13.2 Allocations and Permits Issued under the old Water Act

As far as the Lower Orange Water Management Area (LOWMA) is concerned, all the water usage from the Orange River is quantified in legal documents. There is however minimal quantification of water usage from sources other than the Orange River. In spite thereof, it is still necessary to set out the relevant provisions of the repealed Acts to understand why this is so.

Relevant provisions of the Water Act of 1956

The Water Act of 1956, as amended, regulated *inter alia* the control, conservation and use of water for domestic, agricultural, urban and industrial purposes. The Irrigation and Conservation of Waters Act, 1912 (Act No 8 of 1912) was repealed by the Water Act of 1956, when that Act became inadequate to cope with social needs and industrial progress of the Union of South Africa, during the earlier part of the 20th century.

Most of the principles of the Irrigation and Conservation of Waters Act of 1912 were re-enacted in the Water Act of 1956. However, the State received greater power over the rights to use water, the industrial use of water was given a more rightful place and structures were created enabling non-riparian landowners to obtain rights to use water. (Before that a Special Water Act by parliament was needed if a non-riparian user (also including municipalities) wanted access to water. This lead to the promulgation of various Special Water Acts allowing non-riparian users access to water.)

Determination and Granting of Rights for Water Use

The provision of the Water Act of 1956, dealing with the determination and granting of rights to use water were based on the following two principles:

- The first is a distinction between two categories of water, namely private and public water. In addition, public water consists of normal flow and/or surplus water. The determination and granting of rights to use water from each category are different.
- The second is that the determination and granting of water rights to use water differ for areas declared as Government Water Control Areas and those not declared as such.

a) Public Water

Public water is water flowing in a river. The water must be sufficient for common use for irrigation on two or more pieces of land, which are the subjects of separate original grants riparian to the river.

Normal flow is the water which actually and visibly flows in the river. It must be possible to use the water beneficially for irrigation without the aid of storage. Water that is not normal flow, is surplus water.

i) Areas Not Declared as Government Water Control Areas

In areas not declared as Government Water Control Areas, the owners of riparian land are entitled to use public water as follows:

- As far as normal flow is concerned, the water is divided between the different pieces of land and may only be used for agriculture and urban purposes. The Water Court has jurisdiction on how to divide the water in the case of a dispute between the different owners. The Water Court takes into consideration amongst others the irrigable area on each piece of land and the quantity of water available (the normal flow) when erven's quota is determined.

- As far as surplus water is concerned, every owner is entitled to use as much of the surplus water that may be beneficially used for domestic purposes, stock watering and agricultural (irrigation). The owner is not compelled to share water with other owners, except when a downstream owner is entitled to the water in terms of an agreement. Upstream owners may therefore use surplus water in preference to downstream owners.

A person may obtain the right to use public water on non-riparian land or use more water on riparian land than one is entitled to. There are two scenarios:

- The first is where all the water is not used on land riparian to the stream, for example in the case where all the riparian owners have not developed their land for irrigation purposes or if there is more water available than could be used on the riparian land. The Water Court may then allow a person permanently or temporarily to abstract that water for agricultural, industrial or urban purposes.

- The second is where the granting of permission to reduce the rights of other persons is in the public interest. The Water Court may then allow a person to abstract a specified quantity of water for any purpose.

A municipality owning land has the same rights to public water as other persons. It may not, however, claim the benefit of land belonging to its inhabitants for purpose of claiming water rights. If an owner of land in the area of jurisdiction of a municipality is entitled to use public water and the municipality needs that water, the municipality may use the water with the consent of the province concerned and DWAF. The municipality has to pay the owner compensation as agreed upon or, failing such an agreement, as determined by the Water Court.

A permit from DWAF in terms of Section 9B(1) or 13(3) is needed for the construction of waterworks to store or abstract public water (normal flow and/or surplus water) if the total capacity or rate of all the waterworks on a piece of land exceeds:

- In the case of a municipality, 125 000 m^3 storage or 5 000 m^3/day processing.

- In other cases, 250 000 m^3 storage or 110 ℓ/s processing. This storage capacity or rate may be amended to cater for specific hydrological conditions.

Protection orders issued in terms of Sections 35 and 36 of the repealed Irrigation and Conservation of Waters Act of 1912 to protect surplus water (not normal flow) remain in force. No person may construct a waterworks with a storage capacity in excess of

114 000 m³ or an abstraction rate in excess of 300 ℓ/s except with the permission of the Water Court.

ii) Areas Declared as Government Water Control Areas

Under certain circumstances it may be necessary to allocate rights to public water in a specific area differently from the above principles. For that reason the Minister of Water Affairs and Forestry may by notice in the *Government Gazette* declare an area a Government Water Control Area. This can be done for the following two reasons:

- Unregulated surface water: An area may be declared a Government Water Control Area if the abstraction, utilisation, supply or distribution of the public water must be controlled in the public interest. The area may include non-riparian land. In this case, water for irrigation is not supplied from a government waterworks. If such a waterworks is constructed, then water is usually not supplied or reserved for irrigation from the works. The right to the use and control of water in all the public streams in the area vest, in terms of Section 62, in the Minister. No person may abstract, impound or store any quantity of the public water or use it inside or outside the area except by virtue of a provisional right, a permission (there are three types) or an allocation.

- Regulated surface water: An area may be declared a Government Water Control Area if a government waterworks (constructed) affects the land. In this case, water may be supplied from the government waterworks in terms of Section 56(3) for any purpose approved by the Minister or in terms of Section 63 for irrigation. The water may be supplied and distributed by way of canals or by way of releases into a river.

The rights to the use of private water are not affected in a Government Water Control Area.

b) Private Water

i) Areas Not Declared Subterranean Government Water Control Areas

With some exceptions, the sole and exclusive use and enjoyment of private water vests in the owner of the land on which the water was found. Downstream owners' and other persons' needs do not have to be taken into consideration.

A person may only sell, give or otherwise dispose of private water to another person or convey private water across a property boundary if authorised by the Minister.

A person needs no permission to construct, alter or enlarge a waterworks to exercise these rights, except if it is restricted by for example an agreement.

ii) *Areas Declared Subterranean Government Water Control Areas*

Under certain circumstances it may be necessary to allocate rights to private water in a specific area differently from the above principles. For that reason the Minister may by notice in the *Gazette* declare an area a subterranean Government Water Control Area. This may only be done if it is desirable in the public interest that the abstraction, use, supply or distribution of subterranean water should be controlled. The right to the use and the control of subterranean water in the area vests, in terms of section 29, in the Minister. No person is allowed to abstract any quantity of subterranean water and use it inside or outside the area except by virtue of the acknowledgement of existing use, a permission or an allocation.

Irrigation Boards

An irrigation district may be constituted for a specific area. For each irrigation district there is an irrigation board, which is a body corporate. The Minister could assign various functions to the board, including among others the protection of the water, exercising supervision over the public streams, regulating the flow in the streams and the supervision and regulation of water distribution and its use.

Each irrigation board must compile a schedule of rateable areas setting out among others the area that might be irrigated from the public streams under the jurisdiction of the irrigation board. If the irrigation board's area of jurisdiction falls within a Government Water Control Area, then the schedule of rateable areas may not exceed the allocations made for the Government Water Control Area.

Irrigation boards will be transformed to Water User Associations (WUA) in terms of the National Water Act of 1998. Some boards have done that already.

Effluent Disposal

A person using private or public water for industrial purposes must purify or treat the water and effluent produced so that it complies with a prescribed standard. Industrial use includes the use of water for a sewerage system or water care works. Once correctly purified (or treated), the water and effluent must be discharged into the public stream at the place were the water was abstracted or at another place as the Minister may indicate.

A person may be exempted from the above based on certain conditions as specified by the Minister.

5.13.3 Water Control Areas in the Water Management Area

Many of the water law principles developed during the 19th century by the Water Courts have their roots in the Lower Orange Water Management Area (LOWMA). The criteria that a stream need not be perennial to be classified as a public stream was for example accepted in the case *Van Heerden versus Wiese* of 1880, a Water Court case dealing with the water of the Ongers River.

The Status of the Water Resources

The Orange River together with many of its tributaries like the Ongers, Hartbeest, Sak, Riet, Rhenostervlei, Sout and Fish Rivers in the Northern Cape Province and Namibia are public streams. Except for the Orange River, these streams are for most of their reaches not perennial, with the resulting comment that these rivers contain no normal flow for those particular reaches. This may not be entirely correct, as some of the non-perennial water may be normal flow from downpours but partly diverted directly onto arable land, soaking the land so that it is possible to reap a harvest without any further wetting of the soil. The water so diverted is used under a system of direct irrigation from the streams without the aid of storage, this being the requirement for water to be classified as normal flow.

The smaller streams within the Lower Orange Water Management Area (LOWMA) are predominantly construed as private water. The groundwater is private water.

Government Water Control Areas

The whole area consisting of the riparian land along the South African side of the Orange River within the Lower Orange Water Management Area (LOWMA) was divided into three Government Water Control Areas in 1997 : the Orange River (Namakwaland), the Lower Orange River and the Middle Orange River Government Water Control Areas. The area was so declared due to the impact of the government waterworks in the Orange River, namely the Gariep and Van der Kloof Dams. Water is supplied from these two dams in terms of Section 56(3) for various uses such as household, urban, stock watering and industrial purposes. Irrigation water is provided in terms of Section 63. The water is supplied and distributed by way of releases into the Orange River. Therefore the abstraction of all water out of the Orange River within the LOWMA water management areas is quantified.

Many irrigation boards are exercising control over the abstraction and distribution of irrigation water. From the information obtained, their scheduled lists are exactly the same as for the Government Water Control Area.

There are no other Government Water Control Areas declared in the LOWMA.

Subterranean Government Water Control Area

There are no subterranean Government Water Control Areas declared in the LOWMA.

Abstraction of Water from Rivers other than the Orange River

Water is abstracted from rivers other than the Orange River in the LOWMA. This is mainly for irrigation and stock watering, with hardly any water being abstracted for urban purposes. These rights may be exercised without permission, as a result there is very little documentation available stating the right to use this water. There are however title deeds setting out and regulating the use of the water. The implication of these title deeds was not investigated as it will hardly have any impact on the availability of water in the LOWMA.

Various dams and diversion weirs were constructed in terms of the common law as well as the repealed Irrigation and Conservation of Water Act of 1912, for which no permission was needed. The Smartt Syndicate Dam in the Ongers River is probably the best known example. These dams and diversion weirs are mostly used for irrigation. The implication of such works was not investigated for the purpose of this part of the study as no volume or quantity is contained in any legal document. It is expected that such documentation would prevail should these works be improved, enlarged or repaired.

Protection orders were issued by the Water Court in terms of the Irrigation and Conservation of Waters Act of 1912 to protect the runoff to certain dams, mainly in the Ongers, Sak and Rhenostervlei Rivers. Although no person was allowed to construct waterworks with a storage capacity in excess of 114 000 m³ or an abstraction rate in excess of 300 ℓ/s without the permission of the Water Court, it has apparently happened. Although very important for the protection of the runoff to the different dams, these contraventions will hardly have any impact on the availability of water at the water management area level. DWAF investigated the contravention of protection orders during the late 1970s and early 1980s, but the matter was not resolved. The implication of the protection orders was not investigated as it will hardly have any impact on the availability of water in the Lower Orange Water Management Area (LOWMA). On a local scale, however, these “illegal” structures reduce the amount of water that can be used for irrigation from rainfall using swales.

As of 1975 a permit was required from DWAF for the construction of a dam or diversion weir to store and abstract public water with a capacity exceeding 250 000 m³ or a rate exceeding 110 ℓ/s. Permits were issued mainly to divert some of the flows caused by downpours directly onto the land or into natural vleis or dams for irrigation. These hardly have any impact on the availability of water at a water management area level and were therefore not investigated.

In the case of disputes as far as allocating and distributing the normal flow is concerned, very few cases in the Lower Orange Water Management Area (LOWMA) area have been reported to the Water Court. The decisions of the Water Court are very important at a local level, but have no real impact on the availability of water at a water management area level.

Abstraction of Groundwater

Groundwater is abstracted mainly for stock watering, domestic and urban purposes a small amount is used for irrigation. These rights may be exercised without permission. Very little documentation stating the right to use this water is therefore available. There are title deeds and agreements setting out and regulating the use of the water between individual owners. The implication of these title deeds and agreements was not investigated.

Many of the municipalities buy groundwater from farmers in the neighbourhood. Formal agreements between the municipalities and farmers are concluded, a practice that seems to be followed by all municipalities. The implication of these agreements was not investigated.

A permit is required from DWAF to sell or convey groundwater across a property boundary. Telephone conversations with the different municipalities and DWAF confirmed that permits are issued accordingly.

Irrigation Boards

Appendix C shows the names of all the irrigation boards within the Lower Orange Water Management Area (LOWMA). Many of these boards are currently in the process of being transformed into Water User Assocations.

Effluent Disposal

Water not coming from the Orange River, used for industrial purposes (mainly sewage from municipalities), is purified to a standard and either discharged into oxidation dams or used for irrigation.

Water coming from the Orange River used for industrial purposes (sewage from municipalities and other industrial uses) is purified to a standard and either discharged into oxidation dams or into the Orange River. Except for the bigger municipalities, the implication of these permits was not investigated as it will hardly have any impact on the availability of water in the Lower Orange Water Management Area (LOWMA).

The old Water Act (Water Act 54 of 195) provided a specific type of permit for effluent disposal called an "Exemption". Most of the revised exemptions are for a defined period and have expirey dates. The General Authorisations, as described in the Government Notice (GN 1191 of 8 October 1999), will replace the expired exemptions.

5.13.4 Permits and Other Allocations

The permits and allocations were investigated and practically completed for the then Northern Cape study area, prior to the change in reporting areas to the WMA basis. The Douglas area (C92C) is therefore excluded. There appears to be a discrepancy in the allocated scheduled areas as listed in this section and that obtained from previous reports/studies of the area.

The DWAF Kimberley Office is well advanced in the registration of water users in the Lower Orange Water Management Area (LOWMA) in terms of the National Water Act. The complexity and time requirements to reconcile this discrepancy are immense and it was therefore considered a superfluous task to reconcile the allocated scheduled areas with that from previous reports as the result obtained would most likely not be in agreement with DWAF's new database. This investigation was therefore based on the data from the previous reports/studies.

The water allocations that are quantified in the LOWMA are as follows:

(a) In terms of Section 63 of the Water Act of 1956, scheduling and quotas for irrigation out of a government water schemes are as shown in **Table 5.13.4.1.** See **Appendix C** for more information.

(b) In terms of Section 56(3) of the Water Act of 1956, allocations to water users from government water schemes are as shown in **Table 5.13.4.2**. See **Appendix C** for more information.

Special Water Acts in the Lower Orange Water Management Area (LOWMA)

The Special Water Acts in the Lower Orange Water Management Area (LOWMA) are the following:

- Brandvlei Land and Irrigation Works Act, 1926 (Act No 4 of 1926).
- Van Wyksvlei Settlement Regulation Act, 1970 (Act No 68 of 1970).
- Cannon Island Settlement Management Act, 1939 (Act No 15 of 1939).
- Skanskop Settlement Act, 1947 (Act No 24 of 1947).

a) The Brandvlei Land and Irrigation Works Act of 1926

The Brandvlei Land and Irrigation Works Act of 1926 provided for granting certain Crown land, in the District of Calvinia, to the Village Management Board of Brandvlei.

The responsibility that the State had for the maintenance and repair of the waterworks serving the village of Brandvlei and for the control and distribution of water for domestic and irrigation purposes within the village had been transferred to the Village Management Board of Brandvlei. The waterworks consists of a diversion weir in a river, furrows and storage reservoir.

The Management Board of Brandvlei had the same powers as an Irrigation Board as set out in the Water Act of 1956.

The diversion weir was broken during the floods in 1970 and never repaired. Irrigation has not taken place since then, but due to the good rains of early 2000 water in the river flowed into the diversion furrow and filled the storage reservoir. The different landowners plan to irrigate with this water.

b) The Vanwyksvlei Settlement Regulation Act of 1970

The Van Wyksvlei Settlement Regulation Act of 1970 provided for the vesting of ownership of certain land in the Van Wyksvlei Management Board near or at Van Wyksvlei.

The Van Wyksvlei Management Board must control and maintain the irrigation works serving the settlement of Van Wyksvlei and regulate the distribution of water from the works.

c) The Cannon Island Settlement Management Act of 1939

The Cannon Island Settlement Management Act of 1939 provided for the establishment of a Management Board for the Cannon Island Settlement, in the divisions of Gordonia and Kenhardt. The state transferred the irrigation works serving the settlement to the Management Board.

The management board was a body corporate. Amongst others the Board was empowered to control and maintain the irrigation works associated with the settlement.

Except for the irrigation out of the Orange River the implication of this Act was not investigated.

d) The Skanskop Settlement Act of 1947

The Skanskop Settlement Act of 1939 provided for the establishment of a Management Board for the Skanskop Settlement, in the division of Kenhardt.

The management board was a body corporate. Amongst others the Board was empowered to control and maintain the irrigation works associated with the settlement.

Except for the irrigation out of the Orange River the implication of this Act was not investigated.

Table 5.13.4.1: Article 63 Scheduling and Quotas from Government Water Schemes (for irrigation)

SCHEME	QUATERNARY CATCHMENTS	SCHEDU-LING (ha)	QUOTA	ALLO-CATION
			(m³/ha/a)	(10^6 m³/a)
Middle Orange River	D71A, D71C, D71D, D72A, D72B, D72C, D73C	19 116,1	10 000	191,16
Lower Orange River	D73D, D73E, D73F, D81A, D81B, D81D, D81E, D81F	36 103,7	15 000	541,56
Orange River (Namaqualand)	D82A, D82D, D82E, D82F, D82G, D82L	4 384,6	15 000	65,77
TOTAL		**59 604,4**		**798,49**

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

SCHEME	QUATERNARY CATCHMENTS	ALLOCATIONS (10^6 m³/a)						
		HOUSEHOLD and STOCK WATERING	MUNICIPALITIES	INDUSTRIES	MINING	IRRIGATION	ESKOM	TOTAL
Middle Orange River	D71A, D71C, D71D, D72A, D72B, D72C, D73C	0,01	2,00		0,01			2,02
Lower Orange River	D73D, D73E, D73F, D81A, D81B, D81D, D81E, D81F	14,43	27,79	13,90	11,71	4,16		71,99
Orange River (Namaqualand)	D82A, D82D, D82E, D82F, D82G, D82L	0,03			0,01	0,17	0,06	0,27
TOTAL		14,47	29,79	13,90	11,73	4,33	0,06	74,28

Some allocations are for more than one use. Such allocations are shown in the table under the column with the highest usage.

5.13.5 Allocations in Relation to Water Requirements and Availability

The water allocations and 1995 water requirements are totally disproportionate to the water resources generated within the Lower Orange Water Management Area (LOWMA). **Table 5.13.5** is an elementary summary of the allocations, requirements and resources in the LOWMA. It is clearly evident that the allocations and water use are heavily reliant on upstream inflows. The 1995 water use is approximately 40% greater than the allocations. This can be attributed to the fact that there is very little information available on the allocations not sourced from the Orange River. The survey currently underway by DWAF’s regional office in Kimberley will provide updated details regarding the water allocation data.

The estimated potential yield of the LOWMA shows resources in excess of the current allocations, but it is still insufficient for the current demand i.e. the LOWMA will always remain reliant on upstream inflows.

The household/domestic/municipal water usage and allocations are very much in balance which is contrary to the industrial/mining/bulk allocations. The irrigation allocations and water usage are also reasonably similar (8% difference).

Table 5.13.5 Allocations in relation to water requirements and availability

Description	Household, Stock Watering, Municipal, Urban, Rural (10^6 m³/a)	Industry, Mining, Bulk (10^6 m³/a)	Irrigation (10^6 m³/a)	Hydro Power/ Eskom (10^6 m³/a)	Affore-station (10^6 m³/a)	Dryland Sugarcane (10^6 m³/a)	Alien Vegetation (10^6 m³/a)	River Losses (10^6 m³/a)	Ecological Reserve (10^6 m³/a)	Water Transfers Out (10^6 m³/a)	Total (10^6 m³/a)
Allocations	44,26	25,63	802,82	0,06	-	-	-	-	-	-	872,77
Water Requirements (1:50 year assurance)	42,9	9,1	774,5	0,0	0	0	4,4	527,3	-126,0	6,7	1 239,0
Water Resources 1995 (1:50 year assurance)											29,94
Estimated Water Resources (1:50 year assurance total potential)											953,6

5.14 EXISTING WATER TRANSFERS

5.14.1 Introduction

Existing water transfers in the Lower Orange Water Management Area (LOWMA) take the form of irrigation, rural, urban or bulk user supply schemes. Their water requirements are specified under their respective subsections earlier in this chapter.

The irrigation sector is by far the dominant user in terms of quantity of water transferred. This is usually through a weir/canal system and is alongside the main stem of the Orange River. They are either controlled by a Government Water Control Area or an Irrigation Board. Most irrigation canals flow downstream, and are therefore not considered as transfers (or modelled as such in the WSAM). Details on the irrigation canals (where available) have been included in chapter 4 and **Appendix E.2**, they are no longer discussed in this chapter.

The more traditional transfer schemes supply water from the Orange River to areas well outside of the riparian zone. These schemes are fairly simple, extracting water from a single source and delivering it to a remote point with the occasional off-take enroute. The transfer schemes are operated by the local Water Board or municipality.

Figure 5.14.1 illustrates the main transfers and canals in the Lower Orange WMA.

5.14.2 Transfers To and From Neighbouring States

There are two existing transfer schemes to a neighbouring state at the moment. One is the Noord Oewer irrigation canal on the northern bank of the Orange River at Vioolsdrift, the other is the pipeline to the Rosh Pinah Mine, both in southern Namibia.

Work is currently underway to construct a supply line from the Orange River to the new Scorpion Mine, also in southern Namibia.

5.14.3 Transfers Between Water Management Areas

There are no transfers from or into adjacent water management areas, except for that feeding the irrigated lands at Douglas (C92C). Orange River water is routed via the Orange Vaal Transfer from Marksdrift Weir (D33K) in the Upper Orange WMA to Douglas Weir (C92B) in the Lower Vaal WMA, which is outside the LOWMA.

Table 5.14.3.1: Average Transfers To and From Neighbouring States and Inter-Water Management Area Transfers under 1995 Development Conditions

SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY ($m^3 \times 10^6/a$)	TRANSFER NAME
Transfers to and from neighbouring states :			
Lower Orange	Namibia	Unknown, accepted supply value 9,2 million m^3/a	Sendelingsdrift to Rosh Pinah.

5.14.4 Transfers within the Water Management Area

There are five transfer schemes (excluding irrigation schemes) within the WMA, in all cases the water source is the main stem Orange River. Refer to **Table 15.14.4.1.**

The Karos-Geelkoppen Rural Water Supply Scheme provides water for stock watering purposes. It is located slightly upstream of Upington.

The Kalahari-West Rural Water Supply Scheme draws treated water from the Upington purification plant and pumps it north for stock watering and rural domestic supply.

The Pelladrift Water Supply Scheme is operated by the Pella Water Board and provides water to Poffadder, Pella and the mines at Aggenys and Black Mountain.

The Springbok Regional Water Supply Scheme draws water from Henkriesmond, via the Henkries purification works and supplies the area of Springbok, Okiep, Carolusberg and Kleinsee.

Water is abstracted at Alexander Bay and pumped south to supply Port Nolloth.

Table 5.14.4.1: Average Transfers within the Lower Orange Water Management Area (LOWMA) at 1995 Development Levels

NAME OF SCHEME	WATER SOURCE	DESTINATION CATCHMENT	INCLUDED IN WSAM SIMULATION	SOURCE SECTOR	DESTINATION SECTOR	TRANSFER LIMIT	IMPLEMEN-TATION YEAR	CALCULATED TRANSFER (10^6 m^3/a)
<u>Karos-Geelkoppen Rural Water Supply Scheme</u>								
Stock watering and rural supply	D73E	D42C D42D	Yes	SRD	SRU	Unknown	unknown	0,042
<u>Kalahari-West Rural Water Supply Scheme</u>								
Potable to rural area from Upington municipal reservoir	D73E	D42D D42E	Yes	SRD	SRU	1,34 10^6 m^3/a	Sep-97	0,30 0,120
<u>Pelladrift Water Supply Scheme</u>								
to Pofadder, Pella	D81F	D81G	No	SRD	SSU		unknown	1,286
to Aggenys	D81F	D82C	Yes	SRD	SSM	Unknown	unknown	0,874
to Black Mountain Mine	D81F	D82C	Yes	SRD	SSM		unknown	3,000
<u>Springbok Regional Water Supply Scheme</u>								
Springbok,	D82D	F30D	Yes	SRD	SSU		unknown	0,615
Okiep Copper Mine	D82D	F30E	Yes	SRD	SSM	Pump station on Orange River = 9,69 106 m^3/a	unknown	1,850
Carolusberg	D82D	F30C	Yes	SRD	SSU		unknown	0,18
Kleinsee	D82D	F30G	Yes	SRD	SSU		unknown	0,190
<u>Sendlingsdrift to Rosh Pinah</u>	D82K	Z20F	No	SRD	SSM	Unknown	Unknown	9,200
<u>Alexander Bay to Port Nolloth</u>								
To Port Nolloth	D82L	F20D	Yes	SRD	SSU	Unknown	Unknown	0,67
<u>Boegoeberg Irrigation Scheme</u>								
Noord Oranje Irrigation Board (right bank)	D72C	D73D	No	SRD	SSI		approx 1935	63,070
Gariep Settlement (right bank)	D72C	D73E	No	SRD	SSU		approx 1935	63,070
Rouxville West Scheme (left bank)	D72C	D73E		SRD	SSU	Start of canal = 307,8Mm³/a	approx 1935	12,620
Boegoeberg-Karos GWS (left bank)	D72C	D73C	No	SRD	SSI		approx 1935	84,520
Boegoeberg-Karos GWS (left bank)	D72C	D73D	No	SRD	SSI		approx 1935	84,520

NAME OF SCHEME	WATER SOURCE	DESTINATION CATCHMENT	INCLUDED IN WSAM SIMULATION	SOURCE SECTOR	DESTINATION SECTOR	TRANSFER LIMIT	IMPLEMEN-TATION YEAR	CALCULATED TRANSFER (10^6 m³/a)
Upington Irrigation Area								
Upington Inlands GWS	D73F	D73F	Yes	SRD	SSI	Unknown	-	Unknown
Upington Inland Main Canal	D73E	D73F	Yes	SRD	SSI	Unknown	-	312,2 to 25,5
Kakamas Irrigation Area								
Neusberg weir								
North Furrow	D73F	D81A	Yes	SRD	SSI	Unknown	-	234,9 to 6,0
South Furrow	D73F	D81A	Yes	SRD	SSI	Unknown	-	214,8 to 26,5
Rhenosterkop Weir	D81A	D81A	Yes	SRD	SSI	Unknown	-	247,6 to 11,7
Onseepkans Irrigation Area								
Supplied through canal on the left bank of the Orange River	D81E	D81F	Yes	SRD	SSI	Unknown	-	Unknown
Vioolsdrift-Noordoewer Irrigation Area								
Noordoewer	Z20E	Z20E	Yes	SRD	SSI	Unknown	-	31,2 to 2,8
Vioolsdrift	D82E	D82F	Yes	SRD	SSI	Unknown	-	22,4 to 8,2
Namakwaland Irrigation Area								
Abstracted from Orange River released from Van der Kloof Dam to users	D82A	D82A	Yes	SRD	SSI	Unknown	-	Unknown

Notes on sectors:

SSM Mine bulk user
SSI Irrigation water transfer
SSU Urban water user
SRD Transfers from rivers/dams
SRU Rural

5.15 SUMMARY OF WATER LOSSES AND RETURN FLOWS

The most significant water losses and return flows are in the irrigation sector, being the largest requirement sector in the WMA. There are also major river losses in this WMA. **Table 5.15.1** provides a summary of water requirements, losses and return flows for the Lower Orange Water Management Area (LOWMA).

Table 5.15.1: Summary of Water Requirements, Losses and Return Flows

CATEGORY		ON-SITE REQUIREMENTS	LOSSES		RETURN FLOWS
		(10^6 m³/a)	(10^6 m³/a)	(%)	(10^6 m³/a)
Irrigation		826,00	75,40	9	90,14
Urban		17,84	6,03	20	1,05
Rural		13,62	3,70	20	0,00
Bulk	Strategic	0	0	0	0,00
	Mining	7,85	0,79	10	0,00
	Other	0	0	0	0,00
Hydropower		0	0	0	0
Rivers, Wetlands and Dams		-	589,50	-	0,0
TOTAL		**865,31**	**675,92**	**-**	**91,19**

The figures in the above table are all unassured values.
* Excludes operational losses.

There are no main inter-catchment transfers of return flows in the LOWMA.

Diagram 5.15.1: Water Losses in the Lower Orange WMA

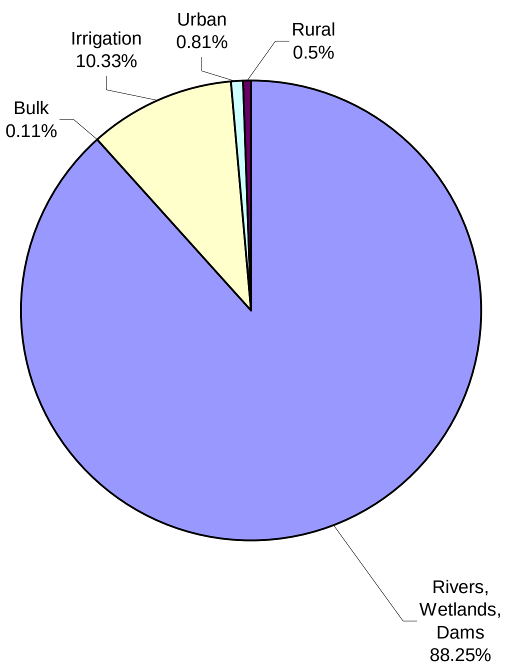
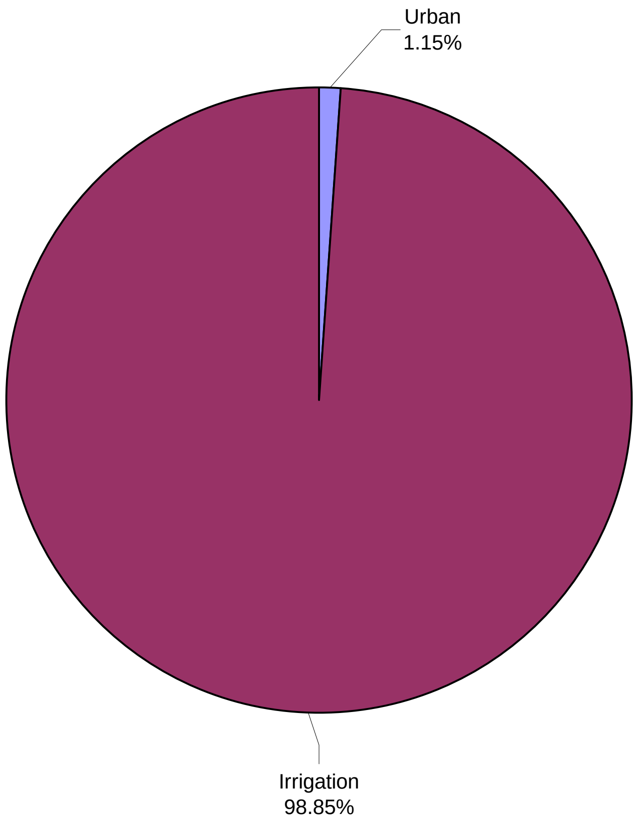


Diagram 5.15.2: Return Flows in the Lower Orange WMA



CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

The water resources in the Lower Orange Water Management Area (LOWMA) can be summed up in two words, very scarce. Rainfall and natural runoff is extremely limited and very sporadic with a total incremental Mean Annual Runoff of only 471 million m³/a for a catchment area of 251 300 km².

Surface water resources are highly dependant on the releases from the Gariep and Van der Kloof Dams in the Upper Orange WMA. There are a few small dams in the WMA, but nothing of significant storage capacity except for the Smartt Syndicate ($99{,}3 \times 10^6$ m³), Van Wyksvlei (143×10^6 m³) and Boegoeberg ($20{,}4 \times 10^6$ m³) dams. Boegoeberg Dam is generally operated as a diversion weir and not a storage structure. There are no formal transfer schemes importing water into the LOWMA except for the one near Douglas. The developed yield from surface water in 1995, at an assurance of 1:50 years, as estimated by the Water Situation Assessment Model is 5 million m³/a. The potential yield of the WMA taking into account a proposed dam at Vioolsdrift could well be increased to 293 million m³/a. The surface water yields have been calculated without the impact of the ecological Reserve being taken into account, i.e. the Reserve has not been deducted from the surface water yield. The Reserve is deducted from the total yield along with other water requirements in calculating the surplus yields presented in Chapter 7. The natural MAR of the river is given in **Table 6.1.1**.

Groundwater is the dominant means of urban/rural water supply, especially as one moves away from the main stem of the Orange River. The groundwater resource is currently underdeveloped with only an estimated 25 million m³/a coming from this source in 1995. The sustainable groundwater potential is estimated to be in the order of 660 million m³/a for a 1:50 year level of assurance.

A broad estimate of total yield can be obtained by combining the 1995 development yields for both the surface and groundwater components and the potential yields from both sources. On this basis, it is estimated that the Lower Orange Water Management Area (LOWMA) could yield, at a 1:50 year assurance, approximately 954 million m³/a instead of the 1995 yield of 25 million m³/a. Although this is a dramatic increase on a local scale, it must be interpreted in the context of the resource potential of the entire Orange River Basin. Developments upstream also influence the efficiency with which a potential Vioolsdrift Dam could convert excess runoff into yield.

Table 6.1.1 details the 1995 status and the potential yields for the various drainage areas for both the surface water and groundwater sectors. **Figures 6.1.1 and 6.1.2** show the combined (surface and groundwater) resources for the current (1995) and fully developed scenarios respectively.

Table 6.1.1: Water Resources

Catchment						Surface Water Resources				Sustainable Groundwater Exploitation Potential Not Contributing to surface base flow		Total Water Resource (Yield)	
Primary		Secondary		Tertiary (Drainage Area)		Natural Runoff	1:50 Year Developed Yield 1995	Future Dam Yield	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,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	84,6	2,0		2,0	3,44	140,52	5,44	142,52
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	191,98	3,09		3,09	9,66	299,94	12,75	303,03
				D55	Sak-Hartbees (WC)	3,92	0,06		0,06	0,05	1,58	0,11	1,64
		D4	Molopo	D42	Nossob-Molo (NC)	6,9	0,0		0,0	2,51	20,57	2,51	20,57
		C9, D7, D8	Orange	D92, D71, D72	Boegoeberg (NC)	72,1	0,0		0,0	3,89	92,04	3,89	92,04
				D73	Neusberg (NC)	71,4	0,0		0,0	0,93	38,09	0,93	38,09
				D81, D82	Vioolsdrift (NC)	14,8	0,0	288,0	288,0	1,42	21,90	1,42	309,90
				D82	AlexanderBay (NC)	1,2	0,0		0,0	0,2	2,63	0,2	2,63
	TOTAL IN NORTHERN CAPE PROVINCE					443,00	5,09	288,0	293,09	22,05	615,69	27,14	908,76
	TOTAL IN WESTERN CAPE PROVINCE					3,92	0,06	0,0	0,06	0,05	1,58	0,11	1,64
	TOTAL IN PRIMARY CATCHMENTS C + D					446,92	5,15	288,0	293,15	22,1	617,27	27,25	910,42
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	22,90	0,0		0,0	2,54	39,61	2,54	39,61
				F50	Coastal (WC)	1,21	0,0		0,0	0,15	3,57	0,15	3,57
	TOTAL IN NORTHERN CAPE PROVINCE					22,90	0,0	0,0	0,0	2,54	39,61	2,54	39,61
	TOTAL IN WESTERN CAPE PROVINCE					1,21	0,0	0,0	0,0	0,15	3,57	0,15	3,57
	TOTAL IN PRIMARY CATCHMENT F					24,1	0,0	0,0	0,0	2,64	43,18	2,64	43,18
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						465,9	5,1	288,0	293,09	24,59	655,3	29,68	948,39
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						5,13	0,06	0,0	0,06	0,20	5,15	0,26	5,21
TOTAL IN LOWER ORANGE WMA						**471,0**	**5,1**	**288,0**	**293,1**	**24,74**	**660,45**	**29,94**	**953,6**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	514,6	98,7	0,0	98,7	-	46,4	98,7	145,1
TOTAL IN REPORTING AREA						**985,6**	**103,8**	**288,0**	**391,8**	**24,74**	**706,86**	**128,64**	**1 908,7**

Rounding off errors occur.

6.2 GROUNDWATER

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

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

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

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

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

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

The groundwater balance then compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilized (see **Figure 6.2.5**). If the total use was greater than the Harvest Potential the groundwater in the catchment was considered to be over-utilized, if the total use was greater than the Exploitation Potential but less than the Harvest Potential the groundwater in the catchment was considered to be heavily utilized, if the total use was more than 66% of the Exploitation Potential the groundwater in the catchment was considered to be moderately-utilized and if the total use was less than 66% of the Exploitation Potential the groundwater in the catchment was considered to be under-utilized.

Table 6.2.1: Groundwater Resources at 1:50 year Assurance of Supply

Catchment						Groundwater Exploitation Potential	Groundwater Use In 1995	Unused Groundwater Exploitation Potential (1995)	Groundwater Contribution To Surface Base Flow	Portion Of Groundwater Exploitation Not Contributing To Surface Base Flow
Primary		Secondary		Tertiary (Drainage Area)						
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	140,52	3,44	137,08	0	140,52
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	299,94	9,66	290,27	0	299,94
				D55	Sak-Hartbees (WC)	1,58	0,05	1,53	0	1,58
		D4	Molopo	D42	Nossob-Molo (NC)	20,57	2,51	18,06	0	20,57
		C9, D7, D8	Orange	D92, D71, D72	Boegoeberg (NC)	92,04	3,89	88,15	0	92,04
				D73	Neusberg (NC)	38,09	0,93	37,17	0	38,09
				D81, D82	Vioolsdrift (NC)	21,9	1,42	20,48	0	21,9
				D82	AlexanderBay (NC)	2,63	0,2	2,43	0	2,63
	TOTAL IN NORTHERN CAPE PROVINCE					615,69	22,05	593,64	0	615,69
	TOTAL IN WESTERN CAPE PROVINCE					1,58	0,05	1,53	0	1,58
	TOTAL IN PRIMARY CATCHMENTS C + D					617,27	22,1	595,17	0	617,27
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	39,61	2,54	37,05	0	39,61
				F50	Coastal (WC)	3,57	0,1	3,47	0	3,57
	TOTAL IN NORTHERN CAPE PROVINCE					39,61	2,54	37,05	0	39,61
	TOTAL IN WESTERN CAPE PROVINCE					3,57	0,1	3,47	0	3,57
	TOTAL IN PRIMARY CATCHMENT F					43,18	2,64	40,52	0	43,18
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						655,3	24,59	630,69	0	655,3
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						5,15	0,15	5,00	0	5,15
TOTAL IN LOWER ORANGE WMA						**660,45**	**24,74**	**635,69**	**0**	**660,45**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	46,41	0	46,41	0	46,41
TOTAL IN REPORTING AREA						**706,86**	**24,74**	**682,1**	**0**	**706,86**

* Groundwater use data for Namibia is not complete

6.3 SURFACE WATER RESOURCES

6.3.1 Streamflow Data

The basis for the analysis of surface water resources for all Water Management Areas (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. More recently, certain adjustments were made to this dataset due to updated estimates of runoff reduction caused by forestry. However, since no forestry areas exist in the Lower Orange Water Management Area (LOWMA), these adjustments had no effect on the streamflow sequences.

The Orange River Development Replanning Study (ORRS, BKS 1997) updated the hydrology of the Upper Orange WMA. However, due to the relatively low and sporadic nature of runoff in the Lower Orange Water Management Area (LOWMA), the WR90 hydrology was deemed sufficiently accurate for analysing contributions to the lower Orange River. In terms of contributions to the Orange River, the ORRS excluded parts of the tributaries that were deemed not to make any significant contribution to the Orange River. In this study, a distributed picture is required at quaternary resolution. All the quaternaries have therefore been assigned runoff according to WR90, in addition to endoreic areas. The WSAM then simulates the balance on a quaternary basis, such that very little water from the incremental catchments actually reaches the Orange River as utilisable yield. This therefore represents an effect on the Orange River similar to that assumed in the ORRS.

The Orange River is wide, and carries a heavy silt load. As a result, accurate measurement of low-flows is very difficult. Significant contributions from the tributaries are usually masked by high-flows in the Orange River at the same time, making accurate determination of the tributary contributions very difficult. This situation is further exacerbated by the large amounts of evaporative losses and irrigation abstractions taking place from the Orange River. The runoff information in the Lower Orange Water Management Area (LOWMA) is therefore not regarded as accurate, but is sufficient given the low and sporadic contributions to the Orange River.

A brief analysis of the Fish River hydrology was carried out by BKS (1991), as part of the Orange River System Analysis Phase 1 for DWAF. The relevant information was captured into the WSAM from this report. Estimates of incremental runoff from other parts of Namibia draining into the Orange River were made by interpolation and extrapolation of unit runoff from the Fish River Catchment and nearby quaternary catchments within South Africa.

The naturalised mean annual runoff is shown in **Figure 6.3.1** and detailed in **Table 6.3.1.**

Table 6.3.1: Surface Water Resources

Catchment						Catchment Area	Mean Annual Precipitation	Mean Annual Evaporation	Naturalised MAR		Yield (1:50 Year)	
Primary		Secondary		Tertiary (Drainage Area)					Incremental	Cumulative	Developed In 1995	Total Potential
No,	Description	No,	Description	No,	Description	(km²)	(mm/a)	(mm/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61 D62	Ongers (NC)	33 730	249	2 249	84,6	84,6	2,0	2,0
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	91 179	161	2 293	191,98	191,98	3,09	3,09
				D55	Sak-Hartbees (WC)	1 861	161	2 293	3,92	3,92	0,06	0,06
		D4	Molopo	D42	Nossob-Molo (NC)	31 810	166	2 900	6,9	143,4	0,0	0,0
		C9 D7 D8	Orange	D92 D71 D72	Boegoeberg (NC)	16 090	255	2 474	72,1	10 640,0	0,0	0,0
				D73	Neusberg (NC)	17 730	167	2 650	71,4	10 780,0	0,0	0,0
				D81 D82	Vioolsdrift (NC)	27 510	99	2 600	14,8	11 150,0	0,0	288,0
				D82	AlexanderBay (NC)	5 511	56	2 200	1,2	11 620,0	0,0	0,0
	TOTAL IN NORTHERN CAPE PROVINCE					223 560	166	2 292	443,0		5,09	293,09
	TOTAL IN WESTERN CAPE PROVINCE					1 861	161	2 293	3,9		0,06	0,06
	TOTAL IN PRIMARY CATCHMENTS C + D					225 421	168	2 294	446,9		5,15	293,15
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	24 539	130	2 200	22,9		0,0	0,0
				F50	Coastal (WC)	1 292	130	2 200	1,2		0,0	0,0
	TOTAL IN NORTHERN CAPE PROVINCE					24 539	130	2 200	22,9		0,0	0,0
	TOTAL IN WESTERN CAPE PROVINCE					1 292	130	2 200	1,2		0,0	0,0
	TOTAL IN PRIMARY CATCHMENT F					25 830	130	2 200	24,1	24,1	0,0	0,0
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						248 100	166	2 292	465,9	11 620,0	5,09	293,15
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						3 159	130	1 694	5,1	8,0	0,06	0,0
TOTAL IN LOWER ORANGE WMA						**251 300**	**168**	**2 294**	**471,0**	**11 620,0**	**5,15**	**293,15**
Z (Part)	Namibia	Z1 Z2	Namibia	Z10 Z20	Namibia	244 300	67	2 750	514,6	483,9	98,7	98,7
TOTAL IN REPORTING AREA						**495 500**	**118**	**2 421**	**985,6**	**11 644,1**	**103,8**	**391,8**

* Rounding errors occur

6.3.2 Yield Analysis

In order to estimate the total potential yield available from the catchments within the Water Management Area, future storage dams of a particular maximum net storage capacity have been postulated. The net incremental storage capacities that have been adopted within the Water Management Area are given in **Appendix G** for each group of quaternary catchments that falls within the same hydrological zone, as defined in WR90 (Midgley, et al., 1994). These range from 307% of the MAR in the higher rainfall quaternary catchments to 408% of the MAR in the drier quaternary catchments within the Water Management Area.

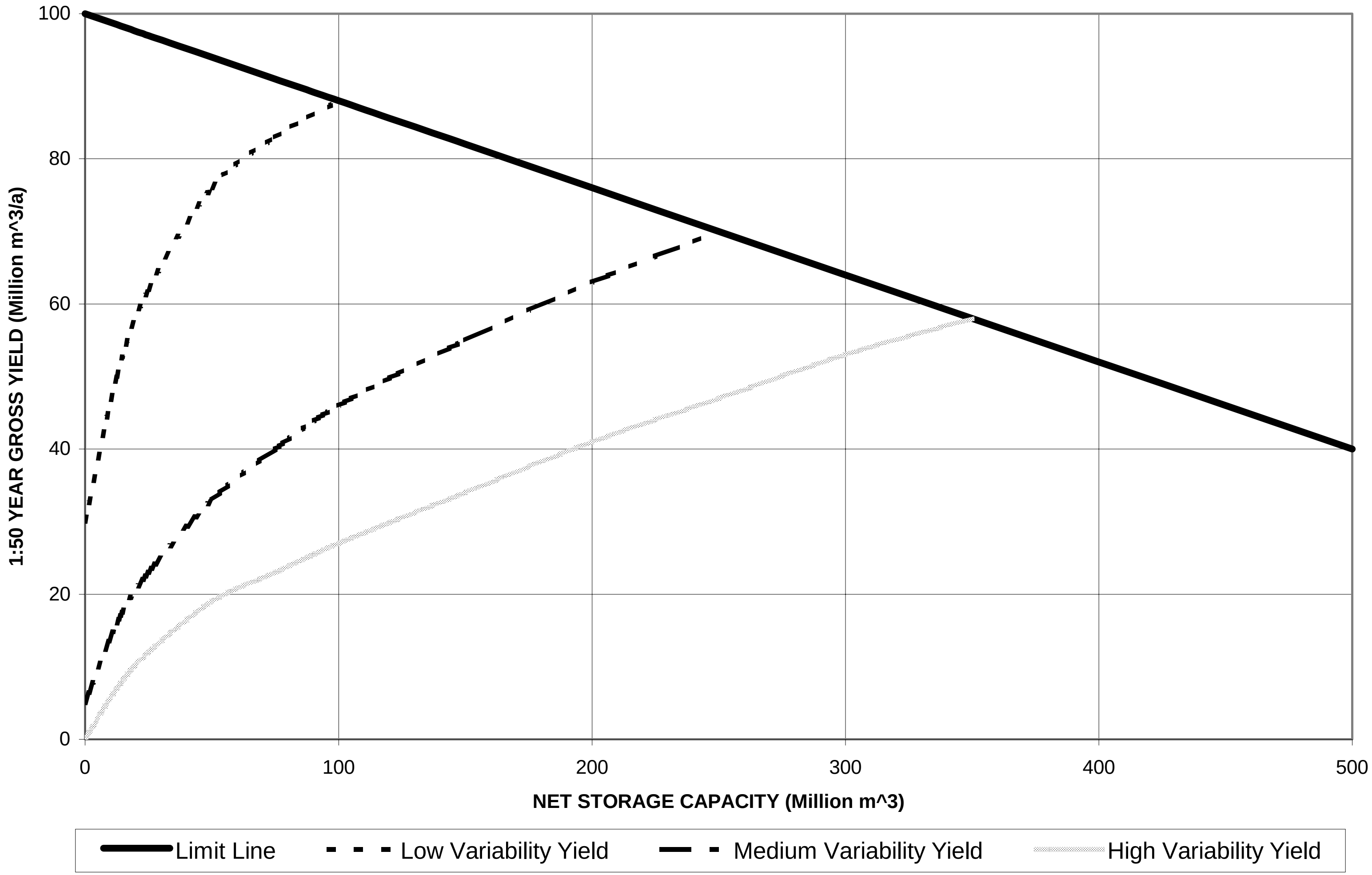
Dams that will capture and regulate all the runoff from a catchment are not economical to build. In the drier areas where the runoff is more variable the sizes of such dams also become prohibitive. A simple technique, based on past experience, has therefore been developed whereby plausible estimates 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.

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 6.3.1**. 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 6.3.1**. This is illustrated by means of the typical net storage-gross yield relationships shown in **Diagram 6.3.1** 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 300% or 400% of the MAR as appropriate.

It was the intention of the Water Resource Situation Assessment (WRSA) studies to estimate the total potential yield available from the catchments within the Water Management Area, using postulated future storage dams of a particular maximum net storage capacity. However, the dams on tributaries to the Orange River receive low and sporadic inflows, and are subject to extremely high evaporation losses. Similarly even dams on the lower Orange River are very inefficient in terms of yield compared to dams in the upper Orange River. The only dam therefore considered was a dam upstream of Vioolsdrift, which can capture operational losses from upstream, as well as hydropower released during winter, and release the water as required for downstream irrigation and ecological requirements at the river mouth. Various sizes of dam at Vioolsdrift were analysed during the ORRS, and further studies on the Orange River are planned which will investigate inter alia the feasibility of a Vioolsdrift Dam.

For the purpose of indicating potential yield contributions from the WMA, a large dam at Vioolsdrift was analysed, with a live capacity of 1 500 million m³ (2 220 million m³ gross storage). Larger dams at Vioolsdrift were also considered in the ORRS for scenarios with pronounced increases in Namibian water requirements. **Table 6.3.1** is a summary of the results. The potential surface resource development including existing and potential future development, is shown in **Figure 6.3.2.**

Diagram 6.3.1: Dam Storage Limits



6.4 WATER QUALITY

6.4.1 Mineralogical Surface Water Quality

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

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

The surface water quality monitoring stations that were used to provide the data are shown in **Figure 6.4.1.1**. The monitoring stations in the Lower Orange Water Management Area (LOWMA) are predominantly situated along the main stem Orange River. Most of the water quality monitoring stations on the tributaries are closed and are no longer functioning. Samples are taken as and when the rivers flow depending on personnel location at the time. There are however a few stations in the upper reaches of the Sak and Ongers Rivers.

Only data sets that had consecutive data for the last two years 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.

The above methodology is not appropriate for the assessment of water quality in ephemeral rivers where no flows occur for long periods of time, resulting in a low frequency of sampling.

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 - 1800
3	Red	Poor water quality	1801 - 3400
4	Purple	Completely unacceptable water quality	>3400

Water quality was assessed at a quaternary catchment level of resolution, where such data was available. 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 water quality of the Lower Orange Water Management Area for those quarternaries with measuring stations is summarised in **Table 6.4.1.3** and is shown in **Figure 6.4.1.1.**

Table 6.4.1.3: Summary of Mineralogical Surface Water Quality of the Lower Orange Water Management Area

Drainage Area	No. of Quarternary Catchments	Number of Quarterly Catchments in Class					
		Blue	Green	Yellow	Red	Purple	No data
Ongers	21	0	0	0	0	0	21
Sak-Hartbees	54	0	0	0	0	0	54
Noosob-Molopo	5	0	0	0	0	0	5
Boegoeberg	8	0	0	0	0	0	8
Neusberg	5	0	3	0	0	0	2
Vioolsdrift	12	0	3	0	0	0	9
Alexander Bay	6	0	0	1	0	0	5
Coastal	30	0	0	0	0	0	30

Table 6.4.1.4: Mineralogical Surface Water Quality at individual stations

QUARTER-NARY CATCHMENT	MAXIMUM TDS (mg/ℓ)	MEAN TDS (mg /ℓ)	DESCRIP-TION OF MAXIMUM TDS	DESCRIP-TION OF MEAN TDS	OVERALL CLASS DESCRIP-TION
D72C	303	204,5	Good	Ideal	Good
D73D	365	245,0	Good	Ideal	Good
D73F	358	254,1	Good	Ideal	Good
D81E	488	328,5	Good	Good	Good
D81F	404	264,9	Good	Good	Good
D82E	597	340,7	Good	Good	Good
D82L	547	337,8	Good	Good	Good

The mineralogical surface water quality of the LOWMA is generally good. This is however a very subjective statement as it is based on 7 measuring stations situated along the main steam of the Orange River as shown in **Table 6.4.1.4.**

6.4.2 Mineralogical Groundwater Quality

The groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO3 as N) and flourides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality was evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (Simonic, 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegter's maps (Vegter, 1995). The potability evaluation done by Simonic (2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume 1 (DWAF, 1998).

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

In catchments where in information was available estimates of the portion of potable goundater were made using Vegters maps (Vegter, 1995).

Figure 6.4.2.1 gives an evaluation of the mean TDS per quarternary catchment and **Figure 6.4.2.2** gives an estimates of the percentage of potable groundwater per quarternary catchment.

The mineralogical ground water quality in the Lower Orange Water Management Area (LOWMA) is not particularly good in terms of its TDS rating. In general the ground water quality is rated as class 2 to class 4, marginal to completely unacceptable. The southern portion of the inland region, De Aar, Victoria West and Sutherland has a class 2 rating, together with the areas surrounding Prieska, Griekwastad, Upington and Springbok. The rest of the WMA, particularly north of Brandvlei and Carnarvon and the coastal strip are rated as class 3 and 4.

The Sutherland, De Aar, Upington belt has a varying range of potable groundwater from a moderate 50% to approximately 90%. The balance of the WMA, has a predominant potable usage of less than 30%, with the occassional improvement to 50%.

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. (See **Appendix G** for more information.) 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 Lower Orange Water Management Area (LOWMA) 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 scale. The portion applicable to the LOWMA 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.

6.4.4 Water Quality Issues

Distribution of Surface Water Quality Monitoring Points

Surface water quality monitoring points are distributed sparsely in the Northern Cape Province study area. The monitoring stations tend to be clustered along the main stem Orange River with a few stations situated in the upper reaches of the Sak River, some on the Ongers River and one in the Molopo River catchment (See **Figure 6.4.1.1**). With the exception of the monitoring points on the Orange River, there are no useful surface water quality monitoring points on the rivers in the western part of the study area (F drainage region) where rivers drain towards the Atlantic ocean station F5H001 Q01, shown on **Figure 6.4.1.1** has insufficient data available. The sparse distribution of surface water monitoring points is directly related to the ephemeral nature of the rivers in most of the study area.

Monitoring in the Orange River appears to be adequate for providing an overview of TDS concentrations in the main river flowing through the LOWMA. The Orange River monitoring programme was also reviewed by DWAF (1998c) to assess its potential to meet the needs for TDS modelling of the Orange River system. They recommended that samples be collected on a monthly basis at D7H002 (Prieska), D7H008 (Boegoeberg), D7H005 (Upington), D8H004 (Onseepkans), D8H003 (Vioolsdrift) and D8H007 (Brand Karos). These samples would be analysed for the standard macro-chemical constituents by the Department. The proposed monitoring programme would probably meet the majority of the information needs. Additional monitoring might be required to assess site specific water quality concerns such as the impact of bacteriological pollution, pesticide contamination from irrigation next to the river or trace metal contamination from mining activities in the lower Orange River. A monitoring programme was specifically designed for the RAMSAR site at the Orange River Mouth as part of the Orange River Development Replanning Study (ORRS) study.

Water quality monitoring in the other Lower Orange Water Management Area (LOWMA) rivers is difficult due to the highly ephemeral nature of these rivers. Some samples are available from the upper reaches of the Sak River system but no samples have been collected in the Ongers River system since 1992. It is recommended that monitoring be resumed in the Ongers River catchment, at least in Smartt Syndicate Dam to provide an indication of present state of surface water quality in the D6 sub-catchment.

The sampling frequency is related to the occurrence of surface water and is reflected in the completeness of the data record. The monitoring stations on the main stem Orange River tended to be sampled on a regular basis whereas the monitoring points on the Sak and Ongers River tributaries tended to be sampled on an ad hoc basis when surface water occurred.

With the exception of the Orange River, flow in most rivers in the study area is highly seasonal and many of the rivers are dry for extended periods of time. A routine sampling programme is therefore inappropriate for these rivers and event-related sampling when flow occurs is more appropriate for the area. An ad hoc sampling routine makes it more difficult to assess the average water quality status in these ephemeral rivers.

Ground Water Monitoring Points

Ground water quality differs considerably over short distances, in the Lower Orange Water Management Area (LOWMA). DWAF is busy compiling geohydrological maps, at a scale of 1:500 000, across the WMA (and the country) to provide up to date information. It is understood that the Alexander Bay/Upington map is available and that the mapping for Springbok and Prieska will be published shortly.

Total Dissolved Salt Concentrations in the LOWMA

In overview, TDS concentrations in the main stem Orange River is classified as a Class 1 (see **Table 6.4.1.1**) water quality, which is generally regarded as good for domestic water supply and irrigation purposes, and have a range of 260-600 mg/ℓ.

Although water quality in the Orange River is generally good, concerns have been expressed about TDS concentrations in irrigation return flows (DWAF, 1996, DWAF, 1998a). Salinities as high as 11 000 mg/ℓ have been recorded in irrigation return flow canals (DWAF, 1996). Measurements of salinities in irrigation canals at Upington in 1995 and 1996 showed an increase of between 5-6 times greater than the river TDS concentration over the same period. Seepage from mine slimes dams in the lower reaches of the Orange River also had a negative impact on TDS concentrations in the lower reaches of the Orange River. However, the impact of high TDS loads from the Vaal River system, upstream of the study area, has a much greater impact on the Orange River.

In future, TDS can be expected to increase in the Orange River. A modelling study by DWAF (1998a) estimated the increase in TDS concentrations up to the year 2030. They estimated that by the year 2030, TDS concentrations would increase by about 27% at Kakamas and 58% at the Orange River Mouth over the year 1995 levels. This was regarded as a worst case scenario, the data used in the modelling was poor and the confidence in the calibration was low.

There was not sufficient data in the Sak River catchment (D5 sub-catchment) to compile data sets which met the 24 consecutive monthly values data requirements. However, when examining the average and maximum values observed in the catchment since September 1992, water quality in the Sak River catchment can be classified as ranging between a Class 2 which is regarded as marginal and a Class 4 that is regarded as unacceptable for domestic water supply and irrigation water supply. The high TDS is mostly ascribed to natural hydrogeological sources and the high evaporation in the study area. Farming practises may also contribute to retaining salts in the catchment. Many small farm dams and swales are built in the upper reaches of the catchment. Any of the infrequent runoff is then captured in these dams and then used for short-term irrigation or when the soils have been saturated in the swales, it is plowed and planted (Knoetze, Streit and Van Dyk, pers. comm.). These farming practises may contribute to retaining the salts in the catchment rather than occasionally washing it out.

There were no TDS observations in the Ongers River catchment (D6 sub-catchment) since September 1992.

Nutrients

Chutter in DWAF (1996) noted concerns about high concentrations of algae in the Orange River causing problems in the potable water treatment works at Upington during summer months. More recent summer algal problems in the river at Upington have also been noted (Conradie pers. comm., Van Ginkel pers. comm.). Algal problems are generally associated with nutrient enrichment. DWAF (1996) identified the source of the algae as water being released from Van der Kloof Dam. High nutrient concentrations in the river would maintain the high algal concentrations in the river as it flows from Van der Kloof Dam. Elevated nutrient concentrations can also be the result of intensive agricultural activities next to the river. DWAF (1996) ascribed elevated nitrates and nitrite values observed in the Orange River to nutrient enrichment from agriculture. Van Ginkel (pers. comm.) ascribed the source of more recent algal blooms, when chlorophyll concentrations greater than 150 g/ℓ were observed, as originating from the Vaal River system.

Treated sewage effluent discharges from the Upington sewage treatment plant would have a localised effect of increasing nutrient concentrations but its effect on algal growth would probably be mitigated by the high turbidity in the Orange River.

Bacteriological Contamination

Concerns have been expressed about the bacteriological water quality in the irrigation canals and along the river in the Upington area. An informal survey of bacteriological water quality in the Upington area found high incidences of water borne diseases in communities where people drank untreated or partially treated water directly from the river or from the irrigation canals (Du Preez, pers. comm.). In an assessment of the risk to surface water of faecal contamination (DWAF, 2000), the Upington area (D73F) was regarded as the only area in the Northen Cape study area that had a medium risk of contamination. The rest of the study area was regarded as low risk.

Trace Metals

Concerns have also been raised about elevated aluminium levels as a result of mining activities in the lower Orange River (Knoetze, Streit and Van Dyk, pers. comm.). It was speculated that this might have a negative impact on the RAMSAR wetland at the Orange River Mouth.

Temperature

Chutter (in DWAF, 1996) expressed concerns about unnatural short-term temperature fluctuations in the Orange River as a result of hydropower releases from Van der Kloof Dam and Gariep Dam. However, these temperature fluctuations in the river would be largely mitigated by the time the water reaches the Lower Orange Water Management Area (LOWMA).

Other Pollutants

Contamination of the Orange River with pesticides and herbicides from the intensive agriculture next to the river has not been raised as a major concern. Neither has contamination of the river with asbestos from the Prieska area been raised as a specific concern to domestic water users.

6.5 SEDIMENTATION

Sediment loads transported by rivers are often deposited in reservoirs, causing loss of storage capacity and adversely affecting the reservoir yield. It also impacts on the design and positioning of dam walls, gates and appurtenant works. The active life of a reservoir is highly dependant on the rate of sedimentation, which in itself carries many uncertainties.

“The catchments in the Orange River basin vary from the highest sediment yield areas in Southern Africa (along the upper reaches of the Orange River) to very low sediment yield areas comprising arid and slow drainage areas along the Lower Orange River.” (DWAF 1997, PD000/00/5497, pg 5-1). There are large quantities of sediment available for transport but because the transporting capacity of the runoff is low, all the sediment very seldomly reaches the river course. A large portion of the catchment is also made up of enclosed drainage basins and pans which further prevent sediment accumulation. Hence, it is the transporting mechanism rather than the availability of sediment which is the limiting factor in determining the sediment yield.

Assessment data on sediment accumulation in the lower Orange River catchment is scarce. The data used was obtained from the WR90 reports and the sedimentation report on the Orange River Basin (November 1997), which was compiled as part of the Orange River Development Replanning Study (ORRS) suite of reports.

The sedimentation data, as listed in **Table 6.5.1** is courtesy of the ORRS report, mentioned above.

The present rate of sedimentation in the Boegoeberg Dam is extremely low. The upstream dams in the upper Orange and Vaal Rivers have considerably decreased the average concentration of sediment in the Boegoeberg Dam such that surveys conducted 24 years apart (1959 and 1983) showed an increase of 2,1% (39,1 to 41,2%). Based on these figures it was felt that the Boegoeberg Dam is in a state of sediment equilibrium with sediment being washed out at the same rate that it is being deposited (DWAF, 1997).

Figure 6.5.1 shows the sediment accumulation potential for the quaternary catchment in the WMA.

Table 6.5.1: Recorded Reservoir Sedimentation Rates for Reservoirs in the Lower Orange Water Management Area (LOWMA)

QUARTER-NARY CATCH-MENT NO.	RIVER	DAM NAME	ECA (km^2)	PERIOD	V_T ($10^6 m^3$)	V_{50} ($10^6 m^3$)	SEDIMENT YIELD ($t/km^2/a$)
D72C	Orange	Boegoeberg	89 752	1931-1983	14,272	14,066	4,23
D61M	Ongers	Smartt Syndicate	13 114	1912 – 1980	2,175	1,950	4,01
D54B	Van Wyksvlei	Van Wyksvlei	1 339	1884 – 1979	2,248	0,049	36,52
D61E	Dorp	Victoria West	280	1924 – 1954	0,44	0,545	52,5

ECA = Total catchment area — catchment area of next major dam upstream.

V_T = Sediment volume at end of period.

V_{50} = Estimated sediment volume after 50 years at the same average yield.

No recorded sedimentation data is available at the proposed reservoir development site at Vioolsdrift.

CHAPTER 7: WATER BALANCE

7.1 METHODOLOGY

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 orgnisations 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 reader is also referred to the WSAM Data Preparation and Processing report, for a more complete description of the data in the WSAM 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 components of the WSAM still being under development, a simplified approach was adopted in the interim as set out in this section. For this reason, the WSAM is not described fully this report. The reader is referred to the WSAM user manual for more information on the 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 problems still in the process of being addressed:

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

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modelling procedure. 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 mostly accepted to be correct. In order to facilitate the production of the WRSA reports, this data was extracted from the WSAM into a spreadsheet and various worksheets set up, which reference this extracted data. These worksheet were structured so as to present most of the information required for the tables of this report. This is not only limited to water requirements, but also lists land uses such as irrigated areas, afforested areas, population, 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 quarternary catchment resolution was abstracted for information purposes only. It is attached in the Appendixes to this report.

Water requirements or return flows 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 assumed to be 10% (except in the areas of the LOWMA remote from the Orange River, as indicated in Section 5.6.4 of this report).

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 as follows:

- The water balance produced by the WSAM, as described in paragraph 7.1.2 above, was mostly deemed to be correct.

  - Runoff into minor dams

    The WSAM asumes that the runoff into minor dams is equal to the entire incremental flow generated within a quarternary 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 afforestation and alien vegetation on catchment yield

    An initial water balance was calculated using the WSAM, as described in paragraph 7.1.2 above, with the forestry and alien vegetation set to zero. Their impacts were then accounted for external to the model when calculating 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 (deficits) 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.

7.2 OVERVIEW

The water balance was investigated at the outlet of each of the selected drainage areas. See **Figure 7.2.1**. The quaternaries at each outlet are given in **Table 7.2.1**. A comprehensive list of all the quaternaries per drainage area is provided in **Appendix D.2.**

Table 7.2.1 : Key Points for Yield Determination

LOCATION OF KEY POINT		DESCRIPTION
DRAINAGE AREA	OUTLET QUATERNARY	
Ongers	D62J	Secondary Drainage Region D6, and tributary of Ongers River into Orange River
Boegoeberg	D72C	Location of Boegoeberg Dam on Orange River
Neusberg	D73F	Location of Neusberg Weir on Orange River
Nossob-Molopo	D42E	Part of Secondary Drainage Region D4, and tributary of Molopo River into Orange River
Sak-Hartbees	D53J	Secondary Drainage Region D5, and tributary of Hartbees River into Orange River
Vioolsdrift	D82E	Location of Vioolsdrift Weir and possible Vioolsdrift Dam on Orange River
Namibia	Z20A	Tributary of Fish River into Orange River, but area includes parts of Namibia supplied from Orange.
Alexander Bay	D82L	Outflow of Orange River into the sea
Coastal	Various	Primary Drainage Region F, which has multiple outlets to the sea
LOWER ORANGE WMA	D82L	Outflow of Orange River into the sea

The tributaries to the Orange and the Coastal area all appear to be approximately in balance for the 1995 scenario. In other words, the balance shows a very small surplus or deficit. The balance for the key points on the lower Orange River show deficits if viewed in isolation, due to higher water requirements and losses than yield. However, their cumulative balance is still in surplus due to unutilised surplus yield from the upper Orange. The actual surpluses at these locations depend on the accuracy of water requirements and yields in Lesotho, the Upper Orange WMA and the Upper, Middle and Lower Vaal WMA's. Surpluses in some of these WMA's are also dependant on other

WMA's due to inter-WMA transfers, such as those between the Upper Vaal WMA and the Crocodile, Olifants, Usutu and Tugela Rivers. The transfers from the Komati system to the Olifants also impact on the Upper Vaal in terms of the volume of water to be transferred from the Vaal to the Olifants. Surplus yields in the Lower Orange Water Management Area (LOWMA) can therefore not be evaluated in isolation, but must be considered in the context of the water resource situation for a large proportion of the country and outside its borders into Lesotho, Botswana and Namibia. The figures presented for surpluses in the Orange River are therefore necessarily subject to change as data or modelling changes occur in the upstream WMA's. The surplus yields illustrated for the LOWMA are taken directly from those at Alexander Bay, as representing the majority of the WMA. This excludes the deficits in the drainage areas remote from the Orange River, but includes the contributions from the entire Orange and Vaal drainage regions. The water requirements for the year 1995 are listed in **Table 7.2.2**, while a comparison between the requirements and availability is listed in **Table 7.2.3**

7.3 DISCUSSION OF RESULTS

Due to the WSAM not being fully completed, a number of simplifications were employed to derive these results. Furthermore, there are a number of known data limitations, which have been referred to throughout this report. These issues all have bearing on the yield balance results. The information provided here should therefore be regarded as draft estimates, being neither final nor highly accurate.

The discussion below is based on the results in **Table 7.2.3** and general knowledge of the area. The description presented for each drainage area is broad, seeing that the WSAM is not yet available to give the balance at each quaternary. Specific localised problem areas could potentially have been overlooked.

7.3.1 Tributaries: Ongers, Sak-Hartbees, and Nossob-Molopo

All of the above tributaries show small deficits at their outlets. Their role in the system is very similar, and they will therefore be discussed together. The little amount of yield generated at the dams in these catchments is generally used at or near the dam, to prevent it being lost through evaporation in the river channel. None of the dams therefore contribute any yield to the Orange River. In terms of run-of-river yield, the runoff in these areas is low and sporadic, and makes almost no firm run-of-river yield available for use. However, although neither dam yield nor run-of-river yield are passed on to the Orange River, unutilised runoff is made available to the Orange River. This runoff, although sporadic, can be turned into yield by storage in the Orange River such a possible Vioolsdrift Dam. The benefit which could be derived from this yield is likely to be small, as inflows from the tributaries often occur during flood flows in the Orange, when any storage dams would be spilling anyway. The only benefit would therefore be from tributary inflows during the dam's critical period without it spilling. The contribution that this water could make to yield is therefore obviously very small. It must however be remembered that the water balanced quoted reflects dam and run-of-river yield, and not variable flow. It is therefore possible that these tributaries could make runoff contributions to the Orange River despite their being in deficit. The deficits could be due to model and data limitations, or could also mean that water requirements are supplied at lower assurance than simulated in the WSAM.

7.3.2 Tributaries: Namibia

In order to present an estimated balance for Namibia it was necessary to mix quaternary information at the outlet of the Fish River with other information on the region, including areas supplied from the Orange River. The figures presented therefore attempt to illustrate the net effect of Namibia on the Orange River, but this approach involves simplifying assumptions and may not be very accurate. With this understanding, the comments made in Section 7.3.1 above on tributaries to the Orange River also relate in many respects to the Fish River. Preliminary results indicate that the Fish River itself (catchment Z20A) has a small surplus. However, it is well known that the Fish River only makes occasional contributions to the Orange River. It is therefore likely that certain of the data in the catchment may require adjustment once the model is finalised, such as proportion of inflow commanded by the dams, and proportions of dam areas exposed to evaporation during the critical period, as well as river losses. The local surplus in the Fish catchment shows up as a deficit in **Table 7.2.3** as a result of the inclusion of water requirements (mainly irrigation) supplied with Orange River water.

7.3.3 Main Stem: Boegoeberg, Neusberg, Vioolsdrift and Alexander Bay

These key points along the Orange show a decrease in surplus yield in a downstream direction. The surplus comes mainly from the Upper Orange WMA, as the lower Vaal WMA does not pass much surplus yield to the Orange. The decrease of surplus downstream is due to river losses and abstractions. The decrease between Boegoeberg and Alexander Bay is in the order of $1\,000 \times 10^6$ m^3/a, which is approximately equal to the sum of river losses and water requirements between these two locations. This is due to the lack of additional storage in the river for generating additional yield.

7.3.4 Coastal Area

The coastal area shows a net deficit. Preliminary results indicate a small surplus for the Buffels River (F30G), but this is balanced out by small deficits in the other catchments. Despite the limited amount of information available for this region, the illustrated situation of the catchments being approximately in balance is thought to be reasonable. This is also confirmed by the fact that Kleinsee, which is located at the mouth of the Buffels River, relies on Orange River water piped via Springbok rather than on the Buffels River.

Table 7.2.2: Water Requirements by Drainage Area in 1995

Catchment						Streamflow Reduction Activities		Water Use		Water Requirements (1:50)						Ecological Reserve *	Total
Primary		Secondary		Tertiary (Drainage Area)													
No,	Description	No,	Description	No,	Description	Afforestation	Dryland Sugar Cane	Alien Vegetation	River Losses	Bulk	Irri-gation	Rural	Urban	Hydro-Power	Water Transfers Out Of WMA		
						(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)	(10^6 m³/a)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0,0	0,0	0,6	0,0	0,0	0,0	3,6	4,2	0,0	0,0	0,0	8,4
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0,0	0,0	3,7	0,0	0,0	11,4	5,4	1,6	0,0	0,0	0,0	22,1
				D55	Sak-Hartbees (WC)	0,0	0,0	0,1	0,0	0,0	0,2	0,1	0,0	0,0	0,0	0,0	0,5
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	0,0	0,0	0,0	0,0	0,0	1,8	0,2	0,0	0,0	0,0	2,0
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,0	0,0	0,0	1 19,3	0,0	199,2	1,6	3,4	0,0	0,0	-131,5	1 92,1
				D73	Neusberg (NC)	0,0	0,0	0,1	1 31,0	0,0	383,2	2,4	9,0	0,0	0,5	5,5	5 31,6
				D81, D82	Vioolsdrift (NC)	0,0	0,0	0,0	1 63,0	3,5	162,0	1,6	1,2	0,0	5,6	0,0	3 36,9
				D82	AlexanderBay (NC)	0,0	0,0	0,0	1 14,0	3,4	18,5	0,3	0,4	0,0	0,7	0,0	1 37,3
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	4,3	5 27,3	6,9	774,3	16,8	20,0	0,0	6,7	-126,0	1 230,3
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,1	0,0	0,0	0,2	0,1	0,0	0,0	0,0	0,0	0,5
	TOTAL IN PRIMARY CATCHMENTS C + D					0,0	0,0	4,4	5 27,3	6,9	774,5	16,9	20,0	0,0	6,7	-126,0	1 230,8
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0	0,0	0,0	0,0	2,1	0,0	1,8	3,9	0,0	0,0	0,0	7,8
				F50	Coastal (WC)	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,2	0,0	0,0	0,0	0,4
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	0,0	0,0	0,0	2,1	0,0	1,8	3,9	0,0	0,0	0,0	7,8
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,2	0,0	0,0	0,0	0,4
	TOTAL IN PRIMARY CATCHMENT F					0,0	0,0	0,0	0,0	2,2	0,0	1,9	4,1	0,0	0,0	0,0	8,2
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						0,0	0,0	4,3	527,3	9,0	774,3	18,6	23,9	0,0	6,7	-126,0	1 238,1
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,0	0,0	0,1	0,0	0,1	0,2	0,2	0,2	0,0	0,0	0,0	0,9
TOTAL IN LOWER ORANGE WMA						**0,0**	**0,0**	**4,4**	**527,3**	**9,1**	**774,5**	**18,8**	**24,1**	**0,0**	**6,7**	**-126,0**	**1 239,0**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	0,0	0,0	0,0	0,0	10,5	68,1	21,6	2,4	0,0	0,0	0,0	1 02,7
TOTAL IN REPORTING AREA						**0,0**	**0,0**	**4,4**	**527,3**	**19,6**	**842,6**	**40,4**	**26,6**	**0,0**	**6,7**	**-126,0**	**1 341,7**

* The ecological reserve is based on the impact on the 1:50 year yield & not the estimated values as detailed on table 5.2.4.1.

Table 7.2.3: Water Requirements and Availability

Catchment						Available in 1:50 Year yield in 1995			Water Transfers at1:50Year Assurance		Return Flows at 1:50Year Assurance		Water Require-ments at 1:50 Year Assurance	Local Water Balance*	Received from Upstream	Water Balance at 1:50 Year Assurance **
Primary		Secondary		Tertiary (Drainage Area)												
No,	Description	No,	Description	No,	Description	Surface water	Ground Water	Total	Imports	Exports*	Re-usable	To Sea				
						$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$	$(10^6 m^3/a)$
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	2,0	3,44	5,44		0,0	0,3		8,4	-2,96	0,0	-2,96
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	3,09	9,66	12,75		0,0	0,0		22,1	-9,35	0,0	-9,35
				D55	Sak-Hartbees (WC)	0,06	0,05	0,11		0,0	0,0		0,5	-0,39	0,0	-0,39
		D4	Molopo	D42	Nossob-Molo (NC)	0,0	2,51	2,51		0,0	0,0		2,0	0,51	0,0	0,51
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0,0	3,89	3,89		0,0	19,92		192,1	-188,21	2 885,0	2 696,79
				D73	Neusberg (NC)	0,0	0,93	0,93		0,46	39,07		531,6	-531,13	2 696,3	2 165,17
				D81, D82	Vioolsdrift (NC)	0,0	1,42	1,42		5,56	16,20		336,9	-341,04	2 165,2	1 824,16
				D82	AlexanderBay (NC)	0,0	0,2	0,2		0,67	0,0	1,85	137,3	-137,77	1 829,0	1 691,23
	TOTAL IN NORTHERN CAPE PROVINCE					5,09	22,05	27,14	0,0	6,69	75,49	1,85	1 230,3	-1 200,99	2 885,0	8 374,51
	TOTAL IN WESTERN CAPE PROVINCE					0,06	0,05	0,11	0,0	0,0	0,00	0,00	0,5	-9,35	0,0	-9,35
	TOTAL IN PRIMARY CATCHMENTS C + D					5,15	22,1	27,25	0,0	6,69	75,49	1,85	1 230,8	- 1 210,34	2 885,0	8 365,16
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0,0	2,54	2,54		0,0	0,0		7,8	-5,26	0,0	-5,26
				F50	Coastal (WC)	0,0	0,15	0,15		0,0	0,0		0,4	-0,25	0,0	-0,25
	TOTAL IN NORTHERN CAPE PROVINCE					0,0	2,54	2,54	0,0	0,0	0,0	0,0	7,8	-5,26	0,0	-5,26
	TOTAL IN WESTERN CAPE PROVINCE					0,0	0,15	0,15	0,0	0,0	0,0	0,0	0,4	-0,25	0,0	-0,25
	TOTAL IN PRIMARY CATCHMENT F					0,0	2,64	2,64	0,0	0,0	0,0	0,0	8,2	-5,51	0,0	-5,51
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						5,09	24,59	29,68	0,0	6,69	75,49	1,85	1 238,1	-1 206,25	2 885,0	1 678,75
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0,06	0,20	0,26	0,0	0,0	0,0	0,0	0,9	-9,60	0,0	-9,60
TOTAL IN LOWER ORANGE WMA						**5,15**	**24,79**	**29,94**	**0,0**	**6,69**	**75,49**	**1,85**	**1 239,0**	**-1 215,85**	**2 885,0**	**1 669,15**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	98,7	-	98,7		0,0	6,8	-	102,7	4,0	0,0	4,0
TOTAL IN REPORTING AREA						**103,8**	**24,79**	**128,64**	**0,0**	**6,69**	**82,3**	**1,85**	**1 341,7**	**-1 211,85**	**2 885,0**	**1 673,15**

* To avoid double accounting, water exports within the WMA are not included in the "water requirements" column. Water losses and water exports from the WMA are included

** Negative numbers indicate deficits.

CHAPTER 8: COSTS OF WATER RESOURCES DEVELOPMENT

8.1 METHODOLOGY

The future water resources development in the Lower Orange Water Management Area (LOWMA) has been addressed in terms of surface and groundwater opportunities. Additional boreholes for each drainage area have been addressed as there is considerable potential for the groundwater harvesting. Only one surface water impoundment was considered, that being a new dam at Vioolsdrift, which is one of the development options proposed in the Orange River Development Replanning Study (ORRS) Reports.

The cost functions as supplied by DWAF have been used for both the surface and groundwater development estimates.

The surface water cost function only considers that cost of the dam itself and does not include appurtenant works such as a purification works or distribution system. The dam cost was deemed to be so much greater than the appurtenant works that it was decided to omit such costs from the cost function. **Diagram 8.1.1** details the surface water cost function.

The ground water cost function has been estimated as the cost to develop 1 kℓ of water per annum. The cost includes all evaluations, borehole siting, drilling, test pumping and equipping of the boreholes with positive displacement pumps and electricity driven motors.

The costs will vary from area to area, particularly in the LOWMA due to its expanse. The main variable factors affecting the cost are:

- availability of existing information.
- borehole yield obtainable (8 hours/day pumping).
- drilling depth.
- drilling success rate.
- drilling conditions.

The cost is based on the borehole deliver rate which therefore makes this factor the critical item.

Diagram 8.1.2 details the estimated development cost for different borehole yields with an upper and lower range.

Table 8.1.1 indicates the gross storage volume for the Vioolsdrift dam and its corresponding incremental yield. It also includes the number of boreholes that theoretically can be sunk to harvest the available groundwater per drainage area.

The 1995 dam and groundwater costings are provided from a year 2000 base date in accordance with the escalation rate factors supplied by DWAF.

Diagram 8.1.1 : Capital Costs of Dams

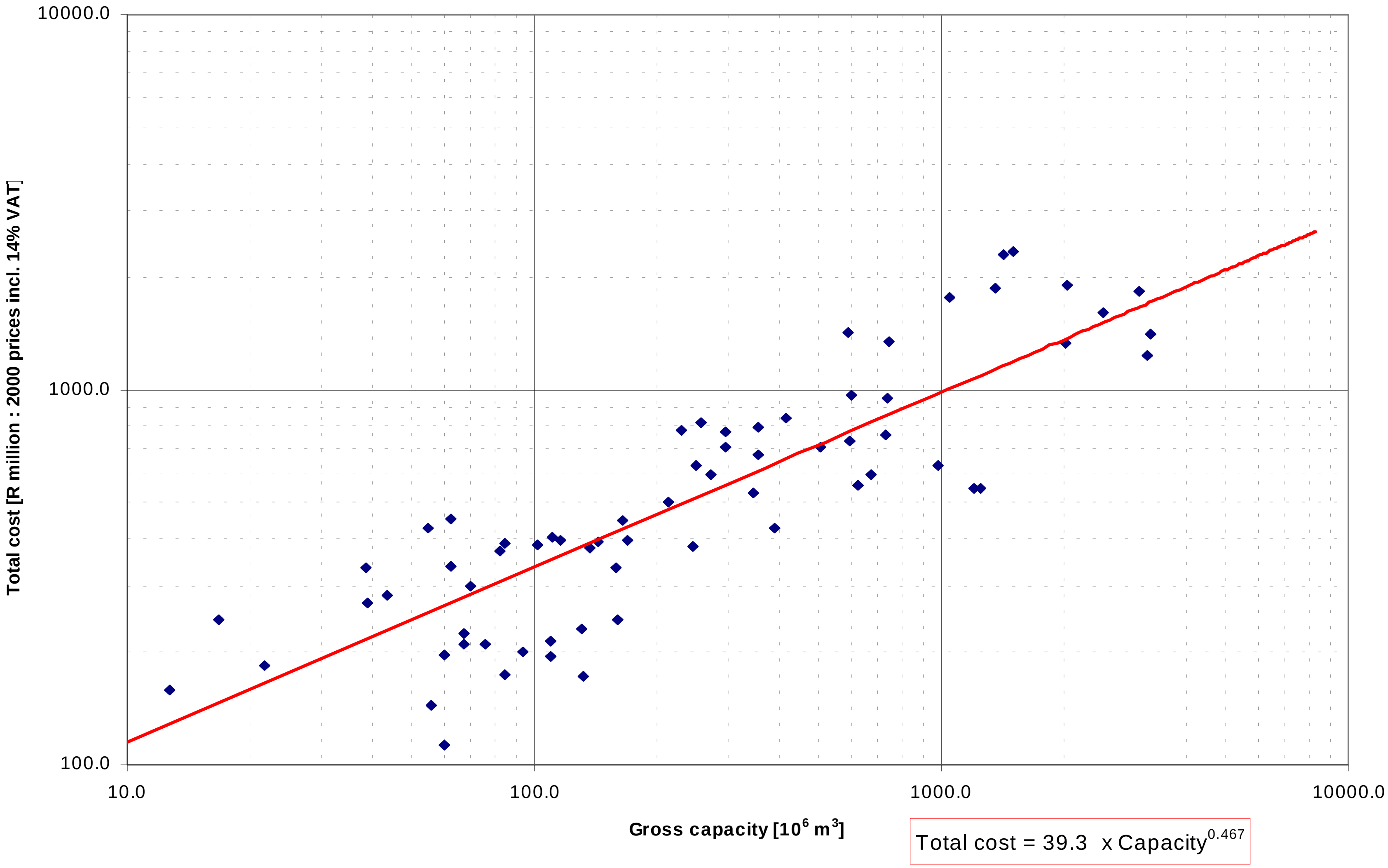


Diagram 8.1.2 : Groundwater Development Cost

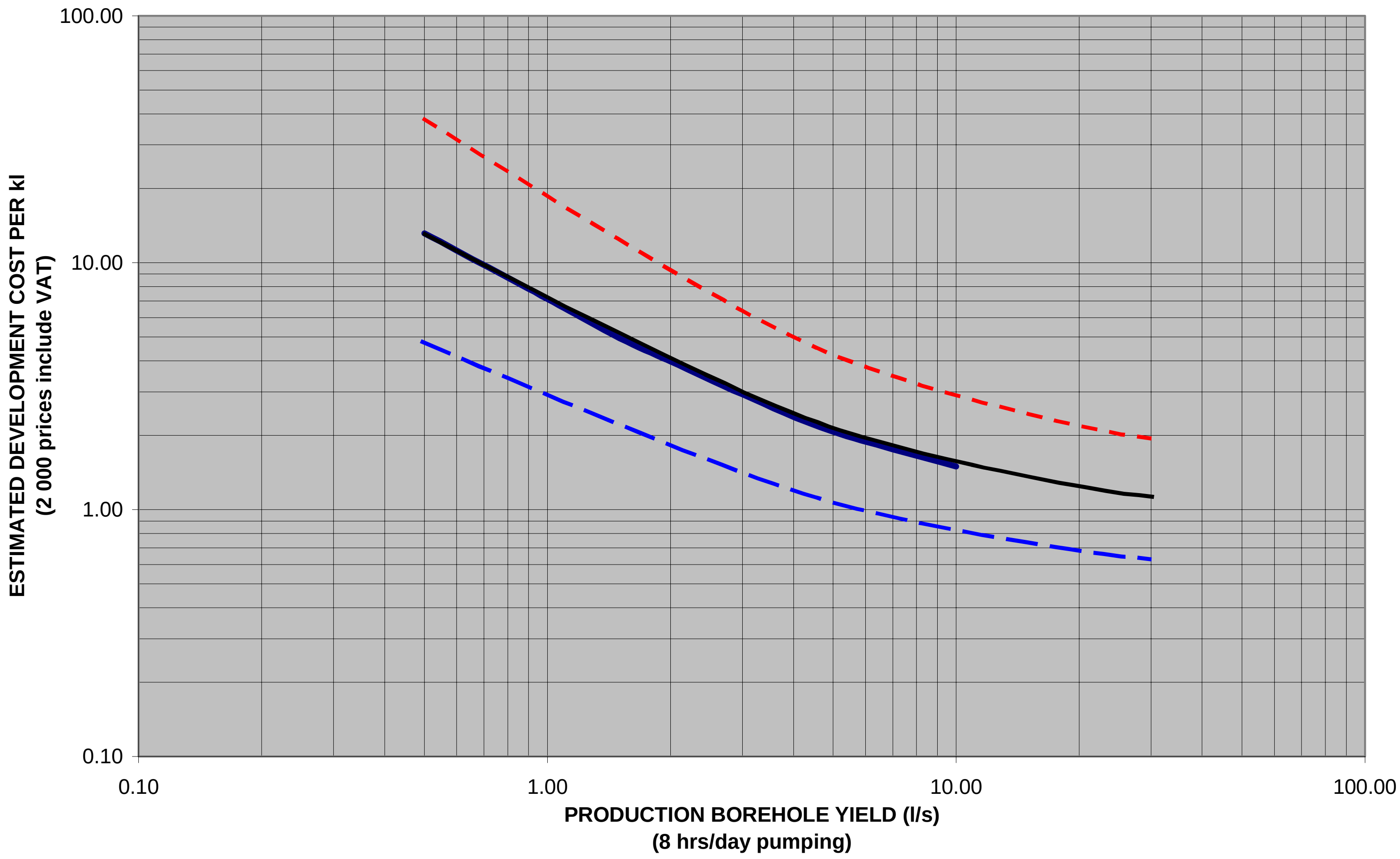


Table 8.1.1: Costs of Water Resource Development

Catchment						Development Options		Incremental Yield		Estimated Cost (Including 14% VAT)			
Primary		Secondary		Tertiary (Drainage Area)		Gross Storage Volume	Number of Boreholes*	Dams	Groundwater	Dams (1995)	Groundwater (1995)	Dams (2000)	Groundwater (2000)
No,	Description	No,	Description	No,	Description	(10^6 m³/a)	(Number)	(10^6 m³/a)	(10^6 m³/a)	(R1 000 000)	(R1 000 000)	(R1 000 000)	(R1 000 000)
C,D (Part)	Orange	D6	Ongers	D61, D62	Ongers (NC)	0	3 266	0	64,8	0	397	0	610
		D5	Hartbees	D51 to D58	Sak-Hartbees (NC)	0	8 380	0	132,4	0	995	0	1 531
				D55	Sak-Hartbees (WC)	0	170	0	2,7	0	20	0	31
		D4	Molopo	D42	Nossob-Molo (NC)	0	1 280	0	9,1	0	143	0	219
		C9, D7, D8	Orange	C92, D71, D72	Boegoeberg (NC)	0	2 606	0	42,7	0	297	0	457
				D73	Neusberg (NC)	0	2 396	0	18,5	0	244	0	376
				D81, D82	Vioolsdrift (NC)	2 220	1 740	288	10,3	975	142	1 500	219
				D82	AlexanderBay (NC)	0	70	0	0,7	0	8	0	12
	TOTAL IN NORTHERN CAPE PROVINCE					2 220	19 738	288	278,5	975	2 226	1 500	3 424
	TOTAL IN WESTERN CAPE PROVINCE					0	170	0	2,7	0	20	0	31
	TOTAL IN PRIMARY CATCHMENTS C + D					2 220	19 908	288	281,2	975	2 246	1 500	3 455
F (Part)	Coastal	F1 to F5	Coastal	F10 to F50	Coastal (NC)	0	2 180	0	18,1	0	229	0	352
				F50	Coastal (WC)	0	114	0	0,94	0	12	0	18
	TOTAL IN NORTHERN CAPE PROVINCE					0	2 180	0	18,1	0	229	0	352
	TOTAL IN WESTERN CAPE PROVINCE					0	114	0	0,94	0	12	0	18
	TOTAL IN PRIMARY CATCHMENT F					0	2 294	0	19,04	0	241	0	371
TOTAL IN LOWER ORANGE WMA IN NORTHERN CAPE PROVINCE						2 220	21 918	288	296,6	975	2 455	1 500	3 776
TOTAL IN LOWER ORANGE WMA IN WESTERN CAPE PROVINCE						0	284	0	3,64	0	32	0	49
TOTAL IN LOWER ORANGE WMA						**2 220**	**22 202**	**288**	**300,2**	**975**	**2 487**	**1 500**	**3 826**
Z (Part)	Namibia	Z1, Z2	Namibia	Z10, Z20	Namibia	0	8 824	0	46,4	0	-	0	-
TOTAL IN REPORTING AREA						**2 220**	**31 026**	**288**	**346,6**	**975**	**2 487**	**1 500**	**3 826**

* The number of boreholes per drainage area has been determined from the unused groundwater exploitation potential in that specific drainage area, taking cognisance of the drainage area's average borehole yield.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The nature and extent of the Lower Orange Water Management Area (LOWMA) results in different problems being encountered along the Orange River to those experienced in land or along the coast.

Based on the results presented in this report, the following conclusions can be drawn:

- **Water Requirements**

  The estimated consumptive water requirements for the Lower Orange Water Management Area (LOWMA) are summarised in **Table 5.1.1**, and equate to 1 502 million m³/a (1 365 million m³/a at 1:50year assurance). The dominant sectors along the Orange River are irrigation and river losses, which together constitute approximately 95% of the total requirement. The dominent sectors in the interior are urban and rural use followed by irrigation. The ecological Reserve has been omitted from these figures due to the difficulty in ascertaining accurate and reliable figures.

  The Namibian consumptive water requirements, for the catchment areas impacting on the Orange River, have been crudely estimated at 103 million m³/a for a 1:50 year assurance. The governing sectors are irrigation followed by rural, bulk and urban use.

- **Water Resources**

  The estimated surface water and groundwater resources in the Lower Orange Water Management Area (LOWMA) are summarised in **Table 6.1.1**, and equate to 35 million m³/a (excluding runoff from the Fish River in Namibia).

  Water quality is becoming more and more important as the availability of water resources becomes more and more scarce. There are very few water quality measuring stations in the LOWMA with acceptable records for assessing the water quality in the WMA. This is partly due to the arid nature of the catchment. It is however important that these facilities be provided and maintained for future studies of this nature so that warning signals are seen timeously and allow the necessary remedial measures to be taken.

  The mineralogical ground water quality varies from marginal to completely unacceptable with the affect that almost half of the WMA has a potable water rating of less than 30%. A band along the southern and eastern boundary including Sutherland, Carnarvon, Victoria West, De Aar, Prieska and Griekwastad has a moderate (50%) to high (90%) potable groundwater source. (This data is based on information varying between 1995 to 2000.)

  The mineralogical surface water quality along the Orange River in the LOWMA is classified as “good” with a TDS range between 260 and 600 mg/ℓ.

There was insufficient data available across the rest of the WMA to be able to provide a water quality rating.

This risk of groundwater contamination is medium to high in the area where the groundwater potability is good. This generally occurs in the populated areas with poor sanitation systems. The central band of the WMA carries a low risk rating.

The area immediately downstream of Upington carries a medium faecal contamination of surface water rating, due to the sewage plant at Upington. The rest of the WMA carries a very low risk, due to the lack of surface water and no sewage plants providing return flows.

There is very little data available for Namibia. Microbiological impacts are unknown while mineralogical groundwater quality is expected to be poor with a resulting low percentage of the water being potable.

- **Water Balance**

It is clear from the figures given above for total water requirements and resources, that the Lower Orange Water Management Area (LOWMA) is a net recipient of water. The shortfall is supplied mainly from yield generated in Lesotho and the Upper Orange WMA, and also to a lesser extent from the Vaal River. Water is received from the Van der Kloof Dam, in the Upper Orange WMA, either from releases for hydro-power generation or as irrigation water for irrigators in the LOWMA. Flood spills are naturally passed onto the LOWMA.

The water received from the Vaal River is generally flood water as there are considerable demands on the Vaal system, fully utilising the available resources.

The surface water consumption and especially the surface water available for further exploitation in the Lower Orange Water Management Area (LOWMA) is highly dependant on the water use in the upstream catchments. Changes in water consumption patterns, dam operating rules, hydropower releases etc also have a significant impact on the incremental yields that can be derived by providing additional storage in the Lower Orange Water Management Area (LOWMA). It is imperative that water resources are interpreted not only locally, but also in the context of a larger system (ie including Upper Orange WMA) and in a national context, since water is a national resource.

- **Costs of Water Resource Development**

The surface water resources of the Lower Orange Water Management Area (LOWMA) can be increased by approximately 288 million ^{3}/a, through the construction of a large dam at Vioolsdrift. The dam, with a gross storage capacity of 2 220 million m^3, is estimated to cost approximately R1,5 billion (2000 base date) that groundwater yield can be increased by approximately 300 million m^3/a, at an estimated cost of R3,83 billion (2000 base date). Due to the cost, groundwater resource development is considered more feasible for small scale, local supply than for major regional supply.

9.2 RECOMMENDATIONS

Based on the study results presented in this report, and observations by the study team while preparing the information, the following recommendations are made:

- **Study Areas**

  Virtually every study on the mainstem Orange River has broken the river course into different reaches. This often poses problems when correlating data from previous reports to current data.

  A similar situation was encountered with the large stock data, which was based on magisterial districts. Considerable reworking of data was required to put it into the format required for this study.

  The creation of the Catchment Management Agencies will hopefully provide a more regulated framework within which future water related information can be recorded.

- **Infrastructure**

  The infrastructure database is incomplete and needs to be further updated. This will require greater input from the various service providers and municipalities who did not provide information when previously approached. The DWAF Kimberley office is/will be attending to this matter as part of the CMA's requirements. It is assumed that this data will be made available to the Water Resources Planning Directorate.

- **Ecological Reserve**

  The determination of the ecological Reserve is always a contentious issue, and this case is no exception. The ecological importance and sensitivity of the rivers, established for this study are general and unrefined estimates. The ecological Reserve has a major impact on the Lower Orange Water Management Area (LOWMA) and needs careful attention.

  There is also limited information available in the parts of the LOWMA away from the mainstem Orange River, regarding input data for the determination of the ecological Reserve. Such a database needs to be created to improve the confidence level of the information provided for the reserve. These are unlikely to have a significant effect on the flows in the Orange River, but are important for local management of the tributary rivers.

- **Mines**

  Future studies of this nature must be aware of the opening and closing of mines in the Lower Orange Water Management Area (LOWMA). Numerous mines have closed in the not too distant past, albeit that most of them are relatively small scale. The proposed mine at Ghamsberg has held a water allocation for many years but has never exercised it. The re-assigning of water rights (entitlements) must be borne in mind with the closure of mines in the future eg. the speculated closure of O'kiep Copper Company in the near future.

- **Namibian Data**

  The Namibian data is very superficial and requires far more in-depth study, which should take place in collaboration with DWAF's Namibian counterpart. The proportion of runoff commanded by dams in the Fish River basin (Z20A quaternary catchment) also requires clarification. The Scorpion mine, currently under construction, will also impose an additional demand on the Orange River resources.

- **Irrigation**

  Irrigation is the largest water use sector in the Lower Orange Water Management Area (LOWMA), and yet there is a general lack of accurate information concerning its water requirements. There are a few key items in the irrigation component which need to be addressed in terms of improving the quality of the data base. They are :

  - The use of crop requirements versus actual scheduled areas, including the crop factors and seasonal distributions associated with the data.

  - The scheduled areas themselves, in terms of the new water law and the licensing procedure currently being undertaken by DWAF : Kimberley on behalf of the CMA.

  - Better information is required on the current practice of opportunistic irrigation through rainfall harvesting. This practice greatly affects the rainfall runoff entering the river system, but is only supplied at a very low assurance.

  - A better measurement of the return flows from irrigation back to the river course.

  - Better understanding of the economic impact of restrictions is required as a sound basis for determination of assurance profiles in the irrigation sector.

- **River Losses**

  River losses consume a large proportion of the surface water resources in the LOWMA. The manner in which the river losses were estimated and the overlap with riparian alien vegetation and dam surface areas must be re-addressed, as the chances of double counting and the impact on the water consumption are critical issues. The behaviour of river losses in ephemeral rivers such as the Fish and Molopo rivers should be given consideration.

  The wetlands/pans, particularly in the Sak-Hartbees drainage area, also play a role in the river losses. Water enters theses pans and does not flow from there unless in flood. The impact on yield needs to be considered, so that they can be represented in a sensible fashion.

- **Alien Vegetation**

  There was much dispute over the alien vegetation coverage in the Lower Orange Water Management Area (LOWMA). The CSIR Figures were accepted for this particular study, although clarity is required in terms of its application. Information is also required on the riparian proportion of the infested areas, and their potential overlap with river loss estimates. The water consumption by alien vegetation is a phenomenon which affects runoff and therefore also the availability of water to other user sectors. Once clarity has been obtained concerning the degree of alien infestation and its impact on yield, the Water Situation Assessment Model (WSAM) will be a useful tool to evaluate the benefits of eradication projects.

- **Water Allocations**

  A number of discrepancies were found in records of irrigation water allocations between previous reports and permits as per the various registers. This is an important factor that must be re-addressed, especially with irrigation being the largest water use sector in the WMA. Once again the DWAF registration process is expected to provide accurate input for further analyses.

- **Groundwater**

  The information in the groundwater database used in this study needs to be updated. The Lower Orange Water Management Area (LOWMA) is highly dependant on groundwater in regions away from the main stem of the Orange River. The data base reflects zero usage in many outlying quarternaries where groundwater is the only possible source. There are discrepencies between the information received and recorded in Table 6.2.1 and that entered into the WSAM data base.

- **Dam Critical Area**

  Evaporation is a critical aspect in the Lower Orange Water Management Area (LOWMA). The average proportion of a dam’s full supply area exposed to evaporation over the critical period needs to be established, particularly in arid areas where yield is extremely sensitive to evaporation from dams. Consideration should be given to allowing the WSAM to adjust the area proportion based on the surplus yield, which could account for both operating rules and aridity of the catchment.

- **Water Quality**

  The surface water mineralogical component is based on a limited number of sampling points. Additional points need to be established to generate better information. The groundwater mineralogical data is based on estimates from previous maps. Groundwater measuring points also need to be established.

  A limitation of the microbial contamination 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 re-plotted. Monitoring data from selected areas should also be collected to assess the validity of the vulnerability assessment presented in this report.

- **Water Balance**

  The estimates of surplus yields in the Lower Orange Water Management Area (LOWMA) are dependant on input information as well as modelling of the upstream catchments. The water balances in the Lower Orange Water Management Area (LOWMA) will require re-visiting as and when the database is improved.

REFERENCES

Alien Vegetation

Le Matre, Versfeld, Chapman, November 1999. The impact of Invading Alien Plants on Surface Water Resources in South Africa: A Preliminary Assessment

Nel, van Wilgen, Gelderblom, January 1999. The Contribution of Plantation Forestry to the Problem of Invading Alien Trees in South Africa : A Preliminary Assessment.

DWAF. (1998). "Memorandum : Methodology for Incorporation of Alien Vegetation Impacts in the National Water Balance Model" Appendices to DWAF report: "Water Balance Model National Database: Data collection and processing." Görgens.

DWAF. (1994). The Surface Water Resources of South Africa 1990. Volumes 1 to 6. Report to the Water Research Commission, Pretoria. Midgley, DC, Pitman, WV, and Middleton, BJ.

DWAF. (1997). Alien Invading Plants and Water Resources in South Africa. Report to the Water Research Commission, Pretoria. Versfeld, DB, le Maitre, DC, and Chapman, RA.

CSIR (1995). Handy Reference Manual on the Impacts of Timber Plantations on Runoff in South Africa. Forestek, Stellenbosh

Department of Water Affairs and Forestry (2000). Water Situation Assessment Model User Manual.

Ninham Shand (Pty) Ltd (1999). Interim Adjustment of WR90 Quaternary Naturalised Flows to Reflect CSIR Afforestation-Related Streamflow Reduction Activities.

Demography

DWAF. (2001). Report PRSA/00/2200. The Distribution of South Africa's Population, Economy and Water Usage into the Long-term Future: Report on Phase 2. to the Department of Water Affairs and Forestry. Schlemmer, L, MarkData (Pty) (Ltd), and Eric Hall and Associates.

Environmental

Abrahams, A. (2001). Draft Management Plan for the Orange River Mouth Northern Cape Nature Conservation Services.

Branch, W. R. 1988. South African Red Data Book — Reptiles and Amphibians. South African National Scientific Programmes Report No 151.

Beaumont, P. B., Van Zinderen Bakker, E. M and Vogel, J. C. (1984). Environmental Changes since 32 000 BP at Kathu Pan, Northern Cape. In Late Cainozoic Palaeoclimates of the Southern Hemisphere, Vogel, G C (ed.), Proceedings of the SAQUA Symposium, Swaziland 1983. Balkema, Cape Town, 329-338.

Beaumont, P B (1984). Aspects of the Northern Cape Pleistocene Project. Pal. of Afr. 15: 41-48.

Brooke, R K (1984). South African Red Data Book — Birds. South African National Scientific Programmes Report No 97.

DWAF. (1995). Report PC 000/00/12894. Orange River Re-Planning Study: The Orange River Valley: Overview of the Natural Environment. Chutter, F.M., Palmer, R.W. and Walmsley J.J.

CSIR. (1985). Report C/SEA 8533. Freshwater Requirements of the Orange River Estuary. Confidential report by the CSIR to the Department of Water Affairs and Forestry.

Cowen, G. I. and Marneweck, G. (1996). South African Report to the RAMSAR Convention. Department of Environment Affairs and Tourism.

Ferrar, AA (1989). The Role of Red Data Books in Conserving Biodiversity. Chapter 8. pp 136-147 In Huntley BJ (ed). Biotic Diversity in southern Africa: Concepts in Conservation. Oxford University Press. 380 pp.

Hamer, M. and Rayner, NA (1996). A Note on the Unusual Crustacean Community of a Temporary pool in the northern Cape. Sth Afr. J. aquatic Sci. 22(1/2): 100-104.

Harrison, J. A., Allan, D. G., Underhill, L. G., Herremans, M., Tree, A. J., Parker V and Brown, CJ (eds) (1997). The Atlas of Southern African Birds, including Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe. Volume 1. Non-passerines. Birdlife South Africa.

Henderson, L (1995). Plant Invaders of Southern Africa. Plant Protection Research Institute Handbook No 5. Agricultural Research Council. Pretoria.

Hendey, QB (1978). Preliminary Report on the Miocene Vertebrates from Arrisdrift, South West Africa. Annals of the South African Museum. 76(1): 1-41.

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.

Jardine, C.L. and Owen, D.R. (1998) Feasibility Study of the Proposed Gariep Transfrontier Conservation Area: Environmental Overview of the South African Section. Internal Report compiled for the Peace Parks Foundation by the Department of Environmental and Geographical Science, University of Cape Town.

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.

DWAF. (1999). A Procedure for the Determination of the Ecological Reserve for the purposes of the National Water Balance Model for South African Rivers. Preliminary Report. Department of Water Affairs and Forestry, Institute for Water Quality Studies. Kleynhans CJ.

DWAF. (1999). Report No ENV-S-C 99077. Prosopis and Groundwater: a Literature Review and Bibliography. Internal report prepared by Environmentek, Stellenbosch, for the Department of Water Afairs and Forestry Working for Water Programme. Le Maitre, D.

(1990). Lloyd, J.W.. The Identification and Evaluation of Potential Conservation Areas along the Orange River between Boegoeberg Dam and Prieska, Northern Cape. Internal Report No 3. Chief Directorate: Nature and Environmental Conservation, Cape Provincial Administration. 20 pp + appendices.

Noble, RG and Hemens, J (1978). Inland Water Ecosystems in South Africa — a Review of Research Needs. South African National Scientific Programmes Report No 34.

Orange River Environmental Task Group (ORETG) (1989). Orange River Ecology — Assessment of Environmental Water Requirement for the Orange River Mouth. Report on the Orange River Environmental Workshop held at Oranjemund, October 1989, compiled by BKS Incorporated.

Orange River Environmental Task Group (ORETG) (1990). Orange River Ecology — assessment of Environmental Water Requirement of the Orange River between PK le Roux dam and the mouth. Report on the Orange River Environmental Workshop held at Golden Gate National Park, August 1990, compiled by BKS Incorporated.

Perkins, JS & Thomas, DSG (1993). Spreading deserts or spatially confined environmental impacts & Land degradation and cattle ranching in the Kalahari desert of Botswana. Land Degradation and Rehabilitation 4: 179-194

Van Rooyen, AF (2000). Rangland degradation in the southern Kalahari. PhD thesis, University of Natal, Pietermaritzburg.

Palmer, AR & van Rooyen, AF (1998). Detecting vegetation change in the southern Kalahari using Landsat TM data. Journal of Arid Environments 39:143-153.

Palmer, RW (1996). Invertebrates in the Orange River, with Emphasis on Conservation and Management. Southern African Journal of Aquatic Sciences 22(1/2): 3-51.

Palmer, R.W (1997). Principles of Integrated Control of Blackflies (Diptera Simuliidae) in South Africa. Water Research Commission Report No 650/1/97. xxv + 307 pp.

Palmer, RW and De Moor, FC (1998). Annotated Records of Blackfly (Diptera: Simuliidae) Distribution in Southern Africa. African Entomology 6(2): 223-251.

Passmore, NI and Carruthers, VC (1979). South African Frogs. Witwatersrand University Press, Johannesburg.

Seaman, MT and Van As, JG (1998). The Environmental Status of the Orange River Mouth as Reflected by the Fish Community. Water Research Commission Report No 505/1/98.

Stuart, C and Stuart T (1997). Guide to Southern African Game and Nature Reserves. Struik Publishers (Pty) Ltd, Cape Town.

Skelton, PH (1987). South African Red Data Book — Fishes. South African National Scientific Programmes Report No 137.

Skelton, PH (1993). A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers. Halfway House

Smithers, RHN (1983). The Mammals of the Southern African Subregion. University of Pretoria Press.

Smithers, RHN (1986). South African Red Data Book — Terrestrial Mammals. South African National Scientific Programmes Report No 125.

Thomas, RJ and Thomas, MA (1989). The Geology of the Noenieput Area. Geological Survey. Department of Mineral and Energy Affairs. Pretoria.

DWAF. (1996). Report No P D000/00/6197. Refinement of the Instream Flow Requirements for the Orange River and Orange River Mouth. Orange River Replanning Study. Venter, A and Van Veelen, M.

Versfeld, DB, Le Maitre DC and Chapman RA (1988). Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment. Report No TT 99/98, Water Research Commission, Pretoria.

Wilcox, AR (1986). Great River. The Story of the Orange River. Drakensberg Publications, Winterton, Natal.

Williams, AJ (1986). Wetland Birds at the Orange River Mouth and their Conservation Significance. Bontebok 5: 17-23.

Williamson, G (1995). Richersveld National Park. National Parks Board. Umdaus Press, Durban. 48 pp.

Versfeld, DB, Le Maitre DC and Chapman RA (1988). Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment. Report No TT 99/98, Water Research Commission, Pretoria.

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Irrigation

BKS. (1991). DWAF report PD000/00/2091. "Hydrology of the Fish River Catchment".

BKS. (1997a). DWAF Report PD000/00/4897. “Orange River Development Replanning Study: Evaluation of Irrigation Water Use”.

BKS. (1997b). DWAF report PD000/00/4497. “Orange River Development Replanning Study: Water Demands of the Orange River Basin”.

BKS. (1999). WRC report 638/1/99. “Evaporation Losses from South African Rivers”.

BKS. (2000). DWAF Report PD000/00/6100. “Orange River System 1999/2000 Operating Analysis.”

DWAF. (1995). "Namibian Water Requirements from the Orange River".

1994. Surface Water Resources of South Africa 1990, Volumes I to VI, WRC Reports No 298/1.1/94 to 298 6.1/94. Midgley, DC, Pitman, WV and Middleton, BJ.

Urban use

DWAF (2001). Report PRSA/00/2200. The Distribution of South Africa's Population, Economy and Water Usage into the Long-term Future: Report on Phase 2. Schlemmer, L, MarkData (Pty) (Ltd), and Eric Hall and Associates.

Water Use and Infrastructure

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Water Resources

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

DWAF (1991) Report PD000/00/2091. "Hydrology of the Fish River Catchment". BKS.

DWAF (1997) Report No PD000/00/4697. Hydrology and System Analysis – Orange River Basin. Orange River Development Replanning Study. BKS.

DWAF (1998). Quality of Domestic Water Supplies. Volume 1 : Assessment Guide.

DWAF (1997). Report PD000/00/5497. “Orange River Development Project Replanning Study: Sedimentation of reservoirs in the Orange River Basin.” BKS.

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.

Vegter, J R (1995). Groundwater Resources of the Republic of South Africa. WRC Project 483.

Water Quality

(Conradie, B. (2000). DWAF, Northern Cape Regional Office.)

(Du Preez, M. (1999). Project Leader, Division of Water, Environment and Forestry Technology, CSIR.)

DWAF. (1996). Report No PD000/00/5295. Environmental Overview of the Orange River. Orange River Development Project Replanning Study.

DWAF. (1998a). Report No PD000/00/5997. Water Quality Aspects — Orange River Basin. Volume 1: Expected Water Quality Changes. Orange River Development Project Replanning Study.

DWAF. (1998b). Report No PD000/00/5997. Water Quality Aspects — Orange River Basin. Volume 2: Water Quality Guidelines. Orange River Development Project Replanning Study.

DWAF. (1998c). Report No PD000/00/5997. Water Quality Aspects — Orange River Basin. Volume 3: Assessment of Water Quality Monitoring Programme. Orange River Development Project Replanning Study.

DWAF. (2000). Water Resources Situation Assessments: Potential Vulnerability of Surface Water and Groundwater to Microbial Contamination. Final report by Ninham Shand, Parsons and Associates and the Institute for Water Quality Studies.

(Knoetze, N, Streit, J. and van Dyk, G (1999). DWAF Northern Cape Office Members, attendees to a workshop on the prioritisation and scheduling of Resource Directed Measures, 1-11 November 1999, DWAF, Pretoria.)

(Van Ginkel, C. (2000). Institute for Water Quality Studies, Department of Water Affairs and Forestry.)

Water Use and Infrastructure

Africon, (1999). “Northern Cape 1st Order Water Services Strategy”.

DWAF. (1997). Report PC000/00/4497. “Orange River Development Replanning Study: Water Demands of the Orange River Basin”. BKS.

DWAF. (1997). Report PC000/00/4297. "Orange River Development Replanning Study: Existing Water Infrastructure in the Orange River Basin". BKS.

DWAF. (1998). Report PC000/00/6797. "Potential Additional Resource Availability from the Orange River". BKS.

DWAF. (1997). Report PC000/00/5497. "Orange River Development Replanning Study: Sedimentation of Reservoirs in the Orange River Basin". BKS.

DWAF Kimberley Office

Namakwa Water Board

Pella Water Board

Various municipalities and District Councils

APPENDICES

APPENDIX A	**DEMOGRAPHIC DATA**
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NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

APPENDIX A

DEMOGRAPHIC DATA

APPENDIX A.1

DEMOGRAPHIC DATA

PER TOWN

APPENDIX A.1

URBAN POPULATION FIGURES, PER TOWN FOR THE 1995 BASE YEAR

Magisterial District	Town	Population data 1995	Quaternary
BRITSTOWN	BRITSTOWN / MZIWABANTU	5 300	D62A
CALVINIA	BRANDVLEI	2 100	D57C
CARNARVON	CARNARVON	5 700	D54B
CARNARVON	VANWYKSVLEI	1 300	D54B
DE AAR	DE AAR/NONZWAKAZI (incl. spoornet & army base)	26 950	D62D
FRASERBURG	FRASERBURG	2 850	D55E
GORDONIA	EKSTEENSKUIL	1 650	D42E
GORDONIA	GROBLERSHOOP	3 350	D73D
GORDONIA	KAKAMAS	6 550	D73F
GORDONIA	KEIMOES	6 950	D73F
GORDONIA	LOUISVALE	700	D73E
GORDONIA	MIER	4 700	D42B
GORDONIA	UPINGTON / PABALLELO	52 850	D73E
HAY	GRIEKWASTAD / MATLHOMOLA	5 000	D71B
HAY	NIEKERKSHOOP	1 200	D71D
HERBERT	CAMPBELL	1 600	C92C
HERBERT	DOUGLAS / BONGANI	9 950	C92C
HOPETOWN	STRYDENBURG	1 750	D62G
KENHARDT	KENHARDT	3 650	D53B
KENHARDT	ONSEEPKANS	1 100	D81F
KENHARDT	POFADDER	2 850	D81G
NAMAQUALAND	AGGENEYS	2 850	D82C
NAMAQUALAND	ALEXANDERBAAI	2 450	D82L
NAMAQUALAND	CAROLUSBURG	1 250	F30C
NAMAQUALAND	CONCORDIA	3 900	D82D
NAMAQUALAND	EKSTEENSFONTEIN	400	D82H
NAMAQUALAND	HONDEKLIPBAAI/BAY	550	F40F
NAMAQUALAND	KAMIESKROON	750	F30C
NAMAQUALAND	KLEINZEE	2 900	F30G
NAMAQUALAND	KOIINGNAAS	800	F40A
NAMAQUALAND	KOMMAGAS	4 300	F30G
NAMAQUALAND	LELIEFONTEIN	5 350	F30A
NAMAQUALAND	OKIEP COPPER COMPANY	-	

Magisterial District	Town	Population data 1995	Quaternary
NAMAQUALAND	NABABEEP/OKIEP	10 250	F30E
NAMAQUALAND	PELLA	1 450	D81G
NAMAQUALAND	PORT NOLLOTH	4 650	F20D
NAMAQUALAND	RICHTERSVELD	1 150	D82L
NAMAQUALAND	SPRINGBOK	10 200	F30D
NAMAQUALAND	STEINKOPF	6 850	F30E
POSTMASBURG	LIME ACRES	6 250	C92C
PRIESKA	MARYDALE	1 750	D72C
PRIESKA	PRIESKA / ETHEMBENI	11 000	D72B
RICHMOND	RICHMOND / SABELO	4 150	D61A
RITAVI	NKOWAKOWA	17 950	D62E
SUTHERLAND	SUTHERLAND	1 850	D51A
VREDENDAL	EBENEZER	1 400	F50A
VICTORIA-WEST	LOXTON	700	D55D
VICTORIA-WEST	VICTORIA-WEST / MASINYUSANE	7 850	D61E
VICTORIA-WEST	VOSBURG	1 350	D62B
WILLISTON	WILLISTON	2 350	D55L
TOTAL		**264 700**	

APPENDIX A.2

DEMOGRAPHIC DATA

PER QUARTERNARY CATCHMENT

APPENDIX A.2

DEMOGRAPHIC DATA PER QUATERNARY CATCHMENT

Quaternary Catchment	Urban	Rural	Total
Ongers	**65 300**	**9 788**	**75 088**
D61A	4150	404	4 554
D61B	0	352	352
D61C	0	317	317
D61D	0	60	60
D61E	7850	1943	9 793
D61F	0	51	51
D61G	0	43	43
D61H	0	53	53
D61J	0	139	139
D61K	0	113	113
D61L	0	285	285
D61M	0	125	125
D62A	5300	678	5 978
D62B	1350	703	2 053
D62C	0	681	681
D62D	26950	831	27 781
D62E	17950	627	18 577
D62F	0	870	870
D62G	1750	405	2 155
D62H	0	353	353
D62J	0	755	755
Boegoeberg	**36 750**	**10 260**	**47 010**
C92C	17800	4970	22 770
D71A	0	396	396
D71B	5000	811	5 811
D71C	0	521	521
D71D	1200	869	2 069
D72A	0	696	696
D72B	11000	873	11 873
D72C	1750	1124	2 874

Quaternary Catchment	Urban	Rural	Total
Neusberg	**70 400**	**52 320**	**122 720**
D73B	0	1318	1 318
D73C	0	1160	1 160
D73D	3350	6030	9 380
D73E	53550	8952	62 502
D73F	13500	34860	48 360
Nossob - Molopo	**6 353**	**4 943**	**11 296**
D42A	0	773	773
D42B	4700	424	5 124
D42C	0	38	38
D42D	0	2082	2 082
D42E	1653	1626	3 279
Sak-Hartbees	**20 500**	**12 221**	**32 721**
D51A	1850	132	1 982
D51B	0	145	145
D51C	0	119	119
D52A	0	92	92
D52B	0	217	217
D52C	0	167	167
D52D	0	378	378
D52E	0	220	220
D52F	0	412	412
D53A	0	87	87
D53B	3650	116	3 766
D53C	0	85	85
D53D	0	70	70
D53E	0	26	26
D53F	0	422	422
D53G	0	133	133
D53H	0	38	38
D53J	0	622	622
D54A	0	402	402
D54B	7000	1198	8 198

Quaternary Catchment	Urban	Rural	Total
D54C	0	111	111
D54D	0	613	613
D54E	0	393	393
D54F	0	316	316
D54G	0	307	307
D55A	0	441	441
D55B	0	182	182
D55C	0	69	69
D55D	700	482	1 182
D55E	2850	240	3 090
D55F	0	404	404
D55G	0	211	211
D55H	0	135	135
D55J	0	291	291
D55K	0	139	139
D55L	2350	219	2 569
D55M	0	236	236
D56A	0	44	44
D56B	0	47	47
D56C	0	138	138
D56D	0	96	96
D56E	0	65	65
D56F	0	109	109
D56G	0	69	69
D56H	0	58	58
D56J	0	134	134
D57A	0	84	84
D57B	0	251	251
D57C	2100	45	2 145
D57D	0	246	246
D57E	0	94	94
D58A	0	254	254
D58B	0	243	243
D58C	0	374	374

Quaternary Catchment	Urban	Rural	Total
Vioolsdrif	**12 150**	**12 080**	**24 230**
D81A	0	6882	6 882
D81B	0	1127	1 127
D81C	0	602	602
D81D	0	348	348
D81E	0	60	60
D81F	1100	49	1 149
D81G	4300	431	4 731
D82A	0	1410	1 410
D82B	0	73	73
D82C	2850	911	3 761
D82D	3900	0	3 900
D82E	0	187	187
Namibia	**31 240**	**55 140**	**86 380**
Z10A	0	13 961	13 961
Z10G	0	11 182	11 182
Z10H	0	10 024	10 024
Z10J	0	753	753
Z20A	27 240	10 000	37 240
Z20B	0	1 590	1 590
Z20C	0	3 343	3 343
Z20D	1 500	1 967	3 467
Z20E	0	1 309	1 309
Z20F	2 500	1 011	3 511
Alexander Bay	**4 000**	**1 897**	**5 897**
D82F	0	220	220
D82G	0	122	122
D82H	400	153	553
D82J	0	16	16
D82K	0	337	337
D82L	3600	1049	4 649

Quaternary Catchment	Urban	Rural	Total
Coastal	**49 250**	**9 850**	**59 100**
F10A	0	5	5
F10B	0	19	19
F10C	0	108	108
F20A	0	45	45
F20B	0	8	8
F20C	0	10	10
F20D	4650	20	4 670
F20E	0	6	6
F30A	5350	134	5 484
F30B	0	44	44
F30C	2000	651	2 651
F30D	10200	440	10 640
F30E	17100	4555	21 655
F30F	0	106	106
F30G	7200	1736	8 936
F40A	800	191	991
F40B	0	17	17
F40C	0	60	60
F40D	0	91	91
F40E	0	581	581
F40F	550	50	600
F40G		28	28
F40H		12	12
F50A		171	171
F50B		44	44
F50C		24	24
F50D		595	595
F50E		52	52
F50F	1400	21	1 421
F50G		26	26

APPENDIX B

MACRO-ECONOMIC DATA

APPENDIX B.1

GRAPHICS

APPENDIX B.1

DESCRIPTION OF GRAPHS

Figure No	Graphic Illustration	Description
	• **Gross Geographic Product**:	
B.1.1	➩ Contribution by Magisterial District to LOWMA Economy, 1997(%)	Each WMA comprises a number of Magisterial Districts. This graph illustrates the percentage contribution of each MD to the WMA economy as a whole. It shows which are the most important sub-economies in the region.
B.1.2	➩ Contribution by sector to National Economy, 1988 and 1997 (%)	This graph illustrates the percentage contribution of each sector in the WMA economy, e.g. agriculture, to the corresponding sector in the national economy.
	• **Labour Force Characteristics**:	
B.1.3	➩ Composition of 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.1.4	➩ Contribution by Sector to LOWMA Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.1.5	➩ Contribution by Sectors of LOWMA Employment to National Sectoral Employment, 1980 and 1994 (%)	Similar to the production function (i.e. GGP), this graph illustrates the percentage contribution of each sector in the WMA economy, e.g. mining, to the corresponding sector in the national economy.
B.1.6	➩ Compound Annual Employment Growth by Sector of LOWMA versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.

Diagram No	Graphic Illustration	Description
B.1.7	• **Shift-Share**: ➩ 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 B1.1: Contribution by Magisterial District to Lower Orange economy, 1997 (%)

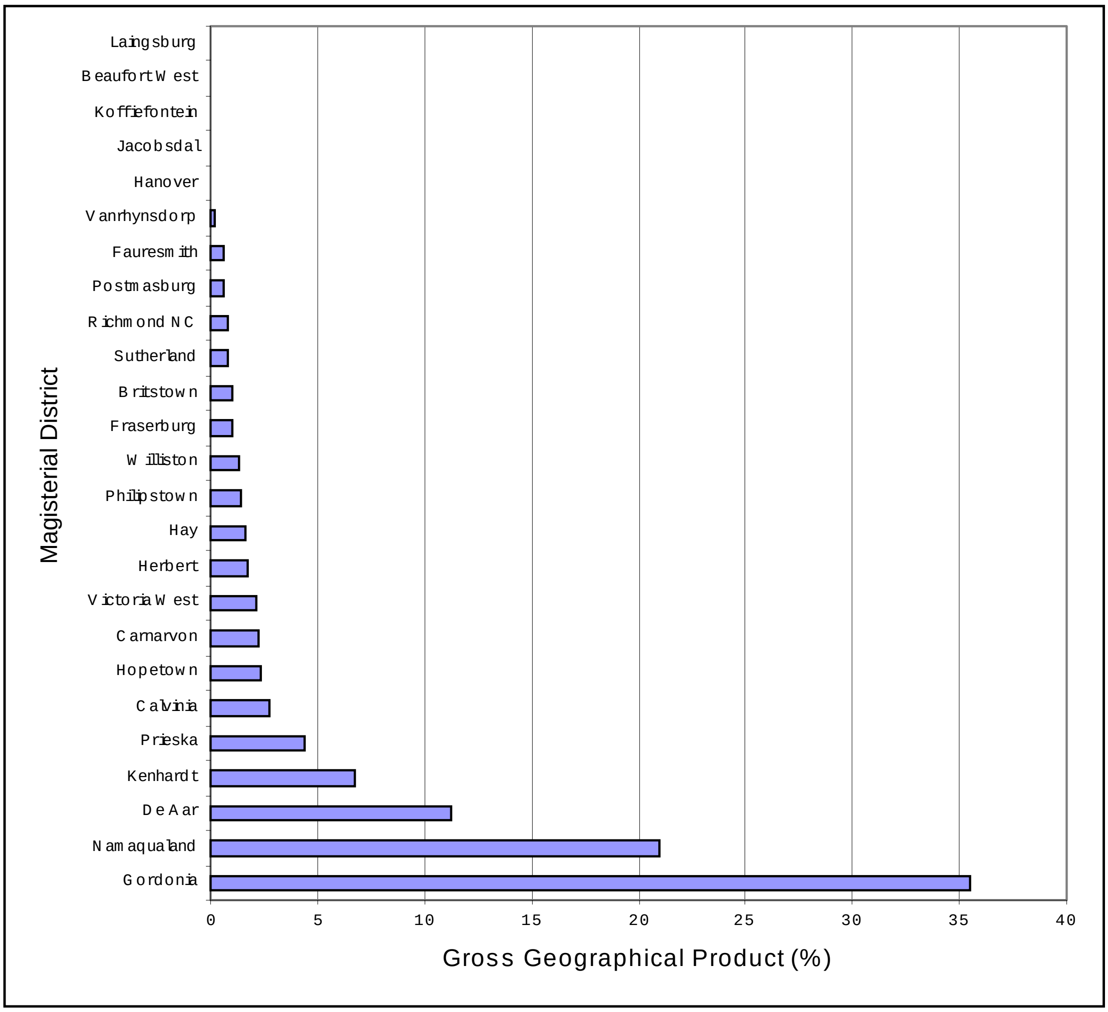


Figure B1.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

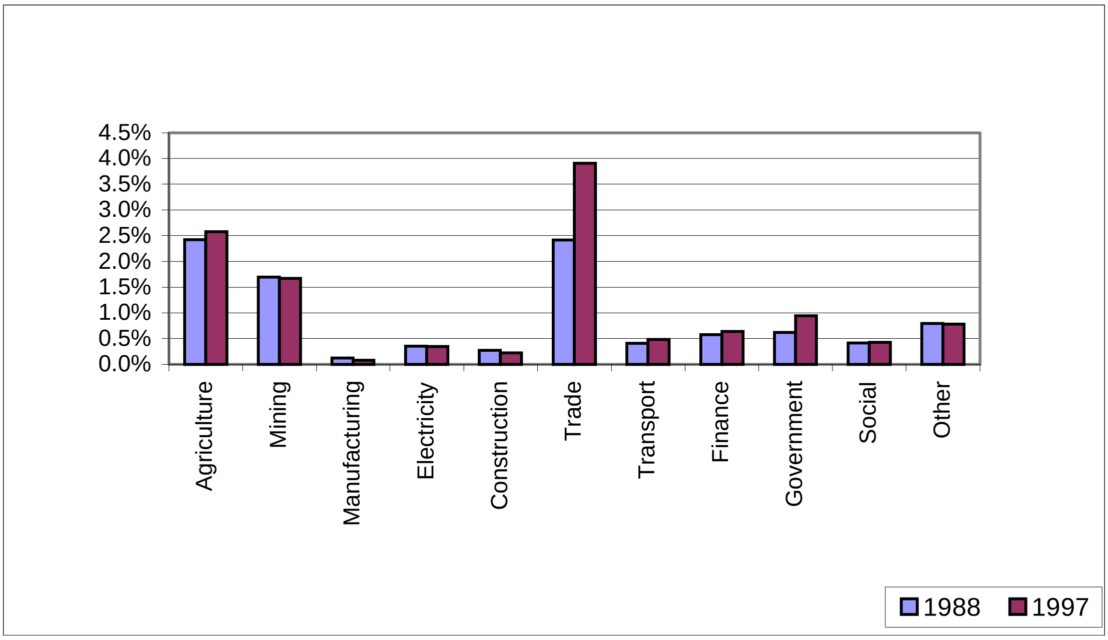


Figure B1.3: Composition of Lower Orange Labour Force, 1994 (%)

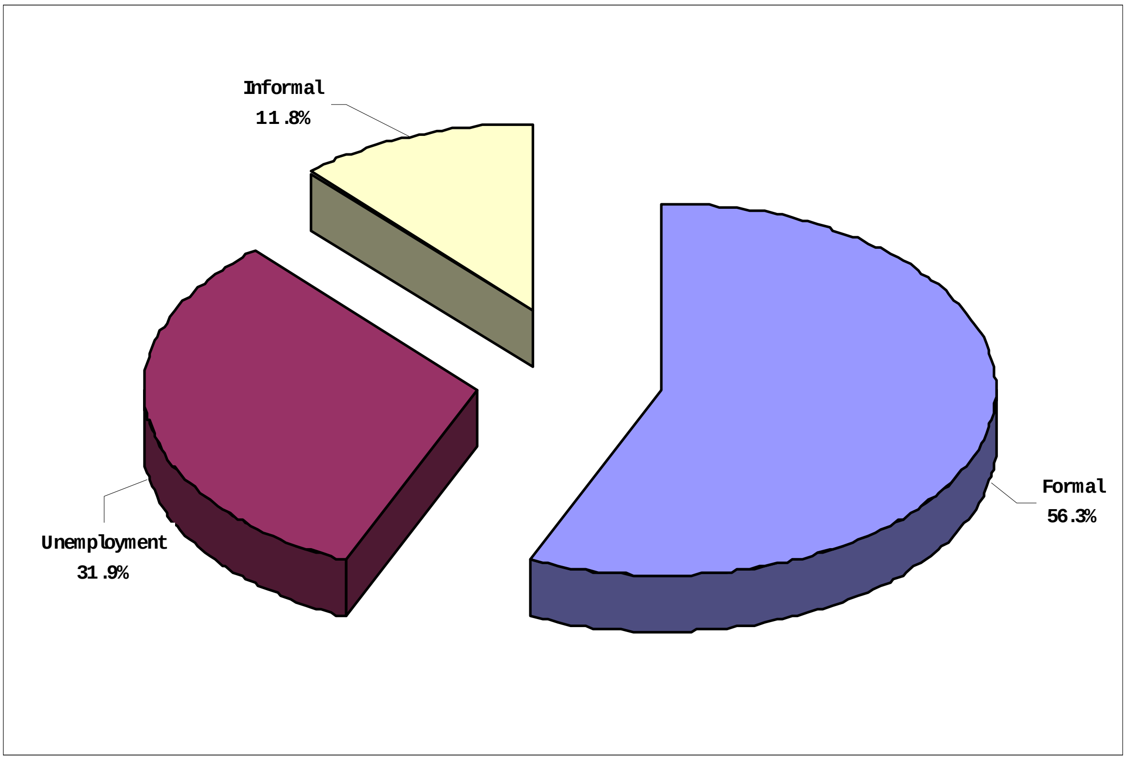


Figure B1.4: Contribution by Sector to Lower Orange Employment, 1980 and 1994(%)

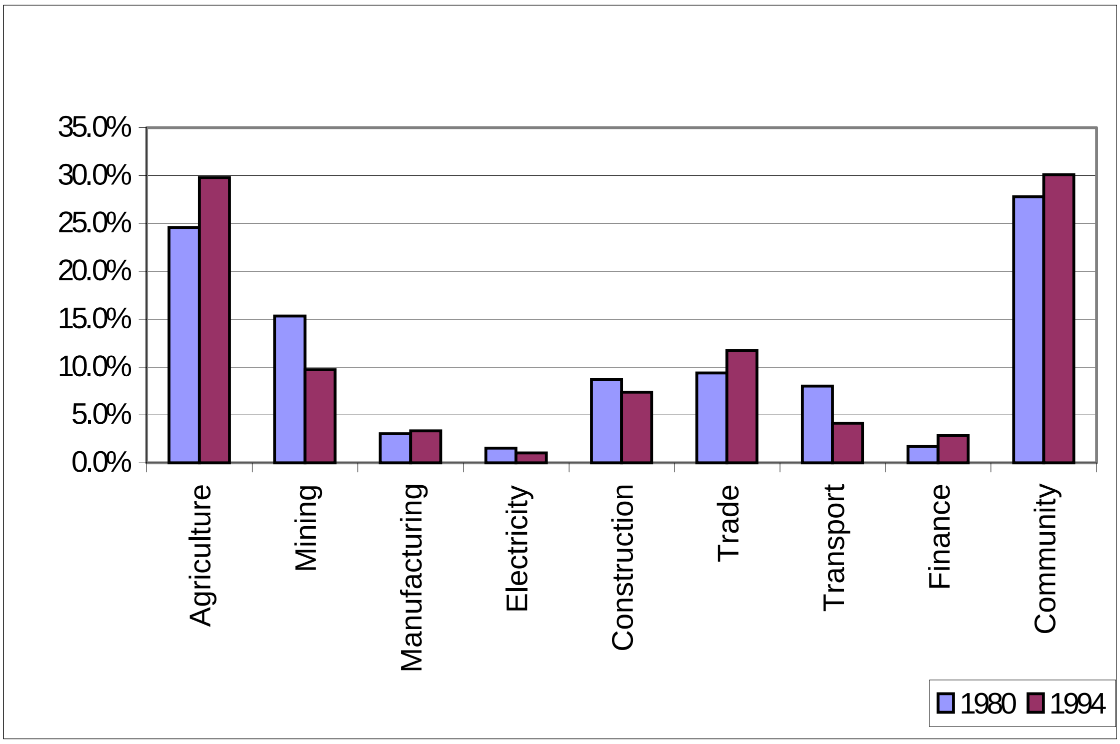


Figure B1.5 Contribution by Sectors of Lower Orange Employment to National Sectoral Employment, 1980 and 1994 (%)

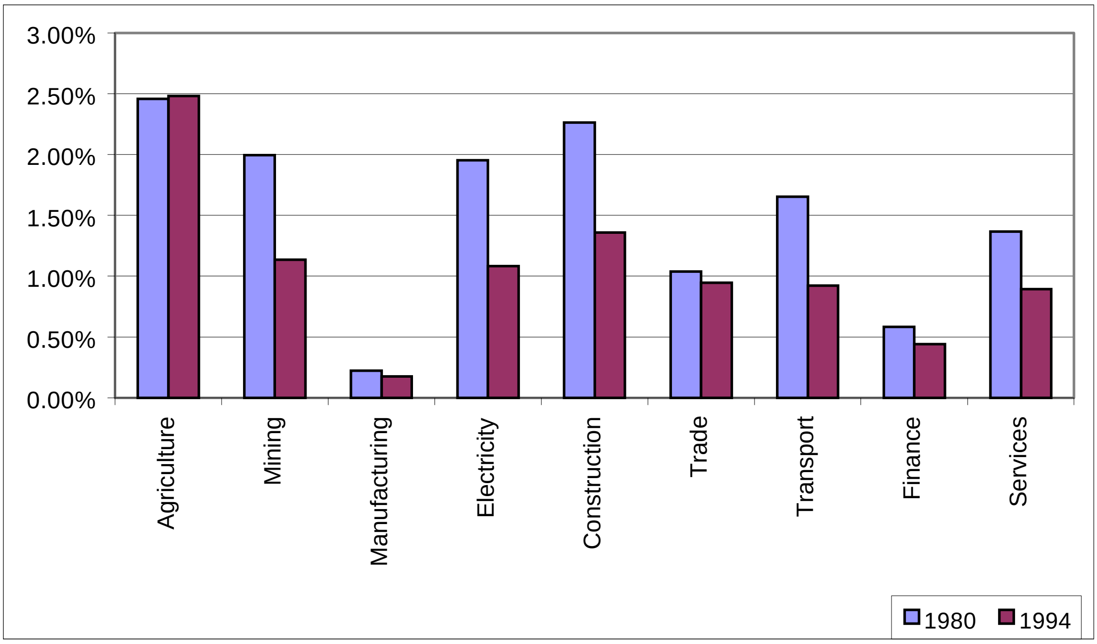


Figure B1.6: Average Annual Employment Growth by Sector of Lower Orange versus South Africa, 1980 to 1994 (%)

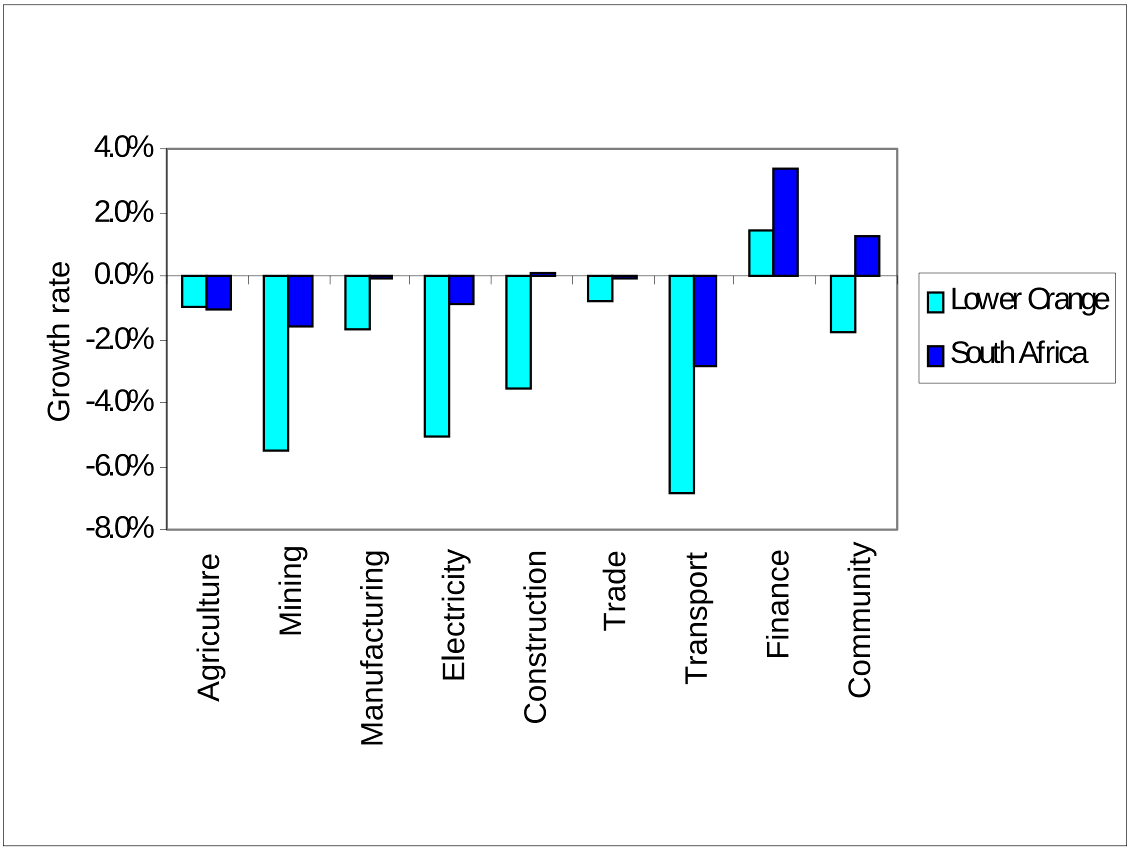
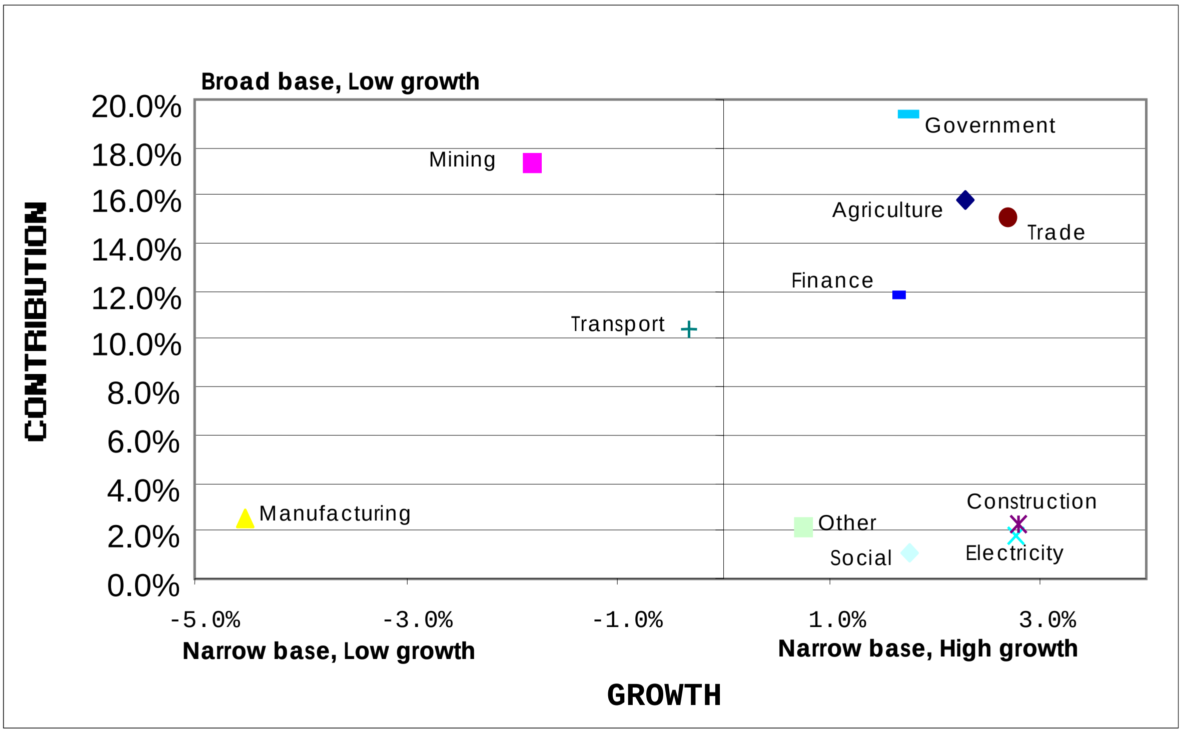


Figure B1.7: Shift-Share Analysis, 1997



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B.1 INTRODUCTION

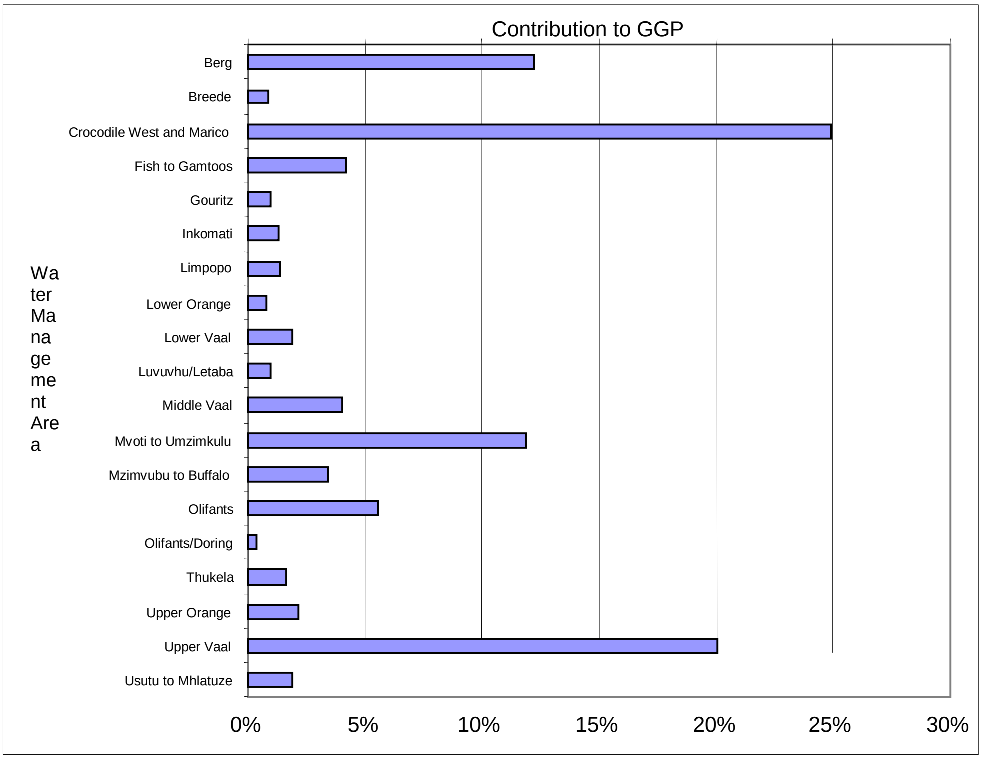
The purpose of this section is to illustrate the relative importance of the nineteen different Water Management Areas (WMAs) in South Africa. The following aspects are outlined:

- 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 GGP. 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 GGP. This WMA comprises mainly portions of Johannesburg, Vereeniging and Vanderbijlpark.
- The Berg WMA contributes 11.25% to the GGP 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 GGP of the national economy. This WMA includes the Durban-Pinetown Metropolitan Area.

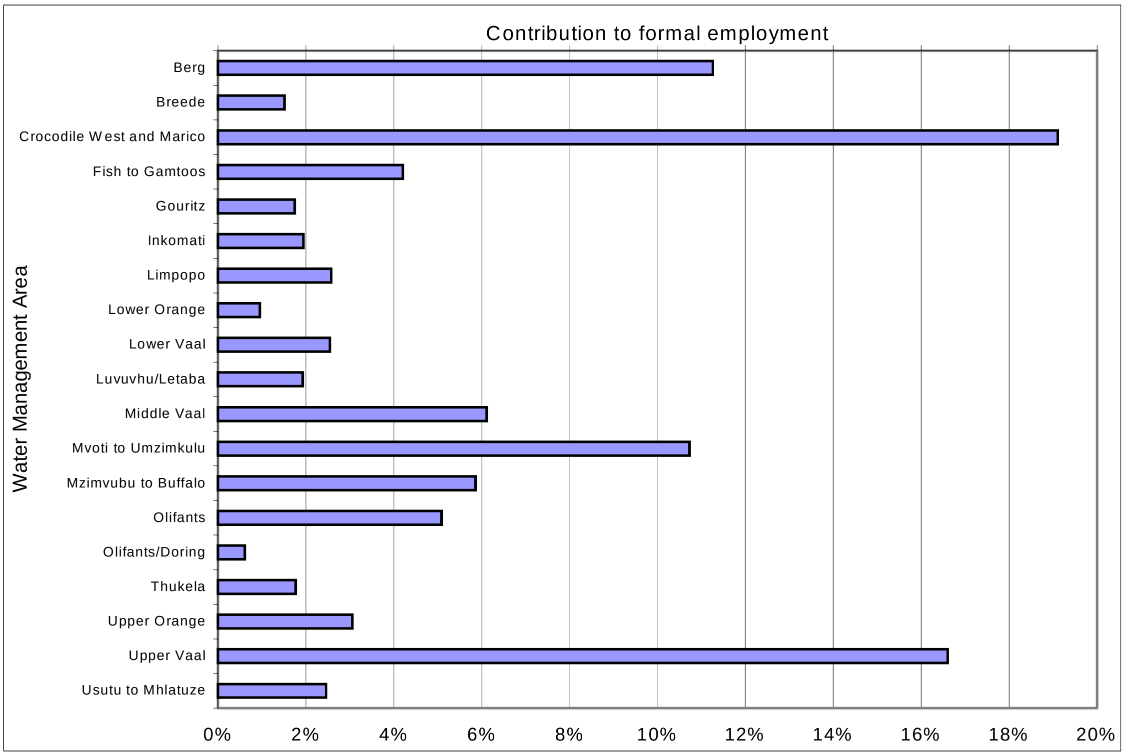
Figure B2.1: Total GGP by Water Management Area (% of Country)



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.

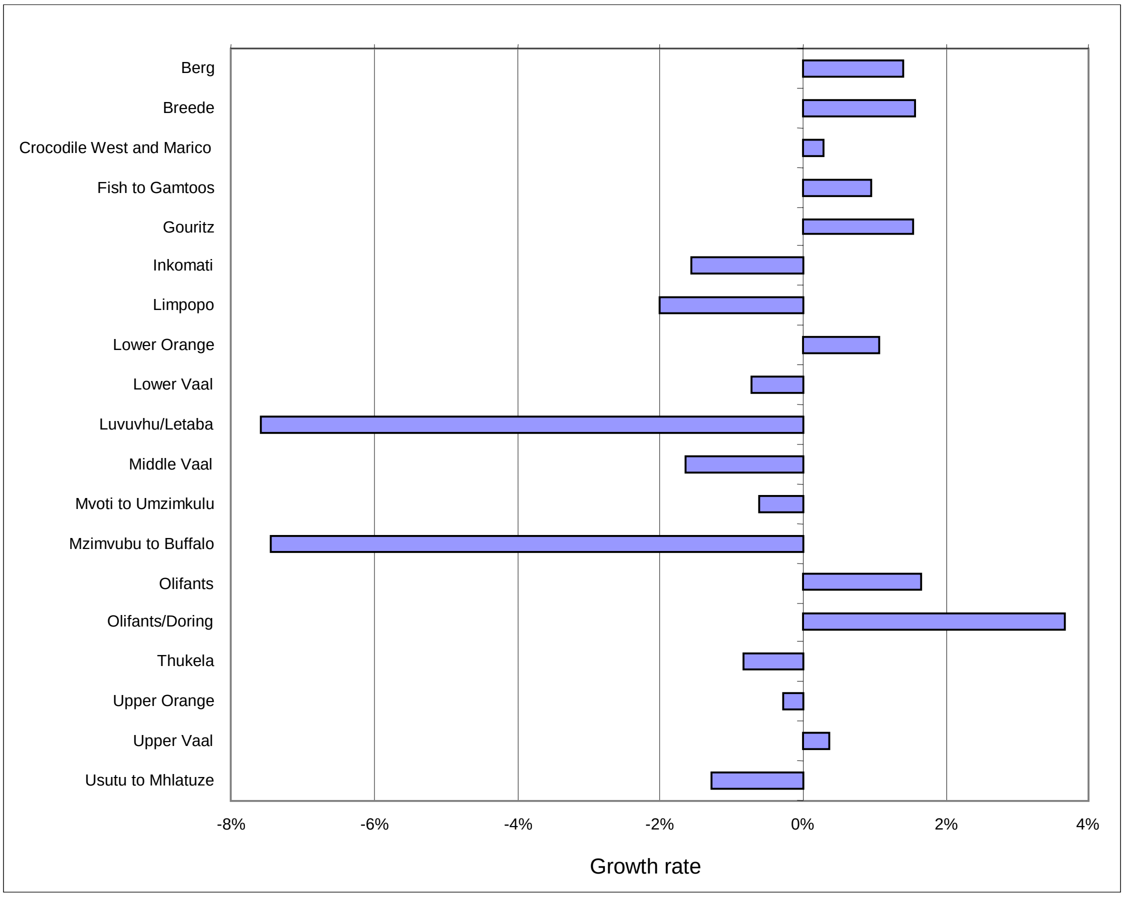
Figure B2.2: Formal Employment by Water Management Area (% of country)



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 B2.3: Average Annual Economic Growth by Water Management Area, 1988-1997 (%)



APPENDIX B.3

ECONOMIC SECTOR DESCRIPTION

APPENDIX B.3

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 fertiliser, forestry, logging and related services and fishing, operation of fish hatcheries and fish farms.

- **Mining:** This section entails the mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore, etc); extraction of crude petroleum and natural gas, service activities incidental to oil and gas extraction; stone quarrying; clay and sand pits; and the mining of diamonds and other minerals.

- **Manufacturing:** Manufacturing includes, inter alia, the manufacturing of food products, beverages and tobacco products; production, processing and preserving of meat, fish, fruit, vegetables, oils and fats, dairy products and grain mill products; textile and clothing; spinning and weaving; tanning and dressing of leather; footwear; wood and wood products; paper and paper products; printing and publishing; petroleum products; nuclear fuel; and other chemical substances.

- **Electricity, Water and Gas:** Utilities comprise mainly three elements, namely electricity, water and gas. The services rendered to the economy include the supply of electricity, gas and hot water, the production, collection and distribution of electricity, the manufacture of gas and distribution of gaseous fuels through mains, supply of steam and hot water, and the collection, purification and distribution of water.

- **Construction:** This sector includes construction; site preparation building of complete constructions or parts thereof; civil engineering; building installation; building completion; and the renting of construction or demolition equipment with operators all form part of the construction sector.

- **Trade:** Trade entails wholesale and commission trade; retail trade; repair of personal household goods; sale, maintenance and repair of motor vehicles and motor cycles; hotels, restaurants, bars canteens, camping sites and other provision of short-stay accommodation.

- **Transport:** The transportation sector comprises land transport; railway transport; water transport; transport via pipelines; air transport; activities of travel agencies; post and telecommunications; courier activities; and storage.

- **Business and Financial Services:** The economic activities under this category include, inter alia, financial intermediation; insurance and pension funding; real estate activities; renting of transport equipment; computer and related activities; research and development; legal; accounting, book-keeping and auditing activities; architectural, engineering and other technical activities; and business activities not classified elsewhere.

- **Government and Social services (Community Services)**: This sector includes public administration and defence, social and related community services (education, medical, welfare and religious organisations), recreational and cultural services and personal and household services.

- **Other:** Private households, extraterritorial organisations, representatives of foreign governments and other activities not adequately defined.

APPENDIX B.4
ECONOMIC INFORMATION SYSTEM

APPENDIX B.4

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.

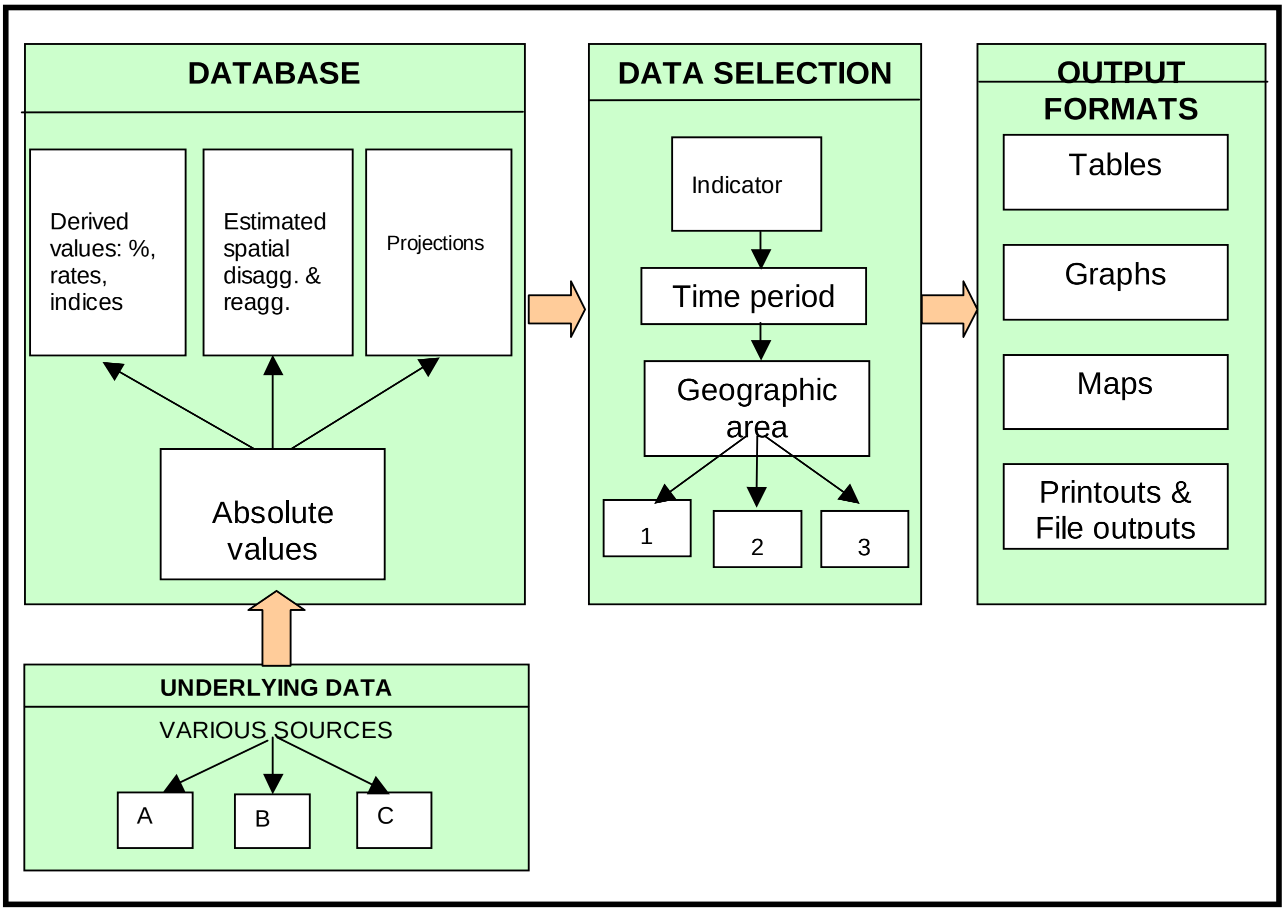
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service 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

APPENDIX C.1

IRRIGATION BOARDS

APPENDIX C.1

IRRIGATION BOARDS IN THE LOWER ORANGE WATER MANAGEMENT AREA

NAME OF IRRIGATION BOARD	NEAREST TOWN	SCHEDULED AREA (ha)
Blaauwskop	Keimoes	790,6
Brakbosch Island	Keimoes	156,2
Douglas	Douglas	7 290,0
Elandskaroo	Calvinia	690,0
Friersdale	Keimoes	1 101,4
Gariep	Groblershoop	1 159,3
Canon Island Settlement	Upington	1 402,0
Keimoes	Keimoes	417,9
Kousas	Keimoes	497,0
Louisvale	Upington	1 214,1
Malanshoek	Keimoes	107,7
Neilersdrift	Keimoes	582,3
Noord Oranje	Groblershoop	1 154,4
Olyvenhoutsdrift-South	Upington	771,5
Onderstekom Island	Kakamas	526,3
Onseepkans	Kakamas	313,6
Rooikop Island	Keimoes	173,4
Skanskop Island Settlement	Keimoes	470,1
Steynsvoor	Upington	1 378,5
Straussburg	Upington	552,4
Swartkop	Upington	1 025,0
Upington Island major	Upington	5 340,8
Upington	Upington	792,7
TOTAL		**27 907,2**

APPENDIX C.2

ALLOCATIONS TO WATER USERS FROM GOVERNMENT WATER WORKS IN TERMS OF SECTION 56(3) OF THE WATER LAW

APPENDIX C.2

INFORMATION REGARDING ALLOCATIONS TO WATER USERS FROM GOVERNMENT WATERWORKS IN TERMS OF SECTION 56(3) OF THE WATER LAW

Name of user	Authorisation No	Allocation (m^3/a)	Type of use
MIDDLE ORANGE GOVERNMENT WATER CONTROL AREA			
Glen Hope Exploration and Mining Development Company (Pty) Ltd	100/77/12/3/84	2 400	Mining
Nederduits Gereformeerde Church Prieska	5/77/12/3/86	10 000	Household and gardening
Prieska municipality	102/77/12/391	2 000 000	Urban
LOWER ORANGE GOVERNMENT WATER CONTROL AREA			
Pelladrift water board	121/77/12/5/78	5 110 000	Urban and industrial
Springbok water board	41/77/12/5/85	2 500 000	Urban and industrial
Nederduits Gereformeerde Church missionary school	65/77/12/5/85	300 000	Irrigation
J. A. Louw	69/77/12/5/85	45 000	Irrigation
Consolidated Diamond mines Ltd	121/77/12/5/85	7 000 000	Urban and mining
Namakwaland regional services council	40/77/12/5/90	4 000	Household
Alexkor	70/77/12/5/90	2 000 000	Household and industrial
Borkers metal and mining Northern Richters (Pty) Ltd	45/77/12/5/91	1 800	Household and industrial
Springbok water board	67/77/12/5/92	4 000 000	Household and industrial
Alexkor	19/77/12/5/93	450 000	Irrigation
B.J. van der Hoven	3893	300 000	Irrigation
Tantalite Valley Minerals (Pty) Ltd	3901	240 000	Irrigation
Witbank Development Trust	32/77/12/5/96	3 000 000	Urban and other usages
Steinkopf Transitional council	33/77/12/5/96	10 095 000	Urban
Trans Hex mining Ltd	35/77/12/5/97	700 000	Mining
Trans Hex mining Ltd	35/77/12/5/97	2 400 000	Mining
Namdeb Diamond Corp (Pty) Ltd	4049	1 260 000	Mining
G. H de Kock	4059	1 875	Household
Orange River Wine Cellars	285/77/12/4/77	81 816	Industrial

Name of user	Authorisation No	Allocation (m^3/a)	Type of use
Keimoes municipality	70/77/10/4/79	11 040 473	Urban
Gordonia Divisional council	85/77/12/4/81	1 800	Urban
Copperton Construction	40/77/12/4/83	1 600	Industrial
SA Defence force	174/77/12/4/83	315 000	Household
C. J. Human	125/77/12/4/84	450 000	Irrigation
Augrabies Fall National Park	138/77/12/84	65 250	Household
SA Co-op karakul breeders	26/77/12/4/85	3 600	Stock watering
Vaal River divisional council	49/77/12/4/85	4 800	Household
Dept of Public works	62/77/12/4/85	20 000	Irrigation
SA Railways	63/77/1/24/85	4 800	Industrial
Karos-Geelkop water board	93/77/12/4/85	42 000	Stock watering
Prieska divisional council	101/77/12/4/85	60 000	Household
Gordonia divisional council	102/77/12/4/85	220 000	Irrigation
J. C. Kruger	106/77/12/4/85	136 000	Irrigation
Groblershoop Municipality	129/77/12/4/85	220 000	Household
Upington Irrigation board	13/77/12/4/86	288 000	Irrigation
Cape Provincial administration	30/77/12/4/86	40	Irrigation
J v d Westhuisen	105/77/12/4/86	105 000	Irrigation
Dept of Local government	129/77/12/4/87	27 000	Household
Dept of Agriculture	40/77/12/4/87.	21 100	Household
Dept of Administration	51/77/12/4/87	30 000	Household
Dept of Administration	87/77/12/4/87	105 000	Irrigation
SA Dry fruit co-op	84/77/12/4/88	2 250 000	Irrigation
Prieska Divisional Council	21/77/12/4/89	15 000	Irrigation
H. A. Steyn	83/77/12/4/89	120 000	Industrial
Kenhardt Divisional council	96/77/12/4/89	20 000	Household
Lower Orange divisional council	22/77/12/4/90	43 800	Household
Lower Orange divisional council	74/77/12/4/90	50 000	Household
Lower Orange divisional council	40/77/12/4/91	100 000	Irrigation
Orange co-operation Ltd	41/77/12/4/91	5 000	Irrigation
Lower Orange regional service council	48/77/12/4/91	35 500	Household

Name of user	Authorisation No	Allocation (m^3/a)	Type of use
Lower Orange service council	47/77/`1/4/9991	100 000	Household
Lower Orange golf club	46/77/12/4/91	3 000	Irrigation
P. A. Louw	53/77/12/4/91	30 000	Irrigation
Kakamas municipality	65/77/12/4/91	1 000 000	Urban
Koch recreation	64/77/12/4/91	45 000	Household
Lowe Orange service council	94/77/12/4/91	53 000	Household
Canon island settlement	9/77/12/4/92	15 000	Irrigation
Kakamas municipality	66/77/12/4/92	500 000	Urban
Trans Hex mining	96/77/12/4/92	260 000	Mining
V. E. van Zyl	W56/473/01/93/2	12	Household
Dept of Education	25/77/12/4/93	5 000	Household
Lower Orange regional service council	34/77/12/4/93	73 000	Household
A. A. Kotze	63/77/12/4/93	6 000	Industrial
Warmsand Poultry farm	69/77/12/4/93	55 000	Industrial
Karos school	9/77/12/4/94	48 000	Household
Loot hostel	29/77/12/4/94	16 000	Household
A. C. G. Folscher	59/77/12/4/96	22 500	Irrigation
ORANGE RIVER (NAMAQUALAND) GOVERNMENT WATER CONTROL AREA			
Cape Provincial administration		167 140	Irrigation
Electricity supply commission	33/159/78	6 000	Industrial
Anglo American services (Pty) Ltd	34/159/78	7 200	Household
Boart International Ltd	120/159/78	5 475	Industrial
Steinkopf Administration	134/159/78	278 280	Household
J. C. N. Boonzaaier	W56/530/361/91/12	360	Household
P. M. A. van Zyl	W56/530/360/91/12	360	Household
P. A. J. Visser	W56/530/364/91/12	360	Household
P. M. A. van Zyl	W56/530/360/91/12	360	Household
J. P. van der Westhuizen	W56/530/359/91/12	360	Household
J. P. Visser	W56/530/358/91/12	360	Household
J. C. N. Boonzaaier	W56/530/361/91/12	360	Household

APPENDIX C.3

STATUS REPORT ON TRANSFORMATION OF IRRIGATION BOARDS AND WATER BOARDS AND THE ESTABLISHMENT OF NEW WATER USER ASSOCIATIONS AS ON 24/08/01

APPENDIX C.3

LOWER ORANGE: STATUS REPORT ON TRANSFORMATION OF IRRIGATION BOARDS, WATER BOARDS AND ESTABLISHMENT OF NEW WATER USER ASSOCIATIONS AS ON 24 AUGUST 2001

IRRIGATION BOARDS	AREAS INCLUDED IN PROPOSED WMA	INITIAL MEETING	CONSULTATION PROCESS	GENERAL MEETING	SUBMIT TO REGION	PROPOSALS RECEIVED AT HEAD OFFICE	REMARKS
1. Upington Eilande	▪ Upington ▪ Swartkop eiland ▪ Steynsvoor ▪ Kanoneiland ▪ Straussberg ▪ Olywenhouts Drift ▪ Louisvale ▪ Blaauwesekop ▪ River abstraction ▪ Recreation	Complete	Complete	Complete	Will submit on 30/11/01		Busy to wrap up outstanding documentations and all relevant inforamtion for submission.

Note: Appendix C3 relates to the transformation of Irrigation Boards, currently in process.
Appendices C1 and C3 may therefore not coincide.

IRRIGATION BOARDS	AREAS INCLUDED IN PROPOSED WAU	INITIAL MEETING	CONSULTATION PROCESS	GENERAL MEETING	SUBMIT TO REGION	PROPOSALS RECEIVED AT HEAD OFFICE	REMARKS
2. Keimoes	▪ Keimoes ▪ Kousas ▪ Brakbosch ▪ Friersdale ▪ Malanshoek ▪ Neilersdrift ▪ Eksteenskuil ▪ Onderstekoms Eiland ▪ Rooikop Eiland ▪ Skanskop Eiland ▪ River abstractions ▪ Recreation	Complete	Steering committee's draft proposal evaluated by attorneys. Discussion with legal services about disagreement with act and guidelines.	Complete	No data available.		Problems with act and guidelines by attorneys is something of the past (chairperson) submission will follow soon.
3. Kakamas	Kakamas	Complete	Complete	Complete	Complete		Minister approve (see government notice 30/05/01)

IRRIGATION BOARDS	AREAS INCLUDED IN PROPOSED WAU	INITIAL MEETING	CONSULTATION PROCESS	GENERAL MEETING	SUBMIT TO REGION	PROPOSALS RECEIVED AT HEAD OFFICE	REMARKS
4. Onseepkans	▪ Onseepkans ▪ Blouputs ▪ Other river abstractions	Complete	Meetings were held : Onseepkans , Blouputs 14//08/01. Next meeting on 4/9/01 more representative steering committee	Not avaiable	30/04/02 due to harvest season.		Positive reaction to the establishment process. DWAF support necessary. Harvest will delay shortterm progress.
5. Smartt	▪ Smartt Irr. ▪ Ongers River	Complete	Complete	29/10/01			Draft proposal and constitution are complete. A representative steering committee meeting on 24/09/01 will be held to accept proposal and confirm data for general meeting.

IRRIGATION BOARDS	AREAS INCLUDED IN PROPOSED WAU	INITIAL MEETING	CONSULTATION PROCESS	GENERAL MEETING	SUBMIT TO REGION	PROPOSALS RECEIVED AT HEAD OFFICE	REMARKS
6. Piet Renoster (West Karoo WU proposed)	▪ Rietriver ▪ Rhenosterriver ▪ Sakrivier ▪ Visriver	Amalgamation with other similar users such as Sak-Visriver various meetings were held by the steering committee.	In principle the boundaries were accepted. Steering committee busy with meetings in new areas to compile a more representative steering committee. Representative steering committee will meet on 04/10/01	Not available			As this proposed WUA seems to cover a large geographic area, it should be monitored closely.
7. Van Wyksvlei		The meeting with Van Wyksvlei Irrigation Board proved that the letter to apply for dis-establishment was only the view of the review Board's chairperson.	Complete	24/09/01	Not more than two weeks after General meeting.		Good progress after initial start. If everything go well this will be the next WUA in Lower Orange.
Lower Orange WMA	Confluence of Orange and Vaal River up to Boegoeberg Dam	No real interest to establish soon.					Inputs on how to initiate establishment are welcome.

IRRIGATION BOARDS	AREAS INCLUDED IN PROPOSED WAU	INITIAL MEETING	CONSULTATION PROCESS	GENERAL MEETING	SUBMIT TO REGION	PROPOSALS RECEIVED AT HEAD OFFICE	REMARKS
Boegoeberg	▪ North Orange ▪ Gariep ▪ Boegoeberg GWS ▪ Rouxville West ▪ Karos Geelkoppen ▪ River abstraction ▪ recreation	Complete	Complete	Complete	Complete		Miniter approve (see government notice 04/05/01).
Orange Vaal	▪ Orange Vaal ▪ Recreation	Complete	Complete	Probably on 09/11/01			An intensive consultation process is complete. Reaction on the General meeting will determine the submission date. Draft constitution and proposal is available.
Goodhouse Witbank							

APPENDIX D

LAND USE DATA

APPENDIX D.1

QUATERNARY CATCHMENT LIST RELEVANT TO MAGISTERIAL DISTRICTS

APPENDIX D.1

Quaternary Catchment List - Relevant to Magisterial Districts

Magisterial District	Quaternary catchment	Portion of Magisterial District in study area	Quat Area (km²)	Portion of Quat in Magisterial District	Area of Quat in District (km²)
Namakwaland D		1			**19 839**
	D81G		2 007	0.3	602
	D82B		4 877	0.8	3 902
	D82C		3 996	1	3 996
	D82A		1 917	1	1 917
	D82D		2 967	1	2 967
	D82E		944	1	944
	D82F		1 039	1	1 039
	D82G		594	1	594
	D82H		822	1	822
	D82J		1 385	1	1 385
	D82K		917	1	917
	D82L		754	1	754
Namakwaland F		1			**24 594**
	F10A		460	1	460
	F10B		1 089	1	1 089
	F10C		1 176	1	1 176
	F20A		1 120	1	1 120
	F20B		514	1	514
	F20C		613	1	613
	F20D		455	1	455
	F20E		435	1	435
	F30A		1 954	1	1 954
	F30B		1 462	1	1 462
	F30C		1 655	1	1 655
	F30D		976	1	976
	F30E		1 260	1	1 260
	F30F		1 469	1	1 469
	F30G		980	1	980
	F40A		984	1	984

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
	F40B		404	1	404
	F40C		608	1	608
	F40D		741	1	741
	F40E		1 065	1	1 065
	F40F		682	1	682
	F40G		348	1	348
	F40H		514	1	514
	F50A		1 303	0.5	652
	F50B		603	1	603
	F50C		439	0.6	263
	F50D		687	0.4	275
	F50E		487	1	487
	F50F		575	1	575
	F50G		775	1	775
Britstown		1			**7 692**
	D61K		1 608	0.2	322
	D61L		1 016	0.8	813
	D61M		943	0.7	660
	D62A		2 243	1	2 243
	D62B		3 117	0.4	1 247
	D62C		2 130	0.2	426
	D62E		1 924	0.5	962
	D62G		2 549	0.4	1 020
De Aar		0,95			**2 802**
	D62C		2 130	0.3	639
	D62D		2 402	0.5	1 201
	D62E		1 924	0.5	962
Hopetown		0,5			**4 079**
	D62F		1 701	0.3	510
	D62G		2 549	0.6	1 529
	D62J		2 200	0.4	880
	D71A		1 210	0.3	363
	D71C		1 592	0.5	796

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
Prieska		1			**12 329**
	D62B		3 117	0.3	935
	D62H		2 062	1	2 062
	D62J		2 200	0.6	1 320
	D71D		1 713	0.2	343
	D72A		1 397	1	1 397
	D72B		2 569	0.5	1 285
	D72C		2 776	0.6	1 666
	D54D		5 071	0.3	1 521
	D54G		4 503	0.4	1 801
Richmond (Cape)		0,4			**4 222**
	D61A		1 466	1	1 466
	D61B		1 199	1	1 199
	D61C		1 170	0.5	585
	D61D		651	0.2	130
	D61L		1 016	0.2	203
	D62C		2 130	0.3	639
Victoria-Wes		0,7			**9 409**
	D61C		1 170	0.5	585
	D61D		651	0.8	521
	D61E		1 091	1	1 091
	D61F		873	1	873
	D61G		744	1	744
	D61H		1 086	1	1 086
	D61J		1 558	0.8	1 246
	D61K		1 608	0.8	1 286
	D61M		943	0.3	283
	D55C		761	0.5	381
	D55D		1 889	0.2	378
	D62B		3 117	0.3	935

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
Philipstown		0,3			**1 191**
	D62F		1 701	0.7	1 191
Hanover		0,3			1 627
	D62D		2 402	0.5	1 201
	D62C		2 130	0.2	426
Hay					**14 034**
	D73A	0,9	3 238	0.2	648
	D73B		3 721	1	3 721
	D73C		6 221	0.3	1 866
	D71A		1 210	0.3	363
	D71B		2 875	1	2 875
	D71C		1 592	0.5	796
	D71D		1 713	0.8	1 370
	D72B		2 569	0.5	1 285
	D72C		2 776	0.4	1 110
Herbert		0,1			**363**
	D71A		1 210	0.3	363
Postmasburg					**12 946**
	D73A	0,7	3 238	0.8	2 590
	D73C		6 221	0.5	3 111
	D42C		18 112	0.4	7 245
Kuruman		0,4			**5 434**
	D42C		18 112	0.3	5 434
Gordonia		1			**52 119**
	D42A		10 282	1	10 282
	D42B		3 198	1	3 198

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
	D42C		18 112	0.3	5 434
	D42D		16 210	1	16 210
	D42E		4 208	1	4 208
	D73C		6 221	0.2	1 244
	D73D		4 291	0.6	2 575
	D73E		3 867	0.7	2 707
	D73F		4 630	0.5	2 315
	D81A		2 311	0.4	924
	D81B		851	0.4	340
	D81C		2 682	1	2 682
Kenhardt		1			**32 269**
	D81A		2 311	0.6	1 387
	D81B		851	0.6	511
	D81D		1 826	1	1 826
	D81E		1 291	1	1 291
	D81F		1 841	1	1 841
	D81G		2 007	0.7	1 405
	D82B		4 877	0.2	975
	D53A		1 939	1	1 939
	D53B		1 713	1	1 713
	D53C		1 899	1	1 899
	D53D		1 842	1	1 842
	D53E		826	1	826
	D53G		4 747	1	4 747
	D53H		1 589	1	1 589
	D53J		455	1	455
	D57D		4 444	0.5	2 222
	D57E		1 957	1	1 957
	D54F		3 809	0.3	1 143
	D54G		4 503	0.6	2 702

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
Calvinia		0,45			**17 838**
	D53F		8 040	1	8 040
	D52D		638	1	638
	D52E		609	1	609
	D52F		1 146	1	1 146
	D55M		1 813	0.2	363
	D58A		763	1	763
	D58B		1 131	1	1 131
	D58C		2 521	1	2 521
	D57A		853	0.6	512
	D57C		637	0.9	573
	D57D		4 444	0.3	1 333
	D51C		522	0.4	209
Sutherland		0,55			**6 265**
	D52A		378	1	378
	D52B		660	1	660
	D52C		465	1	465
	D51A		797	1	797
	D51B		873	1	873
	D51C		522	0.4	209
	D56A		510	1	510
	D56B		519	1	519
	D56C		920	1	920
	D56D		621	1	621
	D56H		447	0.7	313
Fraserburg		1			**10 455**
	D56E		666	1	666
	D56F		1 038	1	1 038
	D56G		651	1	651
	D56H		447	0.3	134

Magisterial District	Quaternary catcment	Portion of Magisterial District in study area	Quat Area	Portion of Quat in Magisterial District	Area of Quat in District
			(km²)		(km²)
	D56J		931	0.6	559
	D55A		1 872	0.2	374
	D55B		1 260	1	1 260
	D55D		1 889	0.5	945
	D55E		2 240	1	2 240
	D55G		1 293	0.4	517
	D55H		1 151	0.8	921
	D55F		2 632	0.2	526
	D55K		1 247	0.5	624
Williston		1			**11 625**
	D54E		3 326	0.3	998
	D54F		3 809	0.3	1 143
	D55H		1 151	0.2	230
	D55J		1 998	1	1 998
	D55K		1 247	0.5	624
	D55L		1 242	1	1 242
	D55M		1 813	0.8	1 450
	D56J		931	0.4	372
	D57A		853	0.4	341
	D57B		2 274	1	2 274
	D57C		637	0.1	64
	D57D		4 444	0.2	889
Carnarvon		1			**16 744**
	D54A		1 518	1	1 518
	D54B		4 053	1	4 053
	D54C		1 342	1	1 342
	D54D		5 071	0.7	3 550
	D54E		3 326	0.3	998
	D54F		3 809	0.4	1 524
	D55D		1 889	0.3	567
	D55F		2 632	0.8	2 106
	D55G		1 293	0.6	776
	D61J		1 558	0.2	312

APPENDIX D.2

REPORTING AREAS WITH APPORTIONMENT PROFILES

APPENDIX D.2

Reporting Areas with Apportionment Profiles

Special Apportionment applied to Irrigation, River Losses and Urban use
(See Chapter 3.1 of main report for further explanation of special apportionment)

Drainage Areas		
Apportionment		
Quat	Area	Special
Ongers		
D61A	100%	100%
D61B	100%	100%
D61C	100%	100%
D61D	100%	100%
D61E	100%	100%
D61F	100%	100%
D61G	100%	100%
D61H	100%	100%
D61J	100%	100%
D61K	100%	100%
D61L	100%	100%
D61M	100%	100%
D62A	100%	100%
D62B	100%	100%
D62C	100%	100%
D62D	100%	100%
D62E	100%	100%
D62F	100%	100%
D62G	100%	100%
D62H	100%	100%
D62J	100%	100%
Boegoeberg		
C92C	100%	100%
D71A	100%	100%
D71B	100%	100%
D71C	100%	100%
D71D	100%	100%
D72A	100%	100%
D72B	100%	100%
D72C	100%	100%

Water Management Area		
Apportionment		
Quat	Area	Special
Lower Orange WMA		
C92C	100%	100%
D42A	100%	100%
D42B	100%	100%
D42C	1%	1%
D42D	86%	86%
D42E	100%	100%
D51A	100%	100%
D51B	100%	100%
D51C	100%	100%
D52A	100%	100%
D52B	100%	100%
D52C	100%	100%
D52D	100%	100%
D52E	100%	100%
D52F	100%	100%
D53A	100%	100%
D53B	100%	100%
D53C	100%	100%
D53D	100%	100%
D53E	100%	100%
D53F	100%	100%
D53G	100%	100%
D53H	100%	100%
D53J	100%	100%
D54A	100%	100%
D54B	100%	100%
D54C	100%	100%
D54D	100%	100%
D54E	100%	100%
D54F	100%	100%

Provinces		
Apportionment		
Quat	Area	Special
Northern Cape		
C92C	100%	100%
D42A	100%	100%
D42B	100%	100%
D42C	1%	1%
D42D	86%	86%
D42E	100%	100%
D51A	100%	100%
D51B	100%	100%
D51C	100%	100%
D52A	100%	100%
D52B	100%	100%
D52C	100%	100%
D52D	100%	100%
D52E	100%	100%
D52F	100%	100%
D53A	100%	100%
D53B	100%	100%
D53C	100%	100%
D53D	100%	100%
D53E	100%	100%
D53F	100%	100%
D53G	100%	100%
D53H	100%	100%
D53J	100%	100%
D54A	100%	100%
D54B	100%	100%
D54C	100%	100%
D54D	100%	100%
D54E	100%	100%
D54F	100%	100%

Drainage Areas		
Apportionment		
Quat	Area	Special
Neusberg		
D73B	95%	100%
D73C	39%	100%
D73D	88%	100%
D73E	87%	100%
D73F	100%	100%
Sak-Hartbees		
D51A	100%	100%
D51B	100%	100%
D51C	100%	100%
D52A	100%	100%
D52B	100%	100%
D52C	100%	100%
D52D	100%	100%
D52E	100%	100%
D52F	100%	100%
D53A	100%	100%
D53B	100%	100%
D53C	100%	100%
D53D	100%	100%
D53E	100%	100%
D53F	100%	100%
D53G	100%	100%
D53H	100%	100%
D53J	100%	100%
D54A	100%	100%
D54B	100%	100%
D54C	100%	100%
D54D	100%	100%
D54E	100%	100%
D54F	100%	100%
D54G	100%	100%
D55A	100%	100%
D55B	100%	100%

Water Management Area		
Apportionment		
Quat	Area	Special
D54G	100%	100%
D55A	100%	100%
D55B	100%	100%
D55C	100%	100%
D55D	100%	100%
D55E	100%	100%
D55F	100%	100%
D55G	100%	100%
D55H	100%	100%
D55J	100%	100%
D55K	100%	100%
D55L	100%	100%
D55M	100%	100%
D56A	100%	100%
D56B	100%	100%
D56C	100%	100%
D56D	100%	100%
D56E	100%	100%
D56F	100%	100%
D56G	100%	100%
D56H	100%	100%
D56J	100%	100%
D57A	100%	100%
D57B	100%	100%
D57C	100%	100%
D57D	100%	100%
D57E	100%	100%
D58A	100%	100%
D58B	100%	100%
D58C	100%	100%
D61A	100%	100%
D61B	100%	100%
D61C	100%	100%
D61D	100%	100%

Provinces		
Apportionment		
Quat	Area	Special
D54G	100%	100%
D55A	19%	19%
D55B	100%	100%
D55C	57%	57%
D55D	99%	100%
D55E	100%	100%
D55F	100%	100%
D55G	100%	100%
D55H	100%	100%
D55J	100%	100%
D55K	100%	100%
D55L	100%	100%
D55M	100%	100%
D56A	100%	100%
D56B	100%	100%
D56C	100%	100%
D56D	100%	100%
D56E	100%	100%
D56F	100%	100%
D56G	100%	100%
D56H	100%	100%
D56J	100%	100%
D57A	100%	100%
D57B	100%	100%
D57C	100%	100%
D57D	100%	100%
D57E	100%	100%
D58A	100%	100%
D58B	100%	100%
D58C	100%	100%
D61A	100%	100%
D61B	100%	100%
D61C	100%	100%
D61D	100%	100%

Drainage Areas		
Apportionment		
Quat	Area	Special
D55C	100%	100%
D55D	100%	100%
D55E	100%	100%
D55F	100%	100%
D55G	100%	100%
D55H	100%	100%
D55J	100%	100%
D55K	100%	100%
D55L	100%	100%
D55M	100%	100%
D56A	100%	100%
D56B	100%	100%
D56C	100%	100%
D56D	100%	100%
D56E	100%	100%
D56F	100%	100%
D56G	100%	100%
D56H	100%	100%
D56J	100%	100%
D57A	100%	100%
D57B	100%	100%
D57C	100%	100%
D57D	100%	100%
D57E	100%	100%
D58A	100%	100%
D58B	100%	100%
D58C	100%	100%
Nossob-Molopo		
D42A	100%	100%
D42B	100%	100%
D42C	1%	1%
D42D	86%	86%
D42E	100%	100%

Water Management Area		
Apportionment		
Quat	Area	Special
D61E	100%	100%
D61F	100%	100%
D61G	100%	100%
D61H	100%	100%
D61J	100%	100%
D61K	100%	100%
D61L	100%	100%
D61M	100%	100%
D62A	100%	100%
D62B	100%	100%
D62C	100%	100%
D62D	100%	100%
D62E	100%	100%
D62F	100%	100%
D62G	100%	100%
D62H	100%	100%
D62J	100%	100%
D71A	100%	100%
D71B	100%	100%
D71C	100%	100%
D71D	100%	100%
D72A	100%	100%
D72B	100%	100%
D72C	100%	100%
D73B	95%	100%
D73C	39%	100%
D73D	88%	100%
D73E	87%	100%
D73F	100%	100%
D81A	100%	100%
D81B	100%	100%
D81C	100%	100%
D81D	100%	100%

Provinces		
Apportionment		
Quat	Area	Special
D61E	100%	100%
D61F	100%	100%
D61G	100%	100%
D61H	100%	100%
D61J	100%	100%
D61K	100%	100%
D61L	100%	100%
D61M	100%	100%
D62A	100%	100%
D62B	100%	100%
D62C	100%	100%
D62D	100%	100%
D62E	100%	100%
D62F	100%	100%
D62G	100%	100%
D62H	100%	100%
D62J	100%	100%
D71A	100%	100%
D71B	100%	100%
D71C	100%	100%
D71D	100%	100%
D72A	100%	100%
D72B	100%	100%
D72C	100%	100%
D73B	95%	100%
D73C	39%	100%
D73D	88%	100%
D73E	87%	100%
D73F	100%	100%
D81A	100%	100%
D81B	100%	100%
D81C	100%	100%
D81D	100%	100%

Drainage Areas		
Apportionment		
Quat	Area	Special
Vioolsdrift		
D81A	100%	100%
D81B	100%	100%
D81C	100%	100%
D81D	100%	100%
D81E	100%	100%
D81F	100%	100%
D81G	100%	100%
D82A	100%	100%
D82B	100%	100%
D82C	100%	100%
D82D	100%	100%
D82E	100%	100%
Namibia		
Z10A	83%	83%
Z10G	100%	100%
Z10H	100%	100%
Z10J	100%	100%
Z20A	100%	100%
Z20B	100%	100%
Z20C	100%	100%
Z20D	100%	100%
Z20E	100%	100%
Z20F	100%	100%
Alexander Bay		
D82F	100%	100%
D82G	100%	100%
D82H	100%	100%
D82J	100%	100%
D82K	100%	100%
D82L	100%	100%
Coastal		
F10A	100%	100%
F10B	100%	100%

Water Management Area		
Apportionment		
Quat	Area	Special
D81E	100%	100%
D81F	100%	100%
D81G	100%	100%
D82A	100%	100%
D82B	100%	100%
D82C	100%	100%
D82D	100%	100%
D82E	100%	100%
D82F	100%	100%
D82G	100%	100%
D82H	100%	100%
D82J	100%	100%
D82K	100%	100%
D82L	100%	100%
F10A	100%	100%
F10B	100%	100%
F10C	100%	100%
F20A	100%	100%
F20B	100%	100%
F20C	100%	100%
F20D	100%	100%
F20E	100%	100%
F30A	100%	100%
F30B	100%	100%
F30C	100%	100%
F30D	100%	100%
F30E	100%	100%
F30F	100%	100%
F30G	100%	100%
F40A	100%	100%
F40B	100%	100%
F40C	100%	100%
F40D	100%	100%
F40E	100%	100%

Provinces		
Apportionment		
Quat	Area	Special
D81E	100%	100%
D81F	100%	100%
D81G	100%	100%
D82A	100%	100%
D82B	100%	100%
D82C	100%	100%
D82D	100%	100%
D82E	100%	100%
D82F	100%	100%
D82G	100%	100%
D82H	100%	100%
D82J	100%	100%
D82K	100%	100%
D82L	100%	100%
F10A	100%	100%
F10B	100%	100%
F10C	100%	100%
F20A	100%	100%
F20B	100%	100%
F20C	100%	100%
F20D	100%	100%
F20E	100%	100%
F30A	100%	100%
F30B	100%	100%
F30C	100%	100%
F30D	100%	100%
F30E	100%	100%
F30F	100%	100%
F30G	100%	100%
F40A	100%	100%
F40B	100%	100%
F40C	100%	100%
F40D	100%	100%
F40E	100%	100%

Drainage Areas		
Apportionment		
Quat	Area	Special
F10C	100%	100%
F20A	100%	100%
F20B	100%	100%
F20C	100%	100%
F20D	100%	100%
F20E	100%	100%
F30A	100%	100%
F30B	100%	100%
F30C	100%	100%
F30D	100%	100%
F30E	100%	100%
F30F	100%	100%
F30G	100%	100%
F40A	100%	100%
F40B	100%	100%
F40C	100%	100%
F40D	100%	100%
F40E	100%	100%
F40F	100%	100%
F40G	100%	100%
F40H	100%	100%
F50A	100%	100%
F50B	100%	100%
F50C	100%	100%
F50D	100%	100%
F50E	100%	100%
F50F	100%	100%
F50G	100%	100%

Water Management Area		
Apportionment		
Quat	Area	Special
F40F	100%	100%
F40G	100%	100%
F40H	100%	100%
F50A	100%	100%
F50B	100%	100%
F50C	100%	100%
F50D	100%	100%
F50E	100%	100%
F50F	100%	100%
F50G	100%	100%

Provinces		
Apportionment		
Quat	Area	Special
F40F	100%	100%
F40G	100%	100%
F40H	100%	100%
F50A	43%	43%
F50B	100%	100%
F50C	72%	72%
F50D	40%	40%
F50E	100%	100%
F50F	100%	100%
F50G	100%	100%
Western Province		
D55A	81%	81%
D55C	43%	43%
D55D	2%	0%
F50A	57%	57%
F50C	28%	28%
F50D	60%	60%
Namibia		
Z10A	83%	83%
Z10G	100%	100%
Z10H	100%	100%
Z10J	100%	100%
Z20A	100%	100%
Z20B	100%	100%
Z20C	100%	100%
Z20D	100%	100%
Z20E	100%	100%
Z20F	100%	100%

ANNEXURE D.2

DRAINAGE AREAS

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km^2)	(km^2)
Ongers			
D61A	100%	1 466	1 466
D61B	100%	1 199	1 199
D61C	100%	1 170	1 170
D61D	100%	651	651
D61E	100%	1 091	1 091
D61F	100%	873	873
D61G	100%	744	744
D61H	100%	1 086	1 086
D61J	100%	1 558	1 558
D61K	100%	1 608	1 608
D61L	100%	1 016	1 016
D61M	100%	943	943
D62A	100%	2 243	2 243
D62B	100%	3 117	3 117
D62C	100%	2 130	2 130
D62D	100%	2 402	2 402
D62E	100%	1 924	1 924
D62F	100%	1 701	1 701
D62G	100%	2 549	2 549
D62H	100%	2 062	2 062
D62J	100%	2 200	2 200
Total Drainage Area			33 733
Boegoeberg			
C92C	100%	1 959	1 959
D71A	100%	1 210	1 210
D71B	100%	2 875	2 875
D71C	100%	1 592	1 592
D71D	100%	1 713	1 713
D72A	100%	1 397	1 397
D72B	100%	2 569	2 569
D72C	100%	2 776	2 776

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km²)	(km²)
Total Drainage Area			16 091
Neusberg			
D73B	95%	3 721	3 535
D73C	39%	6 221	2 426
D73D	88%	4 291	3 776
D73E	87%	3 867	3 364
D73F	100%	4 630	4 630
Total Drainage Area			17 732
Nossob-Molopo			
D42A	100%	10 280	10 280
D42B	100%	3 198	3 198
D42C	1%	18 300	183
D42D	86%	16 210	13 941
D42E	100%	4 208	4 208
Total Drainage Area		52 196	31 810
Sak-Hartbees			
D51A	100%	797	797
D51B	100%	873	873
D51C	100%	522	522
D52A	100%	378	378
D52B	100%	660	660
D52C	100%	465	465
D52D	100%	638	638
D52E	100%	609	609
D52F	100%	1 146	1 146
D53A	100%	1 939	1 939
D53B	100%	1 713	1 713
D53C	100%	1 899	1 899
D53D	100%	1 842	1 842
D53E	100%	826	826
D53F	100%	8 040	8 040
D53G	100%	4 747	4 747

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km²)	(km²)
D53H	100%	1 589	1 589
D53J	100%	455	455
D54A	100%	1 518	1 518
D54B	100%	4 053	4 053
D54C	100%	1 342	1 342
D54D	100%	5 071	5 071
D54E	100%	3 326	3 326
D54F	100%	3 809	3 809
D54G	100%	4 503	4 503
D55A	100%	1 872	1 872
D55B	100%	1 260	1 260
D55C	100%	761	761
D55D	100%	1 889	1 889
D55E	100%	2 240	2 240
D55F	100%	2 632	2 632
D55G	100%	1 293	1 293
D55H	100%	1 151	1 151
D55J	100%	1 998	1 998
D55K	100%	1 247	1 247
D55L	100%	1 242	1 242
D55M	100%	1 813	1 813
D56A	100%	510	510
D56B	100%	519	519
D56C	100%	920	920
D56D	100%	621	621
D56E	100%	666	666
D56F	100%	1 038	1 038
D56G	100%	651	651
D56H	100%	447	447
D56J	100%	931	931
D57A	100%	853	853
D57B	100%	2 274	2 274
D57C	100%	637	637
D57D	100%	4 444	4 444
D57E	100%	1 957	1 957
D58A	100%	763	763

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km²)	(km²)
D58B	100%	1 131	1 131
D58C	100%	2 521	2 521
Total Drainage Area			93 041
Vioolsdrif			
D81A	100%	2 311	2 311
D81B	100%	851	851
D81C	100%	2 682	2 682
D81D	100%	1 826	1 826
D81E	100%	1 291	1 291
D81F	100%	1 841	1 841
D81G	100%	2 007	2 007
D82A	100%	1 917	1 917
D82B	100%	4 877	4 877
D82C	100%	3 996	3 996
D82D	100%	2 967	2 967
D82E	100%	944	944
Total Drainage Area			27 510
Namibia			
Z10A	83%	98 900	82 087
Z10G	100%	8 829	8 829
Z10H	100%	8 632	8 632
Z10J	100%	682	682
Z20A	100%	108 300	108 300
Z20B	100%	10 390	10 390
Z20C	100%	5 590	5 590
Z20D	100%	10 460	10 460
Z20E	100%	5 593	5 593
Z20F	100%	3 733	3 733
Total Drainage Area			244 296
Alexander Bay			
D82F	100%	1 039	1 039
D82G	100%	594	594

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km²)	(km²)
D82H	100%	822	822
D82J	100%	1 385	1 385
D82K	100%	917	917
D82L	100%	754	754
Total Drainage Area			5 511
Coastal			
F10A	100%	460	460
F10B	100%	1 089	1 089
F10C	100%	1 176	1 176
F20A	100%	1 120	1 120
F20B	100%	514	514
F20C	100%	613	613
F20D	100%	455	455
F20E	100%	435	435
F30A	100%	1 954	1 954
F30B	100%	1 462	1 462
F30C	100%	1 655	1 655
F30D	100%	976	976
F30E	100%	1 260	1 260
F30F	100%	1 469	1 469
F30G	100%	980	980
F40A	100%	984	984
F40B	100%	404	404
F40C	100%	608	608
F40D	100%	741	741
F40E	100%	1 065	1 065
F40F	100%	682	682
F40G	100%	348	348
F40H	100%	514	514
F50A	100%	1 303	1 303
F50B	100%	603	603
F50C	100%	439	439
F50D	100%	687	687
F50E	100%	487	487

Drainage Area & Quaternary Catchment	Area Apportionment	Quaternary Catchment Area	Quaternary Area Applicable to Drainage Area
		(km²)	**(km²)**
F50F	100%	575	575
F50G	100%	775	775
Total Drainage Area			25 833

APPENDIX D.3

ALIEN VEGETATION

APPENDIX D.3

ALIEN VEGETATION IN THE LOWMA

The predominant species of alien vegetation in the LOWMA

Description	Total Area Invaded in Northern Cape	Condensed Area	Water Use
	(ha)	(ha)	(Mm^3/a)
Prosopis species (mostly)	1 047 135	134 495	134 088
Nicotiana (river beds)	2 700	1 224	0
Acacia cyclops (catchment F)	123 101	26 722	15 135

The following factors as defined by the CSIR are provided for reference purposes

Density Class	Canopy Cover (%)	Scaling Factor
Rare	< 0.1	0.0001
Occasional	< 5	0.025
Scattered	5 - 25	0.15
Moderate	25 - 75	0.50
Dense	> 75	0.875

APPENDIX D.4

LIVE STOCK CONVERTION

APPENDIX D.4

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

SPECIES	NUMBER PER ELSU
LIVESTOCK	
Cattle	0,85
Sheep	6,5
Goats	5,8
Horses (Reference Value)	**1,0**
Donkeys/Mules	1,1
Pigs	4,0
GAME	
Black Wildebeest	3,3
Blesbuck	5,1
Blou Wildebeest	2,4
Bufffalo	1,0
Eland (Reference Value)	**1,0**
Elephant	0,3
Gemsbok	2,2
Giraffe	0,7
Hippopotamus	0,4
Impala	7,0
Kudu	2,2
Nyala	3,3
Ostrich	2,7
Red Hartebeest	2,8
Roan Antelope	2,0
Sable Antelope	2,0
Southern Reedbuck	7,7
Springbok	10,3
Tsessebe	2,8
Warthog	5,0
Waterbuck	2,4
Rhinoceros	0,4
Zebra	1,6

APPENDIX D.5

GAME AND LIVESTOCK

PER QUARTERNARY CATCHMENT

Appendix D.5

Game and Livestock per quaternary catchment

Drainage Area	Cattle & Horses	Small Livestock	Big game	Large Antelope	Small Antelope	Ostrich	Other	Eqivalent Large Stock Units
Ongers	**12 793**	**1 472 928**	**0**	**0**	**28 924**	**0**	**0**	**151 513**
D61A	1 112	77 105	0	0	1 413	0	0	5 401
D61B	910	63 062	0	0	1 156	0	0	4 418
D61C	548	53 562	0	0	1 061	0	0	4 747
D61D	191	27 140	0	0	568	0	0	2 787
D61E	194	42 508	0	0	928	0	0	4 833
D61F	155	34 014	0	0	742	0	0	3 867
D61G	132	28 988	0	0	633	0	0	3 296
D61H	193	42 313	0	0	923	0	0	4 811
D61J	221	56 573	0	0	1 125	0	0	6 761
D61K	270	58 084	0	0	1 378	0	0	7 006
D61L	261	30 812	0	0	914	0	0	4 052
D61M	137	27 366	0	0	824	0	0	3 936
D62A	294	55 536	0	0	1 983	0	0	9 116
D62B	447	88 123	0	0	2 277	0	0	12 619
D62C	1 166	120 381	0	0	1 836	0	0	11 074
D62D	895	106 644	0	0	904	0	0	8 803
D62E	435	68 356	0	0	2 121	0	0	10 961
D62F	2 311	239 115	0	0	5 569	0	0	13 252
D62G	1 634	122 175	0	0	1 089	0	0	12 585
D62H	259	45 908	0	0	836	0	0	7 519
D62J	1 029	85 161	0	0	643	0	0	9 670
Sak-Hartbees	**3 195**	**1 617 076**	**0**	**0**	**6 034**	**0**	**0**	**232 031**
D51A	83	23 584	0	0	0	0	0	2 059
D51B	91	25 833	0	0	0	0	0	2 256
D51C	22	7 400	0	0	0	0	0	624
D52A	39	11 185	0	0	0	0	0	977
D52B	68	19 530	0	0	0	0	0	1 705
D52C	48	13 760	0	0	0	0	0	1 201
D52D	0	3 730	0	0	0	0	0	259
D52E	0	3 561	0	0	0	0	0	248
D52F	0	6 701	0	0	0	0	0	466

Drainage Area	Cattle & Horses	Small Livestock	Big game	Large Antelope	Small Antelope	Ostrich	Other	Eqivalent Large Stock Units
D53A	114	27 085	0	0	0	0	0	4 441
D53B	101	23 928	0	0	0	0	0	3 924
D53C	112	26 526	0	0	0	0	0	4 350
D53D	108	25 730	0	0	0	0	0	4 219
D53E	49	11 538	0	0	0	0	0	1 892
D53F	0	47 011	0	0	0	0	0	3 269
D53G	280	66 308	0	0	0	0	0	10 873
D53H	94	22 196	0	0	0	0	0	3 640
D53J	27	6 356	0	0	0	0	0	1 042
D54A	0	39 020	0	0	317	0	0	6 041
D54B	0	104 183	0	0	847	0	0	16 129
D54C	0	34 496	0	0	281	0	0	5 340
D54D	191	125 115	0	0	1 359	0	0	19 673
D54E	0	46 253	0	0	277	0	0	7 153
D54F	67	78 723	0	0	397	0	0	12 325
D54G	386	77 842	0	0	730	0	0	12 757
D55A	21	8 596	0	0	0	0	0	1 357
D55B	70	28 929	0	0	0	0	0	4 567
D55C	68	14 825	0	0	324	0	0	1 686
D55D	119	50 972	0	0	440	0	0	7 352
D55E	124	51 429	0	0	0	0	0	8 118
D55F	86	65 878	0	0	247	0	0	10 290
D55G	29	31 817	0	0	162	0	0	4 962
D55H	51	25 895	0	0	16	0	0	4 071
D55J	0	41 259	0	0	138	0	0	6 372
D55K	35	27 191	0	0	43	0	0	4 248
D55L	0	25 647	0	0	85	0	0	3 961
D55M	0	32 071	0	0	100	0	0	4 773
D56A	53	15 092	0	0	0	0	0	1 318
D56B	54	15 358	0	0	0	0	0	1 341
D56C	95	27 224	0	0	0	0	0	2 377
D56D	64	18 376	0	0	0	0	0	1 605
D56E	37	15 291	0	0	0	0	0	2 414
D56F	58	23 832	0	0	0	0	0	3 762

Drainage Area	Cattle & Horses	Small Livestock	Big game	Large Antelope	Small Antelope	Ostrich	Other	Eqivalent Large Stock Units
D56G	36	14 947	0	0	0	0	0	2 359
D56H	40	12 338	0	0	0	0	0	1 295
D56J	31	20 515	0	0	26	0	0	3 212
D57A	0	10 038	0	0	23	0	0	1 296
D57B	0	46 958	0	0	156	0	0	7 252
D57C	0	4 668	0	0	4	0	0	436
D57D	131	57 187	0	0	61	0	0	8 466
D57E	115	27 336	0	0	0	0	0	4 483
D58A	0	4 461	0	0	0	0	0	310
D58B	0	6 613	0	0	0	0	0	460
D58C	0	14 741	0	0	0	0	0	1 025
Nossob-Molopo	**10 831**	**408 992**	**0**	**159**	**1 979**	**147**	**0**	**74 098**
D42A	2 883	130 611	0	49	631	47	0	23 482
D42B	897	40 624	0	15	196	15	0	7 304
D42C	1 962	7 218	0	7	37	1	0	1 864
D42D	3 909	177 086	0	67	856	64	0	31 838
D42E	1 180	53 454	0	20	258	19	0	9 610
Boegoeberg	**18 787**	**550 917**	**0**	**83**	**4 910**	**66**	**0**	**65 980**
C92C	1 100	65 000	0	25	500	0	0	5 424
D71A	11 696	159 021	0	52	2 204	53	0	6 867
D71B	1 787	66 512	0	2	80	5	0	12 447
D71C	1 275	68 864	0	1	120	1	0	7 839
D71D	895	39 331	0	1	177	3	0	7 182
D72A	176	31 103	0	0	567	0	0	5 094
D72B	960	58 314	0	1	557	2	0	10 245
D72C	899	62 772	0	1	706	2	0	10 881
Neusberg	**14 546**	**269 359**	**0**	**65**	**735**	**52**	**0**	**51 805**
D73B	2 197	81 779	0	3	98	7	0	15 304
D73C	10 404	99 477	0	29	211	14	0	20 661
D73D	635	28 780	0	11	139	10	0	5 174
D73E	660	29 915	0	11	145	11	0	5 378

Drainage Area	Cattle & Horses	Small Livestock	Big game	Large Antelope	Small Antelope	Ostrich	Other	Eqivalent Large Stock Units
D73F	649	29 407	0	11	142	11	0	5 287
Vioolsdrif	**3 264**	**359 381**	**0**	**19**	**242**	**18**	**0**	**60 406**
D81A	341	31 111	0	4	57	4	0	5 287
D81B	126	11 456	0	2	21	2	0	1 947
D81C	752	34 069	0	13	165	12	0	6 125
D81D	108	25 506	0	0	0	0	0	4 183
D81E	76	18 033	0	0	0	0	0	2 957
D81F	108	25 716	0	0	0	0	0	4 217
D81G	151	27 199	0	0	0	0	0	4 489
D82A	216	24 116	0	0	0	0	0	4 046
D82B	497	62 706	0	0	0	0	0	10 468
D82C	450	50 269	0	0	0	0	0	8 433
D82D	334	37 324	0	0	0	0	0	6 262
D82E	106	11 875	0	0	0	0	0	1 992
Alexander Bay	**621**	**69 328**	**0**	**0**	**0**	**0**	**0**	**11 631**
D82F	117	13 070	0	0	0	0	0	2 193
D82G	67	7 472	0	0	0	0	0	1 254
D82H	93	10 341	0	0	0	0	0	1 735
D82J	156	17 423	0	0	0	0	0	2 923
D82K	103	11 536	0	0	0	0	0	1 935
D82L	85	9 485	0	0	0	0	0	1 591
Coastal	**3 909**	**441 624**	**0**	**0**	**0**	**0**	**0**	**74 112**
F10A	73	8 260	0	0	0	0	0	1 386
F10B	173	19 555	0	0	0	0	0	3 282
F10C	187	21 117	0	0	0	0	0	3 544
F20A	178	20 112	0	0	0	0	0	3 375
F20B	82	9 230	0	0	0	0	0	1 549
F20C	97	11 008	0	0	0	0	0	1 847
F20D	72	8 170	0	0	0	0	0	1 371
F20E	69	7 811	0	0	0	0	0	1 311
F30A	311	35 088	0	0	0	0	0	5 888
F30B	232	26 253	0	0	0	0	0	4 406

Drainage Area	Cattle & Horses	Small Livestock	Big game	Large Antelope	Small Antelope	Ostrich	Other	Eqivalent Large Stock Units
F30C	263	29 718	0	0	0	0	0	4 987
F30D	155	17 526	0	0	0	0	0	2 941
F30E	200	22 626	0	0	0	0	0	3 797
F30F	233	26 379	0	0	0	0	0	4 427
F30G	156	17 598	0	0	0	0	0	2 953
F40A	156	17 669	0	0	0	0	0	2 965
F40B	64	7 255	0	0	0	0	0	1 217
F40C	97	10 918	0	0	0	0	0	1 832
F40D	118	13 306	0	0	0	0	0	2 233
F40E	169	19 124	0	0	0	0	0	3 209
F40F	108	12 247	0	0	0	0	0	2 055
F40G	55	6 249	0	0	0	0	0	1 049
F40H	82	9 230	0	0	0	0	0	1 549
F50A	104	11 699	0	0	0	0	0	1 963
F50B	96	10 828	0	0	0	0	0	1 817
F50C	42	4 730	0	0	0	0	0	794
F50D	44	4 935	0	0	0	0	0	828
F50E	77	8 745	0	0	0	0	0	1 468
F50F	91	10 325	0	0	0	0	0	1 733
F50G	123	13 917	0	0	0	0	0	2 335
Namibia	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**914 672**
Z10A								187 497
Z10G								20 550
Z10H								18 270
Z10J								1 370
Z20A								399 000
Z20B								20 610
Z20C								9 495
Z20D								241 000
Z20E								9 494
Z20F								7 386

APPENDIX D.6

MINES IN THE LOWER ORANGE WMA

APPENDIX D.6

ACTIVE MINES IN THE LOWER ORANGE WMA

Mine Name	District	Province	Farm Name	Farm No.	Latitude	Longitude	COM1DESCRI	COM2DESCRI	COM3DESCRI	COM4DESCRI	DEPOSIT
MINE NAME UNKNOWN		WESTERN CAPE	LELIEFONTEIN	817	-31.41810	23.11940					
GAMS BARYTES MINE	NAMAQUALAND	NORTHERN CAPE	GAMS	60	-29.26167	18.97556	BARYTES	IRON	MANGANESE		
MINE NAME UNKNOWN		NORTHERN CAPE	STEINKOPF	22	-28.98444	17.72889	BERYLLIUM	FELDSPAR	COPPER	LITHIUM	
MINE NAME UNKNOWN		NORTHERN CAPE	VIOOLSDRIF COMMUNAL RESERVE	226	-28.88778	17.75417	BERYLLIUM	TANTALUM/NIOBIUM	MICA		
MINE NAME UNKNOWN		NORTHERN CAPE	NIGRAMOEP	136	-29.55972	17.59611	COPPER				NIGRAMOEP
O'OKIEP COPPER MINE	NAMAQUALAND	NORTHERN CAPE	MELKBOSCHKUIL	132	-29.64639	17.94083	COPPER				
O'OKIEP COPPER MINE	NAMAQUALAND	NORTHERN CAPE	MELKBOSCHKUIL	132	-29.64528	17.96167	COPPER				
MINE NAME UNKNOWN		NORTHERN CAPE	CAROLUSBERG	NO 1	-29.63333	17.95000	COPPER				
KLEINZEE DIAMOND MINE	NAMAQUALAND	NORTHERN CAPE	KLEIN ZEE	193	-29.65583	17.06611	DIAMOND (ALLUVIAL)				KLEIN SEE
MINE NAME UNKNOWN		NORTHERN CAPE	THE RICHTERSVELD	11	-28.17500	16.83889	DIAMOND (ALLUVIAL)				JAKHALSBERG
MINE NAME UNKNOWN		NORTHERN CAPE	THE RICHTERSVELD	11	-28.40417	16.78056	DIAMOND (ALLUVIAL)				BAKEN
STATE ALLUVIAL DIGGINGS	NAMAQUALAND	NORTHERN CAPE	STATE LAND	1	-28.66167	16.51667	DIAMOND (ALLUVIAL)				
MINE NAME UNKNOWN		NORTHERN CAPE	THE RICHTERSVELD	11	-28.32639	16.80556	DIAMOND (ALLUVIAL)				XARRIES-BLOEDDRIF
ALEXKOR MINE	NAMAQUALAND	NORTHERN CAPE	STATE LAND	1	-28.66667	16.53333	DIAMOND (ALLUVIAL)				
HONDEKLIPBAAI MINE	NAMAQUALAND	NORTHERN CAPE	HONDEKLIP	ERF 1	-30.33750	17.33000	DIAMOND (ALLUVIAL)				
LANG HOOGTE MINE	NAMAQUALAND	NORTHERN CAPE	LANGHOOGTE	184	-29.52139	17.42972	DIAMOND (ALLUVIAL)				
KOINGNAAS	NAMAQUALAND	NORTHERN CAPE	KOINGNAAS	475	-30.20917	17.27417	DIAMOND (ALLUVIAL)				
KOMAGGAS MINE	NAMAQUALAND	NORTHERN CAPE	KAMAGGAS	200	-29.61667	17.50000	DIAMOND (ALLUVIAL)				
FINSCH DIAMOND MINE	HAY	NORTHERN CAPE	CARTER BLOCK	458	-28.38167	23.44333	DIAMOND (IN KIMBERLITE)				FINSCH
MINE NAME UNKNOWN		NORTHERN	KOEGAB	59	-28.97333	20.83944	FELDSPAR	ROSE QUARTZ (GEMSTONE)			

Mine Name	District	Province	Farm Name	Farm No.	Latitude	Longitude	COM1DESCRI	COM2DESCRI	COM3DESCRI	COM4DESCRI	DEPOSIT
		CAPE									
BAUERMEISTER PEGMATITE MINE	KENHARDST	NORTHERN CAPE	KAKAMAS SUID	28	-28.71389	20.45194	FELDSPAR	BERYLLIUM	RARE EARTHS		BAUERMEISTER
MINE NAME UNKNOWN		NORTHERN CAPE	MOTTELS RIVIER	179	-29.48667	21.39778	FELDSPAR	ROSE QUARTZ (GEMSTONE)	BERYLLIUM	RARE EARTHS	
MINE NAME UNKNOWN		NORTHERN CAPE	STEYNS PUTS	178	-29.48917	21.43583	FELDSPAR				
SIDI BARRANI MINE	KENHARDT	NORTHERN CAPE	STEYNS PUTS	178	-29.45000	21.48333	FELDSPAR	GYPSUM	SILICA (GENERAL)		
BOOYSEN MINE	KENHARDST	NORTHERN CAPE	DABERAS	8	-28.48333	19.95000	ROSE QUARTZ (GEMSTONE)				
MINE NAME UNKNOWN		NORTHERN CAPE	WATER KUIL	185	-30.12861	19.56861	GYPSUM				
MINE NAME UNKNOWN		NORTHERN CAPE	STEINKOPF	22	-29.16833	17.76250	LIMESTONE				KINDERLE
LIME ACRES MINE	HAY	NORTHERN CAPE	CARTER BLOCK	458	-28.36583	23.49889	LIMESTONE				
MINE NAME UNKNOWN		NORTHERN CAPE	GROOTRIET	529	-30.68333	18.24278	GRANITE/QUARTZ-PORPHYRY/SYENITE (DIMENSION STONE)				
VRYSOUTPAN SALTWORKS		NORTHERN CAPE	VRYSOUTPAN	251/58	-27.33972	20.82250	SALT				
MINE NAME UNKNOWN		NORTHERN CAPE	GROOT WITPAN	327	-27.74417	20.74833	SALT				NYLON PAN
MINE NAME UNKNOWN		NORTHERN CAPE	ANNESLEY	338	-27.62694	20.49278	SALT				
MINE NAME UNKNOWN		NORTHERN CAPE	STATE LAND	1	-28.65806	16.54139	SALT				
KRANSPAN SALT WORKS	HOPETOWN	NORTHERN CAPE	KRANSPAN	62	-29.52194	23.42778	SALT				
MINE NAME UNKNOWN		NORTHERN CAPE	DWAGGAS OOST	190	-30.22722	19.71361	SALT				KWAGGA SALT PAN
MINE NAME UNKNOWN		NORTHERN CAPE	STATE LAND	18	-28.57222	17.37028	SALT				
MINE NAME UNKNOWN		NORTHERN CAPE	NOROKEI	317	-27.83472	20.90333	SALT				
BLACK MOUNTAIN MINE		NORTHERN CAPE	ZUURWATER	62	-29.24833	18.77833	LEAD	ZINC	SILVER	COPPER	BROKEN HILL
MINE NAME UNKNOWN		NORTHERN CAPE	VICTORIA WEST COMMONAGE		-31.41806	23.11944	ROAD METAL	STONE AGGREGATE, GRAVEL			
PELLA REFRACTORY ORES		NORTHERN CAPE	PELLA MISSION	39	-29.10917	19.10278	SILLIMANITE	CORUNDUM			PELLA
MINE NAME UNKNOWN		NORTHERN CAPE	DROOGEHOUT	442	-28.37500	20.87222	STONE AGGREGATE, GRAVEL				

Mine Name	District	Province	Farm Name	Farm No.	Latitude	Longitude	COM1DESCRI	COM2DESCRI	COM3DESCRI	COM4DESCRI	DEPOSIT
MINE NAME UNKNOWN		NORTHERN CAPE	SPRINGBOK COMMONAGE		-29.66139	17.87528	STONE AGGREGATE, GRAVEL				
MINE NAME UNKNOWN		NORTHERN CAPE	WILGEHOUT FONTEIN	426	-30.47972	18.04750	WOLLASTONITE				
ANGELIERSPAN	KENHARDT	NORTHERN CAPE	ANGELIERS PAN	260	-29.53060	21.74190					
NOUMAS	NAMAQUALAND	NORTHERN CAPE	STEINKOPF COMMUNAL RESERVE	22	-28.98440	17.72890					
STRAUSSHEIM	KENHARDT	NORTHERN CAPE	NROUGAS NOORD	108	-29.09920	21.24810					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	VIOOLSDRIF COMMUNAL RESERVE	226	-28.88780	17.75420					
CAROLUSBERG	NAMAQUALAND	NORTHERN CAPE	CAROLUSBERG	NO 1	-29.63330	17.95000					
NIGRAMOEP	NAMAQUALAND	NORTHERN CAPE	NIGRAMOEP	136	-29.55970	17.59610					
KLEINZEE	NAMAQUALAND	NORTHERN CAPE	KLEIN ZEE	193	-29.65580	17.06610					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	DREYERS PAN	192	-29.60390	17.04440					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	SAND KOP	322	-29.65920	17.05560					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	TWEE PAD	176	-29.42890	17.00000					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	DREYERS PAN	192	-29.60250	17.05640					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	THE RICHTERSVELD	11	-28.40420	16.78060					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	KLEIN ZEE	193	-29.62720	17.05720					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	THE RICHTERSVELD	11	-28.30830	16.78890					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	THE RICHTERSVELD	11	-28.45970	16.77780					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	THE RICHTERSVELD	11	-28.45780	16.77360					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	KLEIN ZEE	193	-29.62860	17.04750					
SWARTKOP	NAMAQUALAND	NORTHERN CAPE	VIOOLSDRIF SETTLEMENT	226	-28.90000	17.76110					
MINE NAME UNKNOWN	KENHARDT	NORTHERN CAPE	MOTTELS RIVIER	179	-29.48670	21.39780					
MINE NAME UNKNOWN	KENHARDT	NORTHERN	STEYNS PUTS	178	-29.48920	21.43580					

Mine Name	District	Province	Farm Name	Farm No.	Latitude	Longitude	COM1DESCRI	COM2DESCRI	COM3DESCRI	COM4DESCRI	DEPOSIT
		CAPE									
MINE NAME UNKNOWN	KENHARDT	NORTHERN CAPE	KOEGAB	59	-28.97330	20.83940					
BOESMANLAND (WATERKUIL)	CALVINIA	NORTHERN CAPE	WATER KUIL	185	-30.12860	19.56860					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	STEINKOPF COMMUNAL RESERVE	22	-29.16830	17.76250					
MINE NAME UNKNOWN	NAMAQUALAND	NORTHERN CAPE	GROOTRIET	529	-30.68330	18.24280					
KWAGG	CALVINIA	NORTHERN CAPE	DWAGGAS OOST	190	-30.22720	19.71360					
NYLONPAN	GORDONIA	NORTHERN CAPE	GROOT WITPAN	327	-27.74420	20.74830					
MINE NAME UNKNOWN	HOPETOWN	NORTHERN CAPE	SOUT PANS PUT	103	-27.83470	20.90330					
BROKEN HILL	NAMAQUALAND	NORTHERN CAPE	ZUURWATER	62	-29.24830	18.77830					
KAALPAN	HOPETOWN	NORTHERN CAPE	KAAL PAN	218	-29.97028	24.03694	SALT				KAALPAN
MINE NAME UNKNOWN	GORDONIA	NORTHERN CAPE	SCHOLTZ FONTEIN NORTH	137	-27.62690	20.49280					
MINE NAME UNKNOWN	CALVINIA	NORTHERN CAPE	BITTER PUTS	187	-30.32278	19.66611	SALT				BITTERPUTS AND BUCHU FONTEIN SALTPAN

	Mines that impact significantly on the economy of the region/town

APPENDIX E

SURFACE WATER RELATED INFRASTRUCTURE

APPENDIX E.1

WATER QUALITY MONITORING STATIONS

APPENDIX E.1

Summary analysis of all surface water monitoring stations in the study area where TDS concentrations were recorded since September 1992. The shaded monitoring stations were the only ones where there were sufficient data to compile a data series of 24 consecutive monthly values.

Station	Description	TDS observations	Average TDS (mg/ℓ)	Average colour	Maximum TDS (mg/ℓ)	Maximum colour	Overall colour
D4R002Q01	Abiekwasputs Pan on Molopo River At Abiekwasputs	1	144.0	Blue	144	Blue	Blue
D5H003Q01	Fish River At Hardeheuwel/Harderug	10	766.9	Yellow	2 449	Red	Red
D5H004Q01	Sak River At Tabaks Fontein/Vastrap	3	240.0	Blue	272	Green	Green
D5H011Q01	Renoster River At Bonekraal	16	815.6	Yellow	1 364	Yellow	Yellow
D5H017Q01	Renoster River At Leeuwenkuil	23	3 975.6	Purple	8 347	Purple	Purple
D5H019Q01	Sak River At Tabaks Fontein	10	667.3	Yellow	1 541	Yellow	Yellow
D5H021Q01	Sak River At De Kruis/Williston	55	2 597.7	Red	6 296	Purple	Purple
D5R001Q01	Rooiberg Dam on Hartbees River: Near Dam Wall	25	560.6	Green	1 345	Yellow	Yellow
D7H002Q01	Orange River At Prieska	38	2 10.2	Blue	319	Green	Green
D7H003Q01	Orange River At Kakamas	1	191.0	Blue	191	Blue	Blue
D7H005Q01	Orange River At Upington	88	245.0	Blue	490	Green	Green
D7H008Q01	Orange River At Boegoeberg Reserve/Zeekoebaart	122	211.0	Blue	612	Yellow	Green
D7H012Q01	Orange River At Irene	11	171.6	Blue	203	Blue	Blue
D7H013Q01	Boegoeberg Dam on Orange River: Left Canal	6	3 34.9	Green	384	Green	Green
D7H014Q01	Orange River At Kakamas South/Neusberg Left Side	45	2 47.6	Blue	393	Green	Green
D7H015Q01	South Canal From Orange River At Kakamas/Neusberg	104	2 43.2	Blue	550	Green	Green

Station	Description	TDS observations	Average TDS (mg/ℓ)	Average colour	Maximum TDS (mg/ℓ)	Maximum colour	Overall colour
D7H016Q01	North Canal From Orange River At Kakamas/Neusberg	98	244.2	Blue	530	Green	Green
D8H003Q01	Orange River At Vioolsdrift	183	303.2	Green	597	Green	Green
D8H004Q01	Orange River At Onseepkans	179	287.6	Green	538	Green	Green
D8H007Q01	Orange River At Korridor/Brand Kaross	3	448.0	Green	635	Yellow	Yellow
D8H008Q01	Orange River At Pella Mission	110	267.2	Green	415	Green	Green
D8H012Q01	Orange River At Alexander Bay/Ernst Oppenheimer Bridge	138	344.3	Green	626	Yellow	Yellow
F6H001R01	Bitterfontein Desalination Plant – Before Treatment	34	3 104.8	Red	4 229	Purple	Purple
F6H001S01	Bitterfontein Desalination Plant – Treated Water	30	744.3	Yellow	3 917	Purple	Purple

APPENDIX E.2

DETAILS OF CANAL SYSTEMS

APPENDIX E.2

DETAILS OF CANAL SYSTEMS

DETAILS OF THE NOORD-ORANJE CANAL

Reach No.	Length (m)	Capacity (m³/s)
1	11 600	1,81
2	7 450	1,53
3	6 630	0,91
4	2 360	0,45
5	2 590	0,23
Total	**30 630**	

DETAILS OF THE UPINGTON INLAND MAIN CANAL

Reach No.	Length (m)	Irrigation Board	Canal Capacity (m³/s)
1	11 598	Straussburg	9,911
2	6 633	Strausburg Olyvenhoursdrift South	8,807
3	7 189	Olyvenhoursdrift South	8,807
4	3 141	Louisvale	8,807
5	10 882	Louisvale	6,230
6	4 937	Louisvale	3,936
7	9 530	Louisvale	1,529
8	4 521	Louisvale Blaauwskop Kanoneiland Upper	0,813
Total	**58 521**	**-**	**-**

DETAILS OF THE IRRIGATION BOARDS IN THE UPINGTON ISLANDS GWS

Name	Area under irrigation (ha)			
	Canal	River		Total
		Basic	Bought	
Straussburg	552,4	-	-	552,4
Olyvenhoutsdrift South	639,3	12,2	120,0	771,5
Swartkop	971,0	34,0	20,0	1 025,0
Louisvale	1 118,5	25,3	70,3	1 214,1
Blaauwskop	690,2	0	100,4	790,6
Steynsvoor	1 353,7	8,4	16,4	1 378,5
Kanoneiland Upper	520,6	-	-	520,6
Total	**5 845,7**	**79,9**	**327,1**	**6 252,7**

DETAILS OF THE CANAL SYSTEMS OF THE KAKAMAS GWS

Reach	Length (m)	Existing Irrigation (ha)	Potential Irrigation (ha)	Capacity (m^3/s)
North Furrow				
1	17 400			7,45
2	7 200			4,09
3 **	2 300			0,19
Total	**26 900**	**2 188**	**261**	
South Furrow				
1	9 300			6,81
2	700			4,43
3	6 350			3,16
4	6 900			2,07
5	9 350			0,84
Total	**32 600**	**1 862**	**482**	
Rhenosterkop, Augrabies and Noudonzies Canals				
1	500			7,85
2	5 050			5,25
3	2 000			3,05
4	6 200			1,05
5	3 650			0,88
6	4 100			0,37
Total	**21 500**	**1 372**	**130**	

Note : ** Also known as the Cilliers Branch Canal

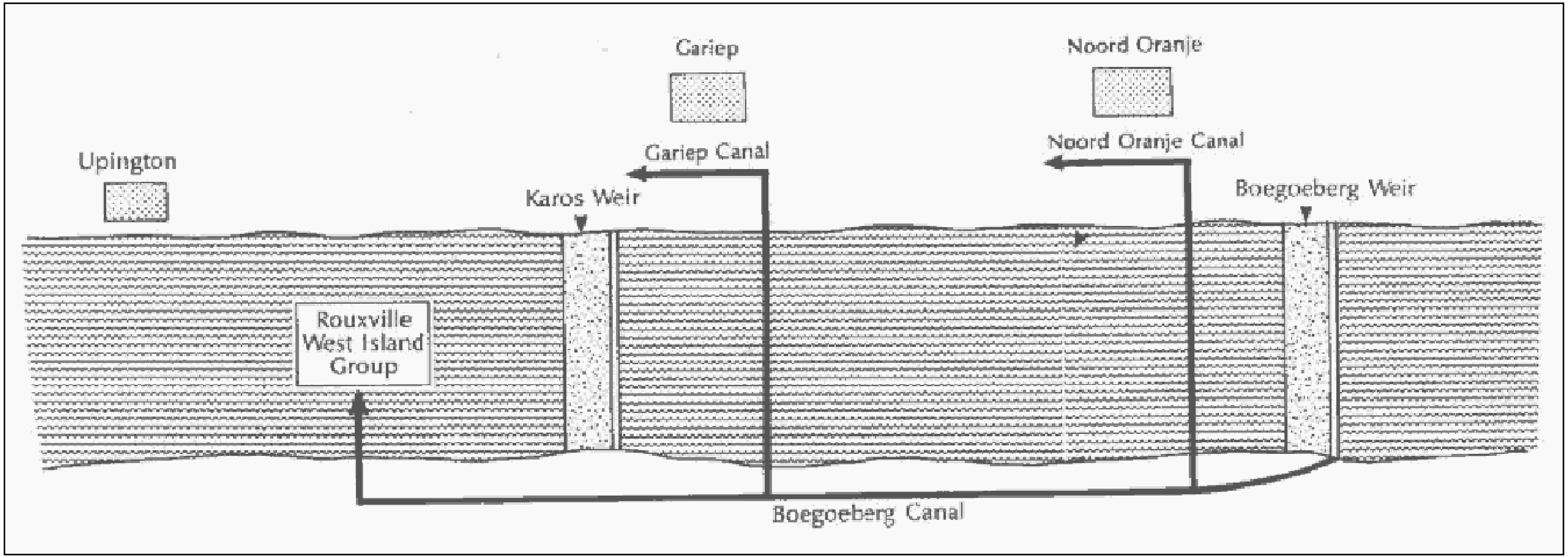
NAME OF SCHEME		WATER SOURCE	DESTINATION CATCHMENT	SOURCE SECTOR	DESTINATION SECTOR	TRANSFER LIMIT	IMPLEMEN-TATION YEAR	CALCULATED TRANSFER (Mm^3/a)
Boegoebergdam Irrigation Scheme							Dam built 1931	
Noord Oranje Irrigation Board	(right bank)	D72C	D73D	SRD	SSI	Start of canal = 307.8Mm^3/a	approx 1935	63.070
Gariep Settlement	(right bank)	D72C	D73E	SRD	SRU		approx 1935	63.070
Rouxville West Scheme	(left bank)	D72C		SRD	SRU		approx 1935	12.620
Boegoeberg-Karos GWS	(left bank)	D72C	D73C	SRD	SSI		approx 1935	84.520
Boegoeberg-Karos GWS	(left bank)	D72C	D73D	SRD	SSI		approx 1935	84.520

SRD : Transfer to / from rivers / dam

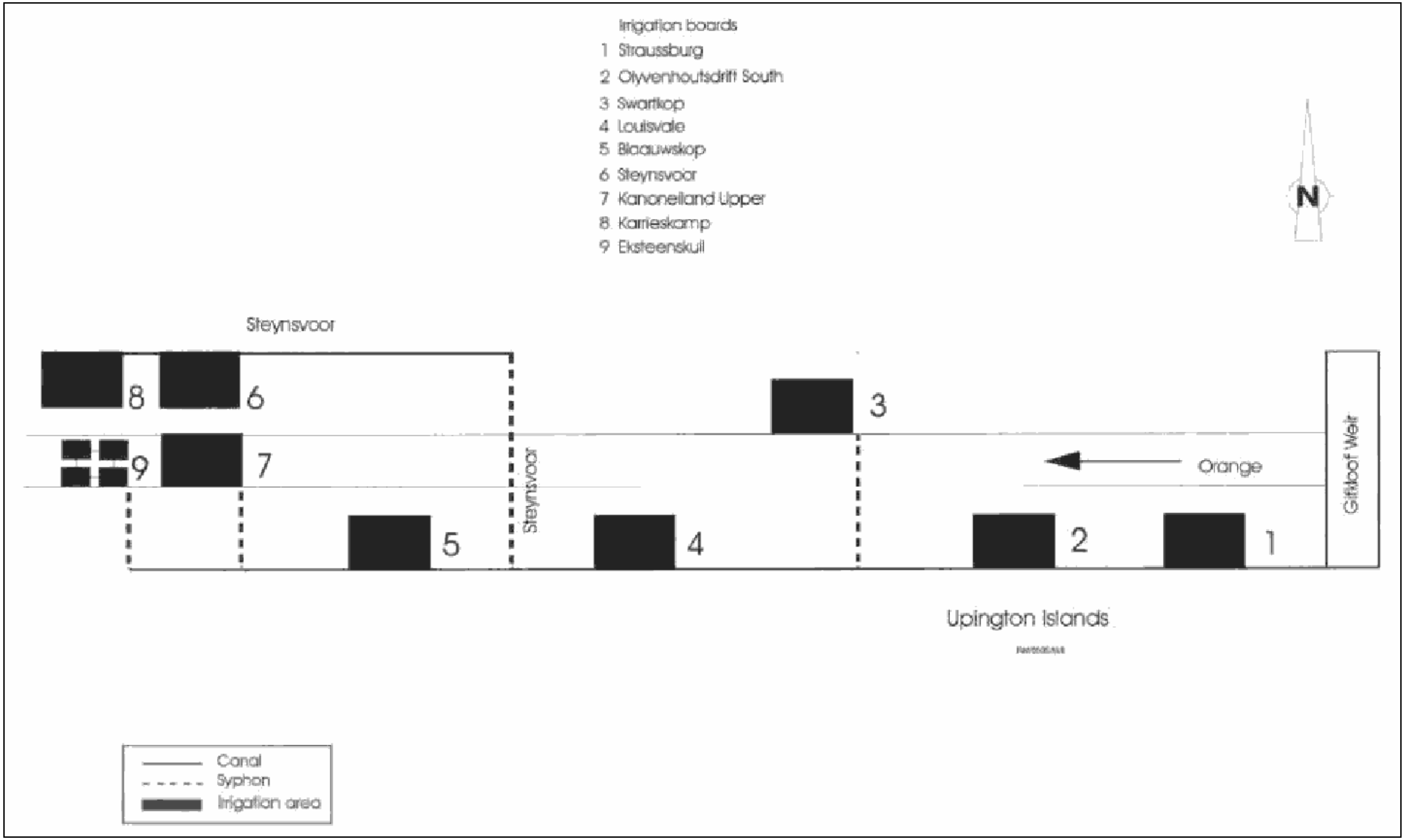
SSI : Irrigation Water Transfer

SRU : Rural Water Use

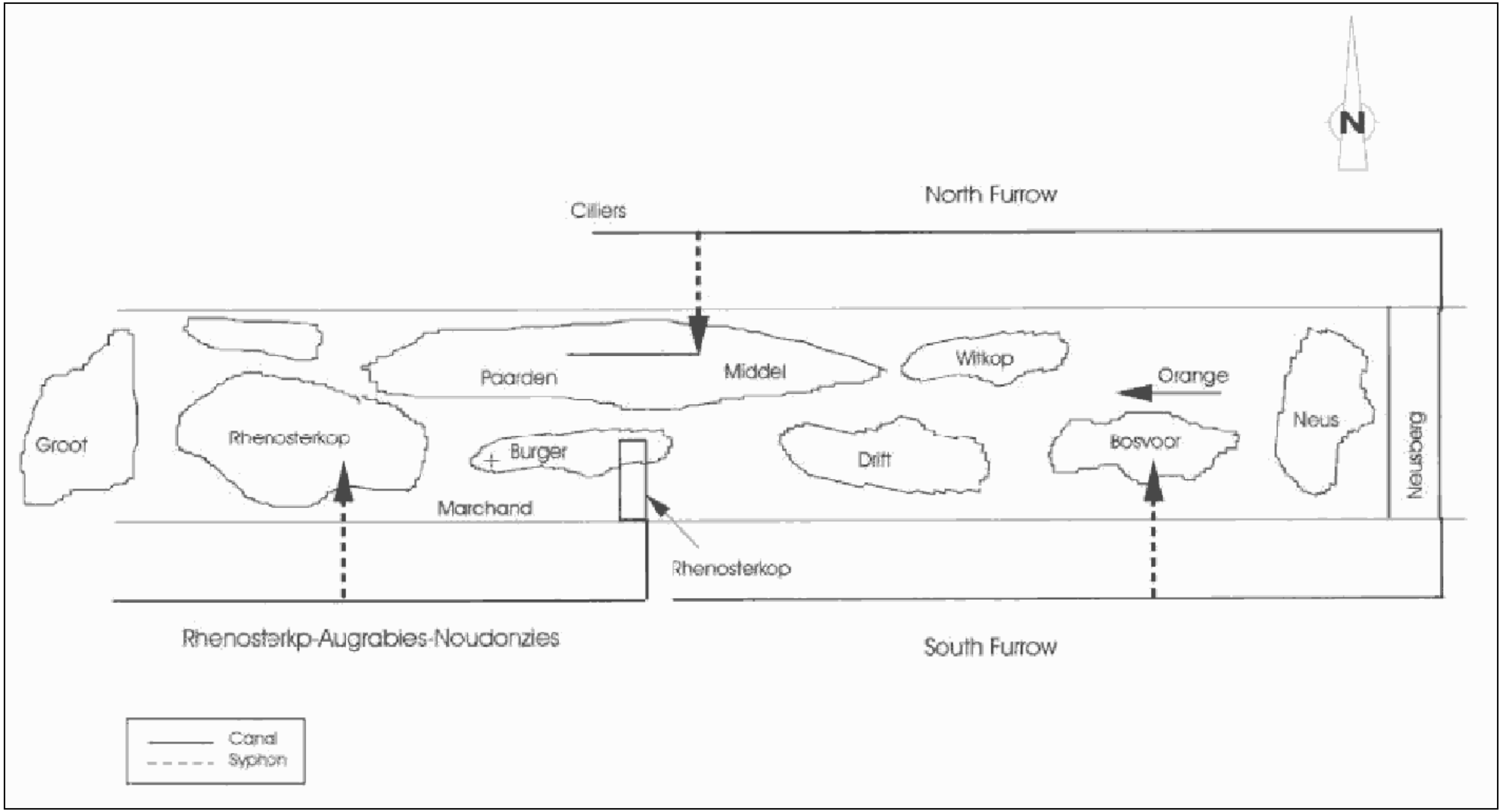
Schematic Layout of the Boegoeberg Karos Scheme



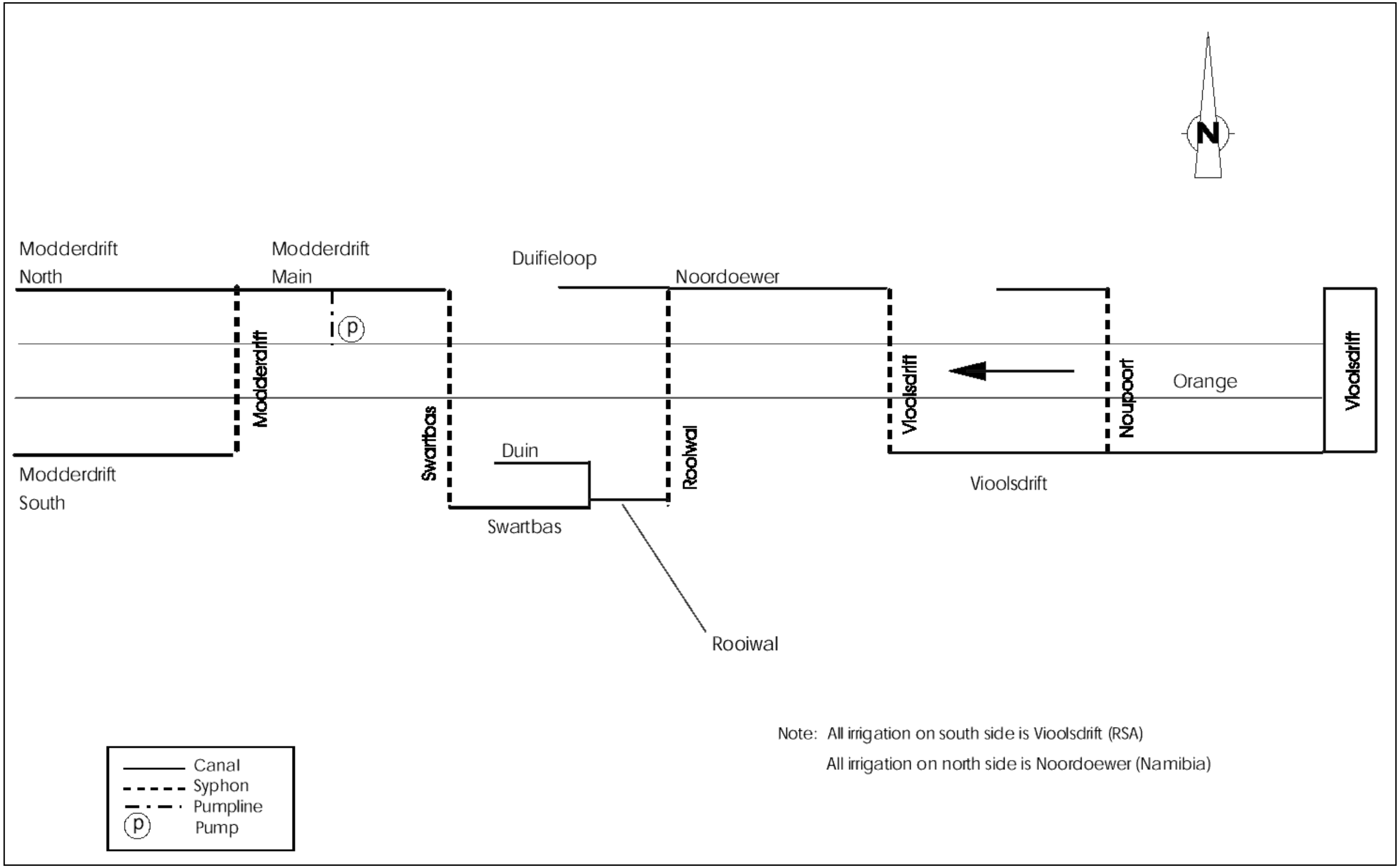
Schematic Layout of the Upington Islands Scheme



Schematic Layout of Kakamas GWS



Schematic Layout of the Vioolsdrift-Noordoewer Irrigation Area



APPENDIX E.3

COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES

APPENDIX E.3

Combined capacities of individual town and regional potable water supply schemes

Drainage area	Population in drainage area	Individual town		Regional scheme				Total Population supplied	% of drainage area population
		Urban Population	Capacity	Name	Urban Population	Rural Population	Capacity		
Ongers	**75 086**	**47 350**			**0**	**0**		**47 350**	**63.06%**
Britstown		5 300							
De Aar		26 950							
Strydenburg		1 750							
Richmond		4 150							
Victoria West		7 850							
Vosburg		1 350							
Boegoeberg	**47 010**	**18 950**			**0**	**0**		**18 950**	**40.31%**
Griekwastad		5 000							
Niekershoop		1 200							
Prieska		11 000							
Marydale		1 750							
Neusberg	**122 720**	**89 050**			**0**	**0**		**89 050**	**72.56%**
Groblershoop		3 350							
Kakamas		6 550							
Keimos		6 950							
Louisville		700							

Drainage area	Population in drainage area	Individual town		Regional scheme				Total Population supplied	% of drainage area population
		Urban Population	Capacity	Name	Urban Population	Rural Population	Capacity		
Upington		52 850							
Postmasburg		18 650							
				Kalahari-West RWSS		?	51l/s at source		
Sak-hartbees	**32 720**	**20 400**			**0**	**0**		**20 400**	**62.35%**
Brandvlei		2 100							
Carnarvon		5 700							
Van Wyksvlei		1 200							
Fraserburg		2 850							
Kenhardt		3 650							
Sutherland		1 850							
Loxton		700							
Williston		2 350							
Nossob-Molopo	**11 296**	**4 700**			**0**	**0**		**4 700**	**41.61%**
Mier		4 700							
Vioolsdrift	**24 230**	**1 100**			**7 150**	**0**		**8 250**	**34.05%**
Pella				Pelladrift WSS	1 450				
Onseepkans		1 100							

Drainage area	Population in drainage area	Individual town		Regional scheme				Total Population supplied	% of drainage area population
		Urban Population	Capacity	Name	Urban Population	Rural Population	Capacity		
Pofadder				Pelladrift WSS	2 850				
Aggeneys				Pelladrift WSS	2 850				
Alexander bay	**5 897**	**400**			**2 450**	**0**		**2 850**	**48.33%**
Alexander bay				Sendlingsdrif	2 450				
Eksteenfontein		400							
Coastal	**59 100**	**13 150**			**40 000**	**0**		**53 150**	**89.93%**
Kamieskroon		750							
Kleinzee				Springbok RWSS	2 900				
Koiingas		800							
Leliefontein		5 350							
Kommagas		4 300							
Concordia				Springbok RWSS	3 900				
Carolusburg				Springbok RWSS	1 250				
Garies		1 400							
Hondeklipbaai		550							
Okiep/ Nababeep				Springbok RWSS	10 250				
Port Nolloth				Alexander Bay	4 650				
Springbok				Springbok RWSS	10 200				
Steinkopf				Springbok RWSS	6 850				

APPENDIX E.4

ABSTRACTION POINT DATA

APPENDIX E.4

Abstraction Point Data

Province	Town Name	Abstraction	Location		Accuracy of coordinates	Primary water source name	Amount abstracted (Ml/a)	Planned or existing
		Point	Longitude	Latitude				
N-Cape	Groblershoop		21º59”	28º54’	Unknown	Orange River	14 81.9	Existing
N-Cape	Kakamas		20º37’0”	28º46’26”	Unknown	Orange River	838.77	Existing
N-Cape	Prieska		22º45’	29º40’	Unknown	Orange River	1 400	Existing
N-Cape	Springbok	Henkriesmond	18º10’09”	28º53’54”	good	Orange River	2 385	Existing
N-Cape	Upington	Water treatment Plant	21º15’39”	28º27’02”	Unknown	Orange River	11 542	Existing

APPENDIX E.5

BOREHOLE DATA

APPENDIX E.5

Borehole data

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours) (hrs/day)	
N-Cape	Carnarvon	6								?			Existing
N-Cape	De Aar	51	Riet 1			73300	3401350	Unknown	Urban & Industrial use	4.7	270.72	Accept 16 hours	Existing
			Riet 2			72800	3401900	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			Riet 3			74800	3404654	Unknown	Urban & Industrial use	1.5	86.40	Accept 16 hours	Existing
			Riet 10			72300	3405302	Unknown	Urban & Industrial use	1	57.60	Accept 16 hours	Existing
			Riet 4			76300	3406950	Unknown	Urban & Industrial use	5	288.00	Accept 16 hours	Existing
			Riet 1 ?			75700	3400700	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Riet 6			75500	3448300	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Riet 11			75006.046	3400319	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Riet 12			74637.839	3400035.244	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			Riet 14			75408.371	3399222.274	Unknown	Urban & Industrial use	3.5	201.60	Accept 16 hours	Existing
			Riet 15			75194.049	3598414.159	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours) (hrs/day)	
			Kaffersdam 5			70095.163	3396158.801	Unknown	Urban & Industrial use	1	57.60	Accept 16 hours	Existing
			Kaffersdam 2			69600	3598950	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Kaffersdam 3			69300	3599950	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Kaffersdam 1			68300	3399000	Unknown	Urban & Industrial use	3	57.60	Accept 16 hours	Existing
			Kaffersdam 4			70200	3398750	Unknown	Urban & Industrial use				Existing
			Nommer 36			65900	1400750	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			Lekkerwater			63050	3400700	Unknown	Urban & Industrial use	3.5	201.60	Accept 16 hours	Existing
			Belergat			61900	3400950	Unknown	Urban & Industrial use	3.5	201.60	Accept 16 hours	Existing
			Hoogste			61050	3402300	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			De Kock			61250	3396100	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Anderkant die Sloot			61450	3396700	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Op die wal			61800	3398100	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			Miergat			61600	3397900	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours) (hrs/day)	
			B-Pomp			63700	3400150	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			A-Pomp			64400	3400050	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			Riet 7							12	691.20	Accept 16 hours	Existing
			Riet 8			79630	3391750	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Riet 9			79300	3394500	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Oukraal			64750	3404500	Unknown	Urban & Industrial use	3	172.80	Accept 16 hours	Existing
			X			62350	3398700	Unknown	Urban & Industrial use				Existing
			Suid Wes 1			108450	3394250	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Suid Wes 2			107700	3394400	Unknown	Urban & Industrial use	7	403.20	Accept 16 hours	Existing
			Suid Wes 3			107500	3394950	Unknown	Urban & Industrial use	8	460.80	Accept 16 hours	Existing
			Suid Wes 4			106750	3395900	Unknown	Urban & Industrial use	3.5	201.60	Accept 16 hours	Existing
			Suid Wes 5			105700	3397750	Unknown	Urban & Industrial use	3.5	201.60	Accept 16 hours	Existing
			Suid Wes 7			105600	3398300	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours) (hrs/day)	
			Suid Wes 6			105500	3398500	Unknown	Urban & Industrial use	5	288.00	Accept 16 hours	Existing
			Suid Wes 8			105500	3396700	Unknown	Urban & Industrial use	4.5	259.20	Accept 16 hours	Existing
			Suid Wes 9			105250	3600150	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Suid Wes 10			105030	3800450	Unknown	Urban & Industrial use	4.5	259.20	Accept 16 hours	Existing
			Suid Wes 11			104600	3400300	Unknown	Urban & Industrial use	6	345.60	Accept 16 hours	Existing
			Suid Wes 12			104850	3600450	Unknown	Urban & Industrial use	4.5	259.20	Accept 16 hours	Existing
			Caroluspoort 6			80273	3391538.991	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Caroluspoort 8			80246.601	3391685.131	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Caroluspoort 9			80100.085	3392065.961	Unknown	Urban & Industrial use	5	288.00	Accept 16 hours	Existing
			Caroluspoort 2			80603.536	3391024.75	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing
			Caroluspoort 3			80164.399	3390358.146	Unknown	Urban & Industrial use	5	288.00	Accept 16 hours	Existing
			Caroluspoort 5			80934.57	3391166.788	Unknown	Urban & Industrial use	4	230.40	Accept 16 hours	Existing

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours)	(hrs/day)
			Paardevlei 4			85890	5385550	Unknown	Urban & Industrial use	7	403.20	Accept 16 hours	Existing
			Paardevlei 3			89200	3386150	Unknown	Urban & Industrial use	8	460.80	Accept 16 hours	Existing
			Paardevlei 2			90300	3387400	Unknown	Urban & Industrial use	8	460.80	Accept 16 hours	Existing
			Paardevlei 1			91100	3386900	Unknown	Urban & Industrial use	5	288.00	Accept 16 hours	Existing
N-Cape	Fraserburg	4		21 32 Oos	31 55 Suid			Unknown	Urban & Industrial use	92400kl/a	253.15	-	Existing
N-Cape	Kamies-kroon	?	?	?	?				Urban & Industrial use	6	?	?	Existing
N-Cape	Kenhardt	7	Golfbaan	?	?					4	230.40	Accept 16 hours	Existing
			Staal Tenk	?	?					2.5	144.00	Accept 16 hours	Existing
			Naby Staal Tenk	?	?					1.5	86.40	Accept 16 hours	Existing
			Groot Voering	?	?					1.5	86.40	Accept 16 hours	Existing
			Mono+Dompel	?	?					2.5	144.00	Accept 16 hours	Existing
			Panty Valley	?	?					1.5	86.40	Accept 16 hours	Existing
			Ou Syfer	?	?					4	230.40	Accept 16 hours	Existing

Province	Name of Town	Number of Boreholes	Name of Borehole	Location		Location		Accuracy of coordinates	Purpose of Borehole	Pump delivery (l/s)	Pump delivery	Daily pump working hours	Existing or planned
				Longitude	Lattitude	Y	X				(kl/day)	(Assumed hours) (hrs/day)	
N-Cape	Niekerks-hoop	?	?	22 49 43	29 19 47			Unknown	Urban & Industrial use	?	?	?	Existing
N-Cape	Postmas-burg	14	Boicholio	23 05	28 19			Unknown	Urban & Industrial use	165 Ml/a	452.05 ?	Accepted 24	Existing
			Postmasburg	23 05	28 20			Unknown	Urban & Industrial use	773.3 Ml/a	2118.63 ?	Accepted 24	Existing
			Tsaltsabale	23 08	28 16			Unknown	Urban & Industrial use	250.3 Ml/a	685.75 ?	Accepted 24	Existing
N-Cape	Richmond		?	?	?				Urban & Industrial use	160 Ml/a	2592.00	Accepted 24	Existing
N-Cape	Strydenburg		?	?	?				Urban & Industrial use	14208 Ml/a	38.92	?	Existing
N-Cape	Victoria-Wes	9	?	?	?				Urban & Industrial use	?	?	?	Existing

APPENDIX E.6

DAM DATA

APPENDIX E.6

Dam data

Dam Name	River Name	Dam wall location		Accuracy of coordinates	Nearest Town	Date of storage capacity deter-mination	FSL surface area	Gross Storage Capacity	Dead storage capacity & date	Rated capacity of outlet works	Net storage capacity	Planned or existing
		Longitude	Lattitude				(km²)	(10^6 m³)	(10^6 m³)	(m³/s)	(10^6 m³)	
Rooiberg	Hartbees	21º11”	29º24”	Unknown	Kenhardt	1900	3.14	3.652		-	3.651	Existing
Victoria West	Dorps	23º06”	31º24”	Good	Victoria – Wes	1921	2.75	3.66		-	3.66	Existing
Smart Syndicate	Ongers	23º18”	30º37”	Good	Between Vosburg & Britstown	1912	31.61	99.300		-	?	Existing
Van Wyksvlei	Carnarvonleegte	21º49”	30º22”	Good	Van Wyksvlei	1884	49.93	10.00		-	?	Existing
Boegoeberg	Oranje	22º 12”	29º02”	Good	Groblershoop	1929	6.95	20.400		-	?	Existing
Ratelfontein	Roodevlaklaagte	20º13”	31º24”	Good	Calvinia	1953	2.00	6.907		-		Existing
Modderpoort	rietfontein	22º08”	31º56”	Good	Beaufort-West	1953	1.25	10.00		-		Existing

Note: There are numerous small farm dams in the area which have not been included in this table. The reader is refered to the relevant pages of the WR90 books for a comprehensive list.

APPENDIX E.7

PIPELINE DATA

APPENDIX E.7

Pipeline Data

Province	Scheme	Starting Point		End Point		Place where pipe starts	Place where pipe ends	Pipe Dia (mm)	Pipe material	Gravity /Rising	Water or Sewage
		Longitude	Lattitude	Longitude	Lattitude						
N-Cape	Karos-Geelkoppen Rural Scheme										Water
	Karos-Geelkoppen					Karos Plaas Adeisestad Plaas Hartbeeskrop	Plaas Adeisestad Plaas Hartbeeskrop Plaas Duineveld		Steel Steel PVC	Rising Rising Rising	Water Water Water
N-Cape	Kalahari-West Rural Water Supply Scheme					Upington	Vaalkoppie, Burgershoop, Omega	250/110 50/80		Gravity	Water
N-Cape	Pelladrift Water Supply Scheme					Pelladrift	Pofadder				Water
N-Cape	Pelladrift Water Supply Scheme					Pelladrift	Aggeneys and Pella				Water
N-Cape	Springbok Regional Water Supply Scheme					Henkriesmond	Henkries purification plant	457	steel, conc lined	Rising	raw water
N-Cape	Springbok Regional Water Supply Scheme					Henkries purif plant	Eenrietberg Reservior (NearSteinkopf)	419	steel, conc lined	Rising	Water
N-Cape	Springbok Regional Water Supply Scheme					Eenrietberg Reservior	Vaalhoek reservoir	520	steel, conc lined	Gravity	Water
N-Cape	Springbok Regional Water Supply Scheme					Vaalhoek	Springbok	300	asbestos	Gravity	Water
N-Cape	Springbok Regional Water Supply Scheme					Springbok	O'Kiep/Nababeep				Water
N-Cape	Springbok Regional Water Supply Scheme					Springbok	Carolusburg				Water
N-Cape	Springbok Regional Water Supply Scheme					Springbok	Kleinsee	475/419		Rising	Water
N-Cape	Sendelingsdrif to Rosh Pinah					Sendelingsdrift	Rosh Pinah				Water

APPENDIX E.8

PUMP STATION DATA

APPENDIX E.8

Pump Station Data

Province	Town	Name	Location		Accuracy of coordinates	Description of location	Pump delivery	Daily pump working hours
			Longitude	Lattitude			(kl/day)	(hrs/day)
N-Cape	De Aar	Paardevlei	24º54'11"	30º36'20"	Unknown		1 382.40	Accepted 16
		Riet (Suid-Oos)	24º10'23"	30º42'13"	Unknown		4 608.00	Accepted 16
		Suid-Wes	23º55'21"	30º41'29"	Unknown		1 728.00	Accepted 16
		Caroluspool	24º9'12"	30º38'23"	Unknown		921.60	Accepted 16
N-Cape	Groblershoop	?	?	?			2 592.00	24
		?	?	?			1 468.80	24
N-Cape	Kakamas	?	?	?			?	?
N-Cape	Prieska	?	22º45'	29º40'	Unknown		11 520.00	Accepted 16
		?	22º45'	29º40'	Unknown		5 760.00	Accepted 16
		?	22º45'	29º40'	Unknown		2 131.20	Accepted 16
N-Cape	Springbok	?	17º53'	29º39'	Unknown		1 760.00	Accepted 16
			17º53'	29º39'	Unknown		1 760.00	Accepted 16
N-Cape	Upington	?	21º15'41"	28º27"06"	Unknown		36 288.00	Accepted 16
		?	21º15'39"	28º27"02"	Unknown		41 472.00	Accepted 16
		?	21º15'43"	28º27"03"	Unknown		10 368.00	Accepted 16
	Henkriesmond	Henkriesmond	18º10'09"	28º53"54"	good	River abstraction	19 080.00	($0.265m^3/s$)
		Henkriesmond	18º08'19"	28º53"53"	good	raw water	22 032.00	($0.306m^3/s$)
		Henkries purif plant	18º05'49"	28º58"22"	good	treated water	10 836.00	($0.1505m^3/s$)
		Dooring water	17º56'20"	29º05"09"	good	treated water	10 836.00	($0.1505m^3/s$)
		Concordia	17º52'59"	29º35"21"	good	treated water	288.00	($0.004m^3/s$)

APPENDIX E.9

RESERVOIR DATA

APPENDIX E.9

Reservoir Data

Province	Town	Reservior	Location		Accuracy of coordinates	Capacity of Reservior (Ml)	Open/ Covered	Raw / Treated	Planned or existing
		Name	Longitude	Lattitude					
N-Cape	Carnarvon	Koeëlkop	?	?	?	1.5			Existing
N-Cape	De Aaar	De Aar West	23º59’35”	30º39’40”	Unknown	13.6			Existing
N-Cape	De Aaar	De Aar Oos	24º10’26”	30º38’36”	Unknown	12			Existing
N-Cape	Fraserburg	?	21º32’	31º55’	Unknown	0.304			Existing
N-Cape	Groblershoop	Munisipale	?	?		1.545			Existing
N-Cape	Kakamas	?	?	?		5.2			Existing
N-Cape	Kamieskroon	Kamieskroon	?	?		0.35			Existing
N-Cape	Kenhardt	Kenhardt	?	?		2.5			Existing
N-Cape	Niekerkshoop	Staal Reservior	22º49’43	29º19’47”	Unknown	0.15			Existing
N-Cape	Postmasburg	Gatkoppies	23º07’	28º18’	Unknown	3.25			Existing
N-Cape	Postmasburg	Boicholo System	23º02’	28º19’	Unknown	1.98			Existing
N-Cape	Postmasburg	Newtown	23º05’	28º20’	Unknown	2.88			Existing
N-Cape	Prieska	Koppie en Uitbr.15	22º45’	29º40’	Unknown	8.65			Existing
N-Cape	Richmond	Hoof Reservior	?	?		1			Existing
N-Cape	Strydenburg	?	?	?		6.29			Existing
N-Cape	Springbok	?	17º53’24”	29º39’36”	Unknown	11			Existing
	Springbok								
	Concordia	Concordia	17º56’07”	29º32’32”	good	0.5	covered	treated	Existing
	Henkries	Henkries purification plant	18º05’49”	28º58’22”	good	4.6	covered	treated	Existing
	Eenrietberg	Eenrietberg	17º48’58”	29º11’09”	good	6.4	covered	treated	Existing
		Vaalhoek	17º53’17”	29º36’26”	good	11.6	covered	treated	Existing

Province	Town	Reservior	Location		Accuracy of coordinates	Capacity of Reservior (Ml)	Open/ Covered	Raw / Treated	Planned or existing
		Name	Longitude	Lattitude					
N-Cape	Upington	Sentraal	21º13'55"	28º26'34"	Unknown	23			Existing
N-Cape	Upington	Updustria	21º12'05"	28º26'13"	Unknown	30			Existing
N-Cape	Upington	Keidebees	21º16'57"	28º25'34"	Unknown	45			Existing
N-Cape	Victoria-Wes	?	?	?	Unknown	2.62			Existing

APPENDIX E.10

WASTE WATER (SEWAGE) TREATMENT WORKS DATA

APPENDIX E.10

Waste Water (Sewage) Treatment Works Data

Province	Name	Location		Accuracy of coordinates	Planned or Existing	Description of process	Point of return flow	Tmt Rate, average
		Longitude	Lattitude					(Mℓ/day)
N-Cape	De Aar	*30º36’30”*	*24º01’40”*	Unknown	Existing	Activated Sludge	D62D	2.7
N-Cape	Kamieskroon	?	?	?	Existing	Oxydation		?
N-Cape	Niekerkshoop	22º49’43”	29º19’47”	Unknown	Existing	Oxydation		0.001
N-Cape	Postmasburg	23º05’	28º21’	Unknown	Existing	Activated Sludge	D73A	1.48
N-Cape	Prieska	22º45’	29º40’	Unknown	Existing	Oxydation		1.068
N-Cape	Richmond	23º56’31”	31º24’53”	Unknown	Existing	Evaporation ponds		0.07
N-Cape	Springbok	17º53’24”	29º39’36”	Unknown	Existing	Oxydation		1.23
N-Cape	Upington	21º12’18”O	28º28’39”S	Unknown	Existing	Biofilter & activated sludge	D73F	11.2

* This lat-long location appears to be incorrect

APPENDIX E.11

WATER TREATMENT WORKS DATA

APPENDIX E.11

Water Treatment Works Data

Province	Town	Location		Accuracy of coordinates	Planned or Existing	Type of water source	Name of water source	Max flow capacity
	Name	Longitude	Lattitude					(m^3/d)
N-Cape	Prieska	22º45’	29º40’	Unknown	Existing	River	Orange river	15 000
N-Cape	Upington	21º15’39”	28º27’02”	Unknown	Existing	River	Orange river	29 450
	Henkries	18º05’49”	28º58’22”	Good	Existing	River	Orange river	13 000

APPENDIX F

WATER REQUIREMENTS

APPENDIX F.1

ENVIRONMENTAL MANAGEMENT CLASS

APPENDIX F.1

NORTHERN CAPE WATER RESOURCES SITUATION ASSESSMENT STUDY : ENVIRONMENTAL MANAGEMENT CLASSES & WATER REQUIREMENTS

QUAT	IFR Classification		
	DEMC	PESC	AEMC
C92C	C	C	C
D42A	B	B	B
D42B	B	B	B
D42C	C	B	B
D42D	D	C	C
D42E	D	C	C
D51A	D	B	B
D51B	D	B	B
D51C	D	B	B
D52A	D	B	B
D52B	D	B	B
D52C	D	B	B
D52D	D	B	B
D52E	D	B	B
D52F	D	B	B
D53A	D	B	B
D53B	D	B	B
D53C	D	B	B
D53D	D	B	B
D53E	D	B	B
D53F	D	B	B
D53G	D	B	B
D53H	D	B	B
D53J	D	B	B

Legend :

Class A :	Unmodified Natural
Class B :	Largely Natural
Class C :	Moderately Modified
Class D :	Largely Modified
Class E :	Seriously Modified
Class F :	Critically Modified

DEMC : Default Ecological Management Class

PESC : Present Ecological Status Class

AEMC : Suggested Future Ecological Management Class

QUAT	IFR Classification		
	DEMC	PESC	AEMC
D54A	D	B	B
D54B	D	B	B
D54C	D	B	B
D54D	D	B	B
D54E	D	B	B
D54F	D	B	B
D54G	D	B	B
D55A	D	B	B
D55B	D	B	B
D55C	D	B	B
D55D	D	B	B
D55E	D	B	B
D55F	D	B	B
D55G	D	B	B
D55H	D	B	B
D55J	D	B	B
D55K	D	B	B
D55L	D	B	B
D55M	D	B	B
D56A	D	B	B
D56B	D	B	B
D56C	D	B	B
D56D	D	B	B
D56E	D	B	B
D56F	D	B	B
D56G	D	B	B
D56H	D	B	B
D56J	D	B	B
D57A	D	B	B
D57B	D	B	B

QUAT	IFR Classification		
	DEMC	PESC	AEMC
D57C	D	B	B
D57D	D	B	B
D57E	D	B	B
D58A	D	B	B
D58B	D	B	B
D58C	D	B	B
D61A	D	B	B
D61B	D	B	B
D61C	D	B	B
D61D	D	B	B
D61E	D	B	B
D61F	D	B	B
D61G	D	B	B
D61H	D	B	B
D61J	D	B	B
D61K	D	B	B
D61L	D	B	B
D61M	D	B	B
D62A	D	B	B
D62B	D	B	B
D62C	D	B	B
D62D	D	B	B
D62E	D	B	B
D62F	D	B	B
D62G	D	B	B
D62H	D	B	B
D62J	D	B	B
D71A	C	C	C
D71B	D	B	B

QUAT	IFR Classification		
	DEMC	**PESC**	**AEMC**
D71C	C	C	C
D71D	C	C	C
D72A	C	C	C
D72B	B	B	B
D72C	B	B	B
D73A	D	B	B
D73B	B	C	B
D73C	C	C	C
D73D	C	C	C
D73E	C	C	C
D73F	C	C	C
D81A	B	C	C
D81B	B	C	C
D81C	D	C	C
D81D	B	C	C
D81E	B	B	B
D81F	B	B	B
D81G	B	B	B
D82A	B	B	B
D82B	D	B	B
D82C	D	B	B
D82D	C	B	B
D82E	B	B	B
D82F	B	B	B
D82G	B	B	B
D82H	B	B	B
D82J	B	C	C
D82K	B	C	C
D82L	D	C	B

QUAT	IFR Classification		
	DEMC	PESC	AEMC
F10A	D	B	B
F10B	D	B	B
F10C	D	B	B
F20A	D	B	B
F20B	D	B	B
F20C	D	B	B
F20D	D	B	B
F20E	D	B	B
F30A	D	B	B
F30B	D	B	B
F30C	D	C	C
F30D	D	C	C
F30E	D	C	D
F30F	D	B	B
F30G	D	C	B
F40A	D	B	B
F40B	D	B	B
F40C	D	B	B
F40D	D	C	B
F40E	D	B	B
F40F	D	B	B
F40G	D	B	B
F40H	D	B	B
F50A	D	B	B
F50B	D	B	B
F50C	D	B	B
F50D	D	B	B
F50E	D	B	B

QUAT	IFR Classification		
	DEMC	PESC	AEMC
F50F	D	B	B
F50G	D	B	B
F60A	D	B	B
F60B	D	B	B
F60C	D	B	B
F60D	D	B	B
Z10A			
Z10G			
Z10H			
Z10J			
Z20A			
Z20B			
Z20C			
Z20D			
Z20E			
Z20F			

APPENDIX G

WATER RESOURCES

APPENDIX G.1

GROUND WATER RESOURCES OF SOUTH AFRICA

APPENDIX G.1

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 (20th 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 □/s	0.7
1.5 - 3.0 □/s	0.6
0.7 - 1.5 □/s	0.5
0.3 - 0.7 □/s	0.4
<0.3 □/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 (as determined by 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 (M Simonic 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegters Maps (Vegter, 1995). The potability evaluation done by Simonic (M Simonic, 2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

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

TABLE 3.6.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

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

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

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

4. DATA LIMITATIONS

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

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

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

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

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

5. OVERVIEW OF THE GROUND WATER RESOURCES OF SOUTH AFRICA

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

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

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

Borehole yields vary considerably. The highest boreholes yields (up to 100 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 10100 x $10^6 m^3$/annum and varies from less than 0.2 mm/annum in quaternary catchment D82G to more than 211 mm/annum in quaternary catchment W12J.

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

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

The extreme north western parts of South Africa show the poorest quality with TDS > 20000 mg/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.1

GROUNDWATER DATA

QUAR-TERNARY	AREA (km^2)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m^3/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m^3/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m^3/a)	MUNI-CIPAL USE (10^6 m^3/a)	RURAL USE (10^6 m^3/a)	LIVE-STOCK USE (10^6 m^3/a)	IRRI-GATION USE (10^6 m^3/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m^3/a) oGWSo
Nossob-Molopo																
D42A	10 282	1.5	15.06	0.56	0.4	0.6	6.02	85	47.23	0.50	0.0000	0.0012	0.0227	0.0000	1.5000	0.0358
D42B	3 198	1.5	4.93	0.61	0.4	0.6	1.97	197	120.86	1.27	0.0300	0.0000	0.0815	0.0000	1.5000	0.1673
D42C	196	1.2	0.23	0.71	0.5	0.6	0.11	1706	1 209.38	12.71	0.0000	0.3538	2.0065	0.0000	0.5600	1.3218
D42D	14 109	0.9	13.38	0.72	0.5	0.5	6.69	917	664.64	6.99	0.1200	0.8638	0.4257	0.0000	0.5600	0.7893
D42E	4 208	2.7	11.54	0.75	0.5	1.4	5.77	166	124.83	1.31	0.0400	0.0000	0.1574	0.0000	1.0000	0.1974
Sak-Hartbees																
D51A	797	9.3	7.41	3.65	0.7	6.5	5.19	15	54.69	0.57	0.1100	0.0000	0.0277	0.0000	0.5000	0.0689
D51B	873	7.8	6.77	1.79	0.6	4.7	4.06	19	33.96	0.36	0.0000	0.0000	0.0305	0.0000	0.5000	0.0153
D51C	522	7.3	3.81	2.31	0.6	4.4	2.29	16	36.96	0.39	0.0000	0.0000	0.0084	8.1280	0.1000	0.8136
D52A	378	7.8	2.96	1.99	0.6	4.7	1.78	27	53.75	0.57	0.0000	0.0000	0.0132	0.0000	0.5000	0.0066
D52B	660	7.9	5.20	2.70	0.6	4.7	3.12	50	134.97	1.42	0.0000	0.0000	0.0230	0.0000	0.5000	0.0115
D52C	465	7.8	3.65	1.67	0.6	4.7	2.19	8	13.36	0.14	0.0000	0.0000	0.0166	0.0000	0.5000	0.0083
D52D	638	8.1	5.17	2.16	0.6	4.9	3.10	21	45.44	0.48	0.0000	0.0000	0.0039	0.0000	0.5000	0.0020
D52E	609	7.8	4.75	3.63	0.7	5.5	3.33	13	47.19	0.50	0.0000	0.0000	0.0037	0.0000	0.5000	0.0019
D52F	1 146	7.6	8.70	1.32	0.5	3.8	4.35	61	80.66	0.85	0.0000	0.0000	0.0061	0.0000	0.5000	0.0031
D53A	1 939	7.4	14.36	0.78	0.5	3.7	7.18	92	71.51	0.75	0.0000	0.0000	0.0729	0.0000	0.5000	0.0365
D53B	1 713	8.0	13.70	1.00	0.5	4.0	6.85	74	73.91	0.78	0.0000	0.0000	0.0645	0.0000	0.5000	0.0323
D53C	1 899	7.9	14.96	1.61	0.6	4.7	8.98	75	120.56	1.27	0.2500	0.0000	0.0715	0.0000	0.5000	0.1608
D53D	1 842	3.2	5.83	1.20	0.5	1.6	2.92	66	79.19	0.83	0.0000	0.0000	0.0693	0.0000	0.5000	0.0347
D53E	826	4.1	3.38	0.78	0.5	2.0	1.69	56	43.48	0.46	0.0000	0.0000	0.0311	0.0000	0.5000	0.0156

QUAR-TERNARY	AREA (km^2)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m^3/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m^3/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m^3/a)	MUNI-CIPAL USE (10^6 m^3/a)	RURAL USE (10^6 m^3/a)	LIVE-STOCK USE (10^6 m^3/a)	IRRI-GATION USE (10^6 m^3/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m^3/a) oGWSo
D53F	8 040	2.8	22.72	1.01	0.5	1.4	11.36	139	139.70	1.47	0.0000	0.0000	0.0037	0.0000	0.5000	0.0019
D53G	4 747	2.4	11.36	0.81	0.5	1.2	5.68	134	108.42	1.14	0.0000	0.0000	0.1779	0.0000	0.5000	0.0890
D53H	1 589	3.0	4.77	1.14	0.5	1.5	2.38	40	45.46	0.48	0.0000	0.0000	0.0598	0.0000	0.5000	0.0299
D53J	455	3.0	1.37	0.77	0.5	1.5	0.68	15	11.50	0.12	0.0000	0.0000	0.0167	0.0000	0.5000	0.0084
D54A	1 518	5.2	7.93	1.12	0.5	2.6	3.97	32	35.87	0.38	0.0000	0.0000	0.0992	0.0000	0.5000	0.0496
D54B	4 053	5.6	22.70	2.13	0.6	3.4	13.62	212	451.31	4.74	0.4100	0.3275	0.2644	0.0000	0.5000	0.5010
D54C	1 342	5.1	6.79	1.12	0.5	2.5	3.40	22	24.62	0.26	0.0000	0.0000	0.0877	0.0000	0.5000	0.0439
D54D	5 071	5.8	29.49	1.36	0.5	2.9	14.74	182	247.70	2.60	0.0000	0.0000	0.2442	0.0000	0.5000	0.1221
D54E	3 326	5.5	18.37	1.59	0.6	3.3	11.02	60	95.26	1.00	0.0000	0.0000	0.1175	0.0000	0.5000	0.0588
D54F	3 809	5.8	22.03	0.67	0.4	2.3	8.81	53	35.41	0.37	0.0000	0.0073	0.2025	0.0000	0.5000	0.1049
D54G	4 503	5.5	24.83	0.92	0.5	2.8	12.41	174	160.01	1.68	0.0000	0.0000	0.1854	0.0000	0.5000	0.0927
D55A	1 872	7.7	14.33	4.12	0.7	5.4	10.03	32	131.72	1.38	0.0000	0.0000	0.0201	0.0000	0.5000	0.0101
D55B	1 260	7.6	9.56	3.12	0.7	5.3	6.69	18	56.14	0.59	0.0000	0.0000	0.0690	0.0000	0.5000	0.0345
D55C	761	7.8	5.97	1.66	0.6	4.7	3.58	11	18.22	0.19	0.0000	0.0000	0.0265	0.0000	0.5000	0.0133
D55D	1 889	7.7	14.47	1.56	0.6	4.6	8.68	21	32.73	0.34	0.0600	0.0000	0.1154	0.0000	0.5000	0.0877
D55E	2 240	7.4	16.50	1.86	0.6	4.4	9.90	41	76.16	0.80	0.1600	0.0661	0.1227	0.0000	0.5000	0.1744
D55F	2 632	7.0	18.56	1.63	0.6	4.2	11.13	55	89.55	0.94	0.0000	0.0000	0.1674	0.0000	0.5000	0.0837
D55G	1 293	7.3	9.38	2.54	0.6	4.4	5.63	11	27.98	0.29	0.0000	0.0000	0.0786	0.0000	0.5000	0.0393
D55H	1 151	6.7	7.67	2.12	0.6	4.0	4.60	16	33.84	0.36	0.0000	0.0000	0.0623	0.0000	0.5000	0.0312
D55J	1 998	6.4	12.75	3.38	0.7	4.5	8.93	7	23.68	0.25	0.0000	0.0000	0.1042	0.0000	0.5000	0.0521
D55K	1 247	6.8	8.50	3.16	0.7	4.8	5.95	17	53.71	0.56	0.0000	0.0000	0.0558	0.0000	0.5000	0.0279
D55L	1 242	6.8	8.44	4.86	0.7	4.8	5.91	143	694.31	7.30	0.5000	3.4658	0.0651	0.0000	0.5000	2.0155
D55M	1 813	6.2	11.32	1.58	0.6	3.7	6.79	43	67.94	0.71	0.0000	0.0000	0.0645	0.0000	0.5000	0.0323
D56A	510	9.8	5.02	1.27	0.5	4.9	2.51	8	10.18	0.11	0.0000	0.0000	0.0177	0.0000	0.5000	0.0089
D56B	519	9.3	4.81	1.85	0.6	5.6	2.88	6	11.12	0.12	0.0000	0.0000	0.0149	0.0000	0.5000	0.0075

QUAR-TERNARY	AREA (km²)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m³/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m³/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m³/a)	MUNI-CIPAL USE (10^6 m³/a)	RURAL USE (10^6 m³/a)	LIVE-STOCK USE (10^6 m³/a)	IRRI-GATION USE (10^6 m³/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m³/a) oGWSo
D56C	920	8.3	7.61	3.01	0.7	5.8	5.33	14	42.19	0.44	0.0000	0.0000	0.0309	0.0000	0.5000	0.0155
D56D	621	7.4	4.59	2.61	0.6	4.4	2.75	5	13.05	0.14	0.0000	0.0000	0.0151	0.0000	0.5000	0.0076
D56E	666	7.9	5.26	2.65	0.6	4.7	3.16	12	31.82	0.33	0.0000	0.0000	0.0284	0.0000	0.5000	0.0142
D56F	1 038	7.6	7.91	2.32	0.6	4.6	4.75	41	95.01	1.00	0.0000	0.0000	0.0562	0.0000	0.5000	0.0281
D56G	651	7.3	4.74	1.74	0.6	4.4	2.84	3	5.23	0.05	0.0000	0.0000	0.0355	0.0000	0.5000	0.0178
D56H	447	7.3	3.27	2.00	0.6	4.4	1.96	0	0.00	0.00	0.0000	0.0000	0.0154	5.7656	0.1000	0.5781
D56J	931	7.2	6.73	1.48	0.5	3.6	3.36	19	28.21	0.30	0.0000	0.0000	0.0497	15.4170	0.1000	1.5467
D57A	853	4.7	4.04	1.00	0.5	2.4	2.02	10	10.00	0.11	0.0000	0.0000	0.0091	0.0000	0.5000	0.0046
D57B	2 274	5.8	13.22	1.92	0.6	3.5	7.93	54	103.54	1.09	0.0000	0.0000	0.1191	0.0000	0.5000	0.0596
D57C	637	3.1	1.96	2.10	0.6	1.8	1.18	40	84.05	0.88	0.0000	1.1441	0.0009	0.0000	0.5000	0.5725
D57D	4 444	3.2	14.06	2.19	0.6	1.9	8.44	122	267.41	2.81	0.1200	1.1441	0.1047	0.0000	0.5000	0.6844
D57E	1 957	5.0	9.76	0.79	0.5	2.5	4.88	42	33.05	0.35	0.0000	0.0000	0.0736	0.0000	0.5000	0.0368
D58A	763	7.0	5.36	1.91	0.6	4.2	3.21	43	82.31	0.87	0.0000	0.0000	0.0010	12.1700	0.1000	1.2171
D58B	1 131	7.2	8.15	1.92	0.6	4.3	4.89	70	134.72	1.42	0.0000	0.0000	0.0027	0.0000	0.5000	0.0014
D58C	2 521	5.2	12.99	0.85	0.5	2.6	6.49	25	21.24	0.22	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000
Ongers																
D61A	1 466	8.6	12.64	4.17	0.7	6.0	8.85	5	20.87	0.22	0.2200	0.0000	0.0616	0.0000	0.5000	0.1408
D61B	1 199	9.3	11.12	2.87	0.6	5.6	6.67	10	28.74	0.30	0.0000	0.0000	0.0424	0.0000	0.5000	0.0212
D61C	1 170	7.5	8.74	2.35	0.6	4.5	5.24	4	9.41	0.10	0.0000	0.0000	0.0776	0.0000	0.5000	0.0388
D61D	651	7.5	4.88	4.05	0.7	5.2	3.41	4	16.20	0.17	0.0000	0.0000	0.0453	0.0000	0.5000	0.0227
D61E	1 091	7.4	8.05	5.82	0.7	5.2	5.63	11	64.03	0.67	0.4500	0.0000	0.0794	0.0000	0.5000	0.2647
D61F	873	7.7	6.76	2.46	0.6	4.6	4.05	52	127.74	1.34	0.0000	0.0000	0.0635	0.0000	0.5000	0.0318
D61G	744	7.6	5.68	1.90	0.6	4.6	3.41	11	20.90	0.22	0.0000	0.0000	0.0541	0.0000	0.5000	0.0271
D61H	1 086	7.3	7.91	1.82	0.6	4.4	4.74	8	14.54	0.15	0.0000	0.0000	0.0790	0.0000	0.5000	0.0395
D61J	1 558	7.0	10.83	1.97	0.6	4.2	6.50	45	88.49	0.93	0.0000	0.0000	0.1111	0.0000	0.5000	0.0556

QUAR-TERNARY	AREA (km^2)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m^3/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m^3/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m^3/a)	MUNI-CIPAL USE (10^6 m^3/a)	RURAL USE (10^6 m^3/a)	LIVE-STOCK USE (10^6 m^3/a)	IRRI-GATION USE (10^6 m^3/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m^3/a) oGWSo
D61K	1 608	6.1	9.79	1.89	0.6	3.7	5.88	17	32.08	0.34	0.0000	0.0000	0.1147	0.0000	0.5000	0.0574
D61L	1 016	6.9	7.02	3.48	0.7	4.8	4.91	11	38.27	0.40	0.0000	0.0000	0.0655	0.0000	0.5000	0.0328
D61M	943	6.1	5.79	2.72	0.6	3.7	3.48	5	13.59	0.14	0.0000	0.0000	0.0638	0.0000	0.5000	0.0319
D62A	2 243	5.8	12.99	0.97	0.5	2.9	6.50	35	34.06	0.36	0.3400	0.0000	0.1467	0.0000	0.5000	0.2434
D62B	3 117	5.7	17.85	1.19	0.5	2.9	8.93	18	21.38	0.22	0.0300	0.0000	0.2043	0.0000	0.5000	0.1172
D62C	2 130	8.3	17.61	2.40	0.6	5.0	10.56	139	333.89	3.51	0.0000	0.4120	0.1465	0.0000	0.5000	0.2793
D62D	2 402	10.9	26.21	2.55	0.6	6.5	15.72	287	731.33	7.69	2.7300	0.4120	0.1304	0.0000	0.5000	1.6362
D62E	1 924	5.7	11.00	2.82	0.6	3.4	6.60	7	19.73	0.21	0.0000	0.0000	0.1724	0.0000	0.5000	0.0862
D62F	1 701	6.8	11.50	1.10	0.5	3.4	5.75	4	4.41	0.05	0.0000	0.0000	0.2007	0.0000	0.5000	0.1004
D62G	2 549	6.9	17.51	1.10	0.5	3.4	8.76	8	8.79	0.09	0.0700	0.0000	0.1740	0.0000	0.5000	0.1220
D62H	2 062	6.7	13.88	1.70	0.6	4.0	8.33	105	178.71	1.88	0.0000	0.0000	0.0582	0.0000	0.5000	0.0291
D62J	2 200	6.0	13.19	1.16	0.5	3.0	6.59	34	39.47	0.41	0.0000	0.0000	0.1289	0.0000	0.5000	0.0645
Boegoe-berg																
C92C	1 959	20.5	40.22	2.37	0.6	12.3	24.13	91	216.03	2.27	0.0200	0.7026	0.1446	0.0000	1.0000	0.8672
D71A	1 210	13.4	16.19	2.80	0.6	8.0	9.72	6	16.82	0.18	0.0000	0.0000	0.0934	0.0000	1.2000	0.1121
D71B	2 875	12.7	36.45	1.92	0.6	7.6	21.87	123	236.09	2.48	0.1900	0.6076	0.1839	0.0000	1.2000	1.1778
D71C	1 592	6.2	9.83	0.43	0.4	2.5	3.93	6	2.57	0.03	0.0000	0.0000	0.1034	0.0000	1.2000	0.1241
D71D	1 713	7.1	12.20	1.69	0.6	4.3	7.32	53	89.69	0.94	0.0900	0.2864	0.1005	0.0000	1.0000	0.4769
D72A	1 397	6.4	8.98	1.77	0.6	3.9	5.39	53	93.63	0.98	0.0000	0.0000	0.0062	0.0000	1.2000	0.0074
D72B	2 569	7.4	19.10	1.17	0.5	3.7	9.55	160	186.69	1.96	0.0000	0.0000	0.0745	0.0000	1.2000	0.0894
D72C	2 776	7.3	20.29	1.09	0.5	3.7	10.15	85	92.39	0.97	0.8277	0.1336	0.0698	0.0000	1.0000	1.0311
Neusberg																
D73B	3 525	6.7	23.53	1.10	0.5	3.3	11.77	357	392.06	4.12	0.0000	0.0000	0.2300	0.0000	1.2000	0.2760

QUAR-TERNARY	AREA (km^2)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m^3/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m^3/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m^3/a)	MUNI-CIPAL USE (10^6 m^3/a)	RURAL USE (10^6 m^3/a)	LIVE-STOCK USE (10^6 m^3/a)	IRRI-GATION USE (10^6 m^3/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m^3/a) oGWSo
D73C	2 433	2.7	6.49	0.74	0.5	1.3	3.25	560	413.45	4.35	0.0000	0.0000	0.3894	0.0000	1.2000	0.4673
D73D	3 783	4.5	16.91	0.68	0.4	1.8	6.76	199	136.24	1.43	0.0000	0.0000	0.0320	0.0000	1.2000	0.0384
D73E	3 383	3.4	11.65	0.78	0.5	1.7	5.83	98	76.70	0.81	0.0000	0.0000	0.0429	0.0000	1.2000	0.0515
D73F	4 630	5.7	26.23	0.53	0.4	2.3	10.49	115	61.27	0.64	0.0000	0.0000	0.0769	0.0000	1.2000	0.0923
Vioolsdrift																
D81A	2 311	3.0	6.90	0.94	0.5	1.5	3.45	80	74.85	0.79	0.0000	0.0000	0.0817	0.0000	1.2000	0.0980
D81B	851	3.0	2.55	0.40	0.4	1.2	1.02	21	8.45	0.09	0.0000	0.0000	0.0320	0.0000	1.2000	0.0384
D81C	2 682	3.0	8.05	0.77	0.5	1.5	4.02	62	47.60	0.50	0.0000	0.0000	0.1006	0.0000	1.2000	0.1207
D81D	1 826	2.3	4.13	0.39	0.4	0.9	1.65	79	30.45	0.32	0.0000	0.0000	0.0686	0.0000	1.2000	0.0823
D81E	1 291	2.0	2.59	0.33	0.4	0.8	1.03	66	21.52	0.23	0.0300	0.0000	0.0484	0.0000	1.2000	0.0941
D81F	1 841	1.5	2.83	0.51	0.4	0.6	1.13	96	49.16	0.52	0.0000	0.0000	0.0689	0.0000	1.2000	0.0827
D81G	2 007	2.6	5.20	0.94	0.5	1.3	2.60	64	60.36	0.63	0.2400	0.0000	0.0708	0.0000	1.2000	0.3730
D82A	1 917	2.7	5.24	1.11	0.5	1.4	2.62	10	11.10	0.12	0.0000	0.0000	0.0593	0.0000	1.2000	0.0712
D82B	4 877	0.5	2.53	0.45	0.4	0.2	1.01	265	119.62	1.26	0.0000	0.0000	0.1471	0.0000	1.2000	0.1765
D82C	3 996	0.9	3.52	0.77	0.5	0.4	1.76	116	89.48	0.94	0.0000	0.0000	0.1247	0.0000	1.2000	0.1496
D82D	2 967	1.5	4.52	0.89	0.5	0.8	2.26	103	91.57	0.96	0.0000	0.0000	0.0000	0.0000	1.2000	0.0000
D82E	944	0.7	0.64	0.03	0.3	0.2	0.19	3	0.08	0.00	0.0000	0.0000	0.0294	0.0000	1.2000	0.0353
Alexander Bay																
D82F	1 039	0.9	0.96	0.97	0.5	0.5	0.48	8	7.73	0.08	0.0000	0.0000	0.0324	0.0000	1.2000	0.0389
D82G	594	0.5	0.30	0.14	0.3	0.2	0.09	7	0.99	0.01	0.0000	0.0000	0.0185	0.0000	1.2000	0.0222
D82H	822	0.8	0.66	1.13	0.5	0.4	0.33	22	24.78	0.26	0.0000	0.0273	0.0256	0.0000	1.2000	0.0634
D82J	1 385	0.5	0.69	2.27	0.6	0.3	0.42	3	6.80	0.07	0.0000	0.0000	0.0432	0.0000	1.2000	0.0518
D82K	917	0.5	0.46	2.72	0.6	0.3	0.28	15	40.74	0.43	0.0500	0.0000	0.0286	0.0000	1.2000	0.0943
D82L	754	0.5	0.38	0.77	0.5	0.3	0.19	3	2.32	0.02	0.0000	0.0000	0.0235	0.0000	1.2000	0.0282

QUAR-TERNARY	AREA (km²)	HARVEST POTEN-TIAL (mm)	HARVEST POTEN-TIAL (10^6 m³/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOI-TATION FACTOR fGECi	EXPLOI-TATION POTEN-TIAL (mm)	EXPLOI-TATION POTEN-TIAL (10^6 m³/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BORE-HOLE YIELDS (10^6 m³/a)	MUNI-CIPAL USE (10^6 m³/a)	RURAL USE (10^6 m³/a)	LIVE-STOCK USE (10^6 m³/a)	IRRI-GATION USE (10^6 m³/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m³/a) oGWSo
Coastal																
F10A	460	1.6	0.73	0.82	0.5	0.8	0.36	10	8.23	0.09	0.0100	0.0000	0.0205	0.0000	0.7000	0.0214
F10B	1 089	2.2	2.35	1.23	0.5	1.1	1.18	27	33.12	0.35	0.0000	0.0000	0.0485	0.0000	0.7000	0.0340
F10C	1 176	0.5	0.61	0.28	0.3	0.2	0.18	4	1.10	0.01	0.0000	0.0000	0.0520	0.0000	0.7000	0.0364
F20A	1 120	3.0	3.32	0.55	0.4	1.2	1.33	56	30.67	0.32	0.1000	0.0000	0.0499	0.0000	0.7000	0.1049
F20B	514	2.9	1.50	0.59	0.4	1.2	0.60	31	18.26	0.19	0.0000	0.0000	0.0229	0.0000	0.7000	0.0160
F20C	613	3.0	1.83	1.44	0.5	1.5	0.92	38	54.76	0.58	0.0200	0.2716	0.0272	0.0000	0.7000	0.2231
F20D	455	0.6	0.28	2.23	0.6	0.4	0.17	11	24.51	0.26	0.0000	0.0000	0.0200	0.0000	0.7000	0.0140
F20E	435	0.6	0.27	0.11	0.3	0.2	0.08	5	0.55	0.01	0.0000	0.0000	0.0191	0.0000	0.7000	0.0134
F30A	1 954	4.9	9.51	1.11	0.5	2.4	4.76	130	144.03	1.51	0.0600	0.1997	0.0871	0.0000	0.7000	0.2427
F30B	1 462	2.3	3.36	0.64	0.4	0.9	1.34	26	16.54	0.17	0.0000	0.0000	0.0651	0.0000	0.7000	0.0456
F30C	1 655	7.0	11.53	0.73	0.5	3.5	5.77	174	127.72	1.34	0.0240	0.1004	0.0737	0.0000	0.7000	0.1387
F30D	976	6.0	5.83	1.11	0.5	3.0	2.92	77	85.52	0.90	0.0077	0.0000	0.0435	0.0000	0.7000	0.0358
F30E	1 260	3.8	4.78	0.80	0.5	1.9	2.39	35	27.83	0.29	0.0200	0.3212	0.0561	0.0000	0.7000	0.2781
F30F	1 469	3.9	5.77	0.90	0.5	2.0	2.88	32	28.64	0.30	0.0000	0.0000	0.0654	0.0000	0.7000	0.0458
F30G	980	2.6	2.55	1.71	0.6	1.6	1.53	46	78.85	0.83	0.3000	0.4402	0.0437	0.0000	0.7000	0.5487
F40A	984	0.5	0.49	0.14	0.3	0.2	0.15	2	0.27	0.00	0.0600	0.0000	0.0434	0.0000	0.7000	0.0724
F40B	404	1.8	0.71	0.34	0.4	0.7	0.28	19	6.39	0.07	0.0000	0.0000	0.0180	0.0000	0.7000	0.0126
F40C	608	3.9	2.35	0.38	0.4	1.5	0.94	9	3.42	0.04	0.0400	0.0000	0.0271	0.0000	0.7000	0.0470
F40D	741	0.7	0.52	0.28	0.3	0.2	0.16	3	0.85	0.01	0.0000	0.0000	0.0330	0.0000	0.7000	0.0231
F40E	1 065	3.9	4.14	0.85	0.5	1.9	2.07	118	100.42	1.06	0.0000	0.0589	0.0474	0.0000	0.7000	0.0744
F40F	682	0.5	0.36	3.93	0.7	0.4	0.25	2	7.85	0.08	0.0600	0.0000	0.0298	0.0000	0.7000	0.0629
F40G	348	4.4	1.55	1.08	0.5	2.2	0.77	47	50.86	0.53	0.0000	0.2718	0.0155	0.0000	0.7000	0.2011
F40H	514	1.2	0.60	0.44	0.4	0.5	0.24	3	1.31	0.01	0.0000	0.0000	0.0227	0.0000	0.7000	0.0159
F50A	1 303	5.5	7.23	0.82	0.5	2.8	3.61	145	119.00	1.25	0.0000	0.0000	0.0293	0.0000	0.7000	0.0205

QUARTERNARY	AREA (km^2)	HARVEST POTENTIAL (mm)	HARVEST POTENTIAL (10^6 m^3/a) oGHPi	AVERAGE YIELD BOREHOLES (l/s, 8hrs/day)	EXPLOITATION FACTOR fGECi	EXPLOITATION POTENTIAL (mm)	EXPLOITATION POTENTIAL (10^6 m^3/a) oGEPo	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (l/s)	SUM OF BOREHOLE YIELDS (10^6 m^3/a)	MUNICIPAL USE (10^6 m^3/a)	RURAL USE (10^6 m^3/a)	LIVESTOCK USE (10^6 m^3/a)	IRRIGATION USE (10^6 m^3/a)	TOTAL USE FACTOR	TOTAL USE (10^6 m^3/a) oGWSo
F50B	603	8.0	4.82	0.58	0.4	3.2	1.93	73	42.14	0.44	0.0000	0.0000	0.0268	0.0000	0.7000	0.0188
F50C	439	7.8	3.43	0.48	0.4	3.1	1.37	52	24.96	0.26	0.0000	0.0000	0.0119	0.0000	0.7000	0.0083
F50D	687	3.0	2.06	1.50	0.6	1.8	1.23	55	82.70	0.87	0.0000	0.0000	0.0130	0.0000	0.7000	0.0091
F50E	487	8.1	3.93	1.31	0.5	4.0	1.96	127	166.07	1.75	0.0100	0.0297	0.0217	0.0000	0.7000	0.0430
F50F	575	5.3	3.03	1.13	0.5	2.6	1.51	74	83.82	0.88	0.0800	0.1903	0.0256	0.0000	0.7000	0.2071
F50G	775	0.9	0.70	0.31	0.4	0.4	0.28	11	3.39	0.04	0.0000	0.0000	0.0343	0.0000	0.7000	0.0240

APPENDIX G.2

SURFACE WATER RESOURCES

APPENDIX G.2

SURFACE WATER RESOURCES

Quaternary Catchment	Catchment Area (km²)	Mean Annual Precipitation (mm/a)	Mean Annual Evaporation (mm/a)	Naturalised Mean Annual Runoff (10^6 m³/a)
C92C	1 959	326	2 300	10.18
D42A	10 280	222	2 900	5.01
D42B	3 198	176	2 950	0.52
D42D	16 210	151	2 750	1.21
D42E	4 208	148	2 750	0.28
D51A	797	312	1 950	9.45
D51B	873	240	1 950	3.68
D51C	522	176	1 950	0.66
D52A	378	319	1 900	4.48
D52B	660	267	1 900	4.22
D52C	465	193	1 900	0.74
D52D	638	246	1 900	2.99
D52E	609	194	1 900	1
D52F	1 146	162	1 950	1.11
D53A	1 939	160	2 475	5.61
D53B	1 713	167	2 475	5.72
D53C	1 899	149	2 300	4.32
D53D	1 842	136	2 300	3.06
D53E	826	140	2 300	1.52
D53F	8 040	90	2 450	3.11
D53G	4 747	99	2 300	2.59
D53H	1 589	131	2 300	2.32
D53J	455	134	2 300	0.72
D54A	1 518	177	2 325	4.31
D54B	4 053	191	2 325	14.79
D54C	1 342	155	2 325	2.43
D54D	5 071	173	2 450	13.08
D54E	3 326	163	2 325	7.15
D54F	3 809	161	2 450	7.67
D54G	4 503	169	2 450	10.72
D55A	1 872	221	2 150	5.95

Quaternary Catchment	Catchment Area (km²)	Mean Annual Precipitation (mm/a)	Mean Annual Evaporation (mm/a)	Naturalised Mean Annual Runoff (10^6 m³/a)
D55B	1 260	187	2 150	2.23
D55C	761	217	2 150	3.78
D55D	1 889	191	2 150	6.17
D55E	2 240	173	2 150	3.01
D55F	2 632	176	2 300	6.53
D55G	1 293	171	2 300	2.91
D55H	1 151	158	2 300	1.88
D55J	1 998	162	2 300	3.56
D55K	1 247	158	2 300	2.04
D55L	1 242	156	2 300	1.94
D55M	1 813	143	2 300	2.08
D56A	510	292	1 950	3.64
D56B	519	266	1 950	2.56
D56C	920	245	1 950	3.25
D56D	621	189	1 950	0.87
D56E	666	229	2 000	3.01
D56F	1 038	191	2 000	2.51
D56G	651	176	2 000	1.18
D56H	447	174	1 950	0.46
D56J	931	167	2 000	1.4
D57A	853	126	2 200	0.64
D57B	2 274	147	2 200	2.97
D57C	637	126	2 200	0.48
D57D	4 444	138	2 450	6.89
D57E	1 957	145	2 450	3.6
D58A	763	144	2 100	0.48
D58B	1 131	163	2 100	1.12
D58C	2 521	136	2 100	1.28
D61A	1 466	275	2 100	4.36
D61B	1 199	272	2 100	3.42
D61C	1 170	247	2 100	2.32
D61D	651	242	2 100	1.2
D61E	1 091	231	2 250	2.62
D61F	873	204	2 250	1.32

Quaternary Catchment	Catchment Area (km²)	Mean Annual Precipitation (mm/a)	Mean Annual Evaporation (mm/a)	Naturalised Mean Annual Runoff (10^6 m³/a)
D61G	744	216	2 250	1.39
D61H	1 086	231	2 250	2.61
D61J	1 558	215	2 250	2.87
D61K	1 608	227	2 250	3.62
D61L	1 016	270	2 100	2.82
D61M	943	252	2 250	3.11
D62A	2 243	248	2 150	4.01
D62B	3 117	221	2 150	6.14
D62C	2 130	278	2 150	5.9
D62D	2 402	299	2 150	8.79
D62E	1 924	273	2 150	4.98
D62F	1 701	290	2 150	5.53
D62G	2 549	256	2 350	8.71
D62H	2 062	216	2 350	3.72
D62J	2 200	231	2 350	5.12
D71A	1 210	283	2 350	5.69
D71B	2 875	315	2 350	20.01
D71C	1 592	250	2 350	4.75
D71D	1 713	248	2 350	4.96
D72A	1 397	210	2 350	3.09
D72B	2 569	215	2 475	12.7
D72C	2 776	200	2 475	10.76
D73B	3 721	258	2 450	26.34
D73C	6 221	230	2 450	30.07
D73D	4 291	185	2 650	15.3
D73E	3 867	183	2 650	13.29
D73F	4 630	158	2 650	9.62
D81A	2 311	128	2 700	2.74
D81B	851	113	2 750	0.65
D81C	2 682	120	2 750	2.53
D81D	1 826	113	2 750	2
D81E	1 291	97	2 750	0.82
D81F	1 841	91	2 750	0.93
D81G	2 007	102	2 650	0.85

Quaternary Catchment	Catchment Area (km²)	Mean Annual Precipitation (mm/a)	Mean Annual Evaporation (mm/a)	Naturalised Mean Annual Runoff (10^6 m³/a)
D82A	1 917	77	2 650	0.28
D82B	4 877	80	2 650	0.83
D82C	3 996	83	2 650	0.78
D82D	2 967	111	2 650	1.72
D82E	944	100	2 550	0.66
D82F	1 039	106	2 400	0.89
D82G	594	79	2 400	0.18
D82H	822	60	2 400	0.09
D82J	1 385	29	2 400	0.01
D82K	917	31	2 200	0.01
D82L	754	42	2 200	0.02
F10A	460	64	2 250	0.04
F10B	1 089	62	2 250	0.09
F10C	1 176	53	2 250	0.05
F20A	1 120	99	2 100	0.53
F20B	514	91	2 100	0.18
F20C	613	80	2 100	0.13
F20D	455	71	2 100	0.06
F20E	435	92	2 100	0.15
F30A	1 954	162	2 200	2.84
F30B	1 462	107	2 200	0.47
F30C	1 655	184	2 200	3.75
F30D	976	162	2 200	1.42
F30E	1 260	153	2 200	1.49
F30F	1 469	112	2 200	0.56
F30G	980	102	2 200	0.26
F40A	984	118	1 900	0.36
F40B	404	130	1 900	0.21
F40C	608	173	1 900	0.92
F40D	741	123	1 900	0.32
F40E	1 065	186	1 900	2.08
F40F	682	118	1 900	0.25
F40G	348	168	1 900	0.47
F40H	514	109	1 900	0.14

Quaternary Catchment	Catchment Area (km²)	Mean Annual Precipitation (mm/a)	Mean Annual Evaporation (mm/a)	Naturalised Mean Annual Runoff (10^6 m³/a)
F50A	1 303	179	1 900	2.11
F50B	603	208	1 900	1.65
F50C	439	159	1 900	0.46
F50D	687	112	1 900	0.2
F50E	487	246	1 900	2.49
F50F	575	133	1 900	0.31
F50G	775	96	1 900	0.12
Z10A	98 900	111	2 900	12
Z10G	8 829	90	2 950	1.4
Z10H	8 632	64	2 750	8.1
Z10J	682	48	2 750	0.6
Z20A	108 300	64	2 750	483.9
Z20B	10 390	36	2 750	7.8
Z20C	5 590	7	2 400	0.6
Z20D	10 460	16	2 650	1.5
Z20E	5 593	10	2 400	0.6
Z20F	3 733	8	2 200	0.1

APPENDIX G.3

ESTIMATES OF MAXIMUM FEASIBLE DAM STORAGE

APPENDIX G.3

ESTIMATES OF MAXIMUM FEASIBLE DAM STORAGE (EXPRESSED AS A PERCENTAGE OF MAR)

Hydro Zone	Volume II		Volume II		Volume III		Volume IV		Volume V		Volume VI	
	1*	2*	1*	2*	1*	2*	1*	2*	1*	2*	1*	2*
A	91	100	110	100	127	125	113	125	122	125	102	100
B	111	100	197	200	144	150	98	100	128	125	116	125
C	146	150	223	200	161	150	107	100	132	150	109	100
D	168	150	230	200	210	200	123	125	127	125	118	125
E	163	150	207	200	228	200	141	150	159	150	139	150
F	165	150	232	200	279	250	148	150	153	150	168	150
G	149	150	195	200	322	300	220	200	170	150	169	150
H	213	200	245	250	307	300	183	200	173	150	160	150
J	168	150	245	250	330	300	189	200	157	150	145	150
K	203	200	270	300	327	300	202	200	159	150	166	150
L	195	200	309	300	388	400	199	200	180	200	203	200
M	202	200	350	300	408	400	214	200	193	200	200	200
N	268	250			322	300	250	250	210	200	198	200
P	300	300			384	400	223	200	192	200	219	200
Q	248	250					328	300	225	250	240	250
R	247	250					225	200	232	250	277	300
S	323	300					238	250	197	200		
T	208	200					323	300	216	200		
U	247	250					271	250	255	250		
V	280	300					279	300	267	250		
W	318	300					279	300	301	300		
X	296	300					342	300	319	300		
Y							305	300				
Z							300	300				

1* Determined from intersection of 50-year storage yield curve with limit line.
2* Adopted value after grouping of similar zones

APPENDIX G.4

POTENTIAL VULNERABILITY OF SURFACE WATER AND GROUNDWATER TO MICROBIAL CONTAMINATION

G.4-1

WATER RESOURCES SITUATION ASSESSMENTS

DEPARTMENT: WATER AFFAIRS & FORESTRY
DIRECTORATE: WATER RESOURCE PLANNING

POTENTIAL VULNERABILITY OF SURFACE WATER & GROUNDWATER TO MICROBIAL CONTAMINATION

AUGUST 2001

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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

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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)

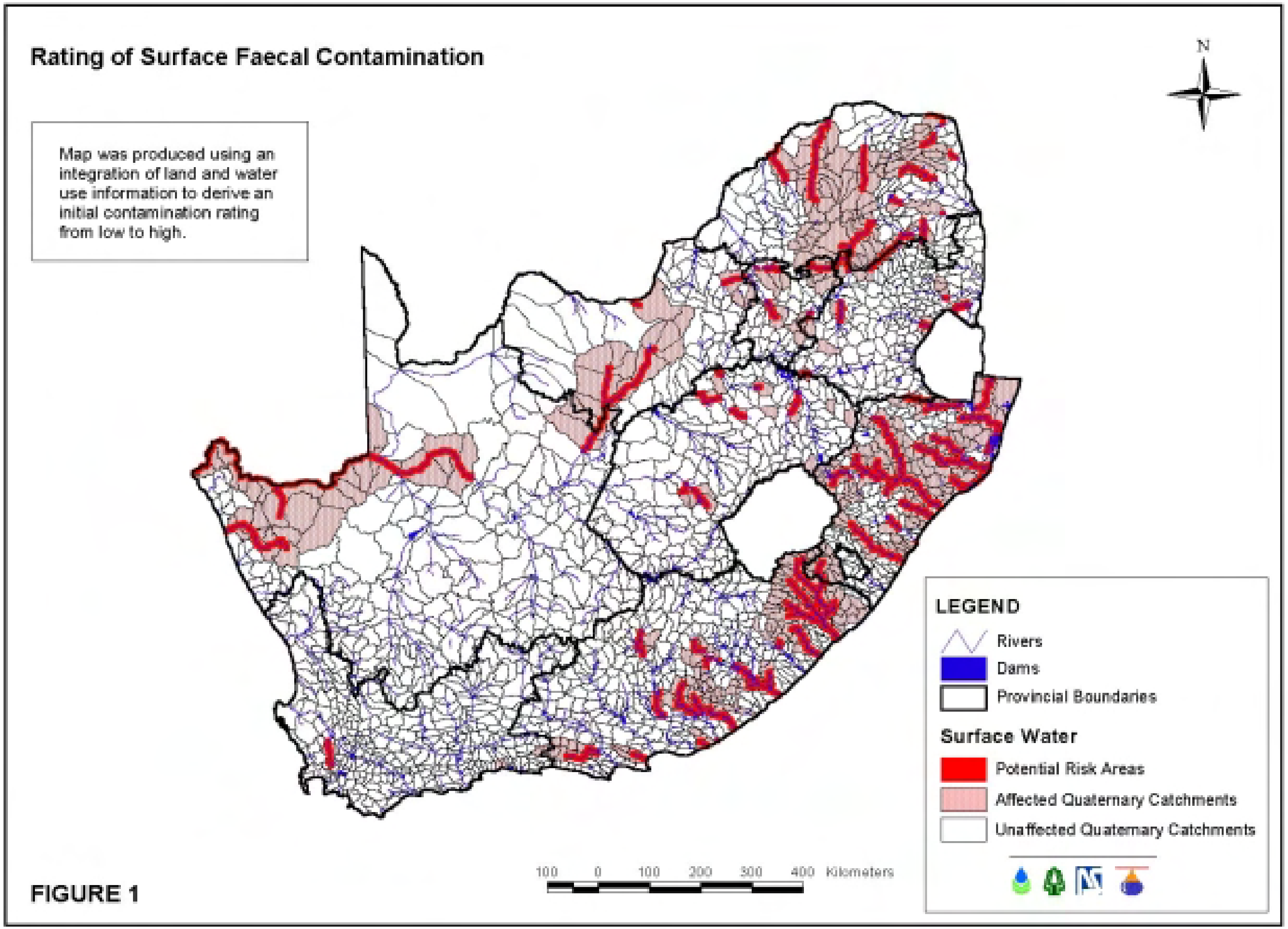
Each area was assigned a rating to indicate low (1), medium (2) or high (3) potential risk to users in the catchment area. The following values were used to designate each class:

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
Map was produced using an integration of land and water use information to derive an initial contamination rating from low to high.
N
LEGEND
Rivers
Dams
Provincial Boundaries
Surface Water
Potential Risk Areas
Affected Quaternary Catchments
Unaffected Quaternary Catchments
100 0 100 200 300 400 Kilometers
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).

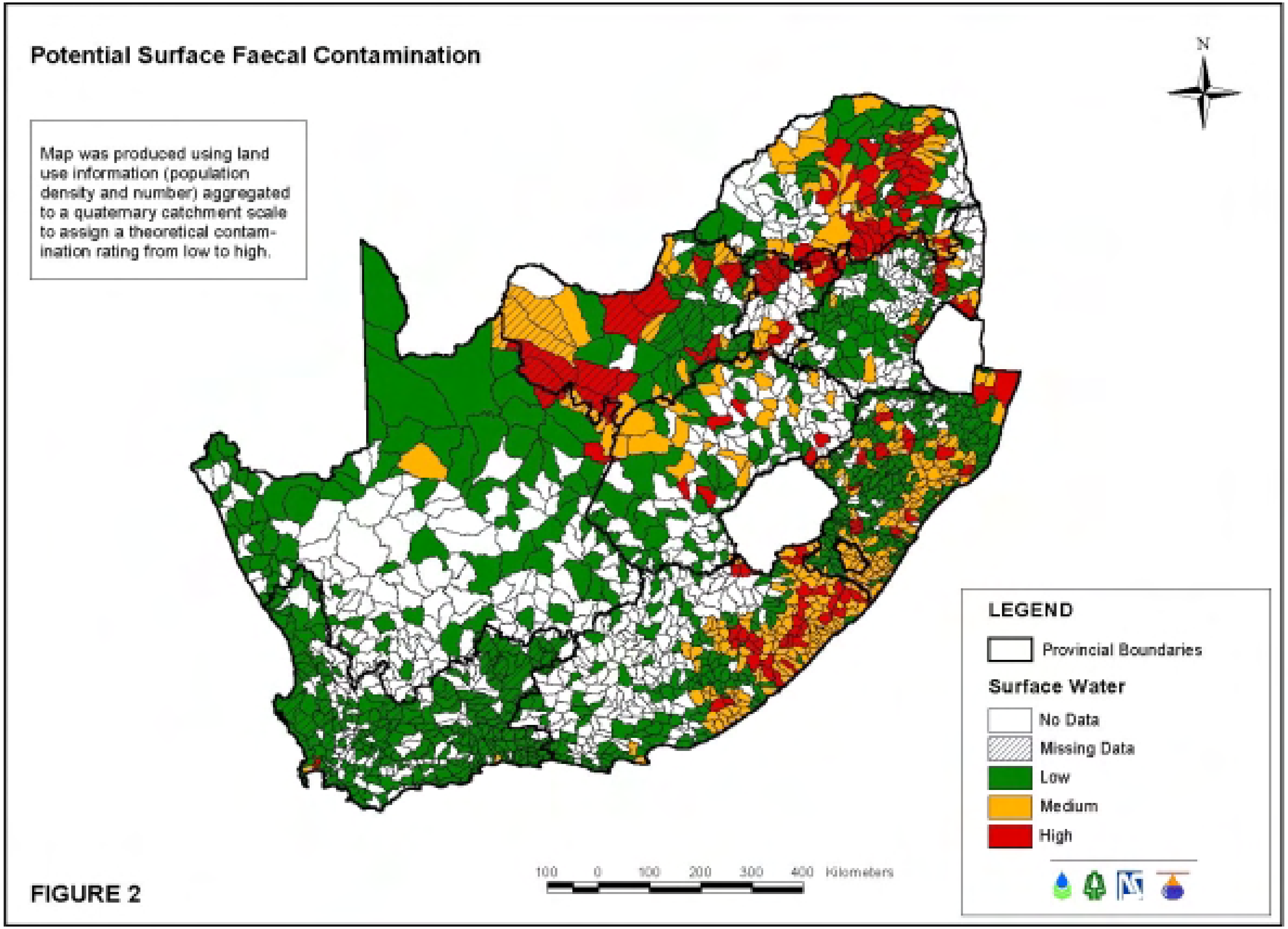

Potential Surface Faecal Contamination
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
N
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
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.

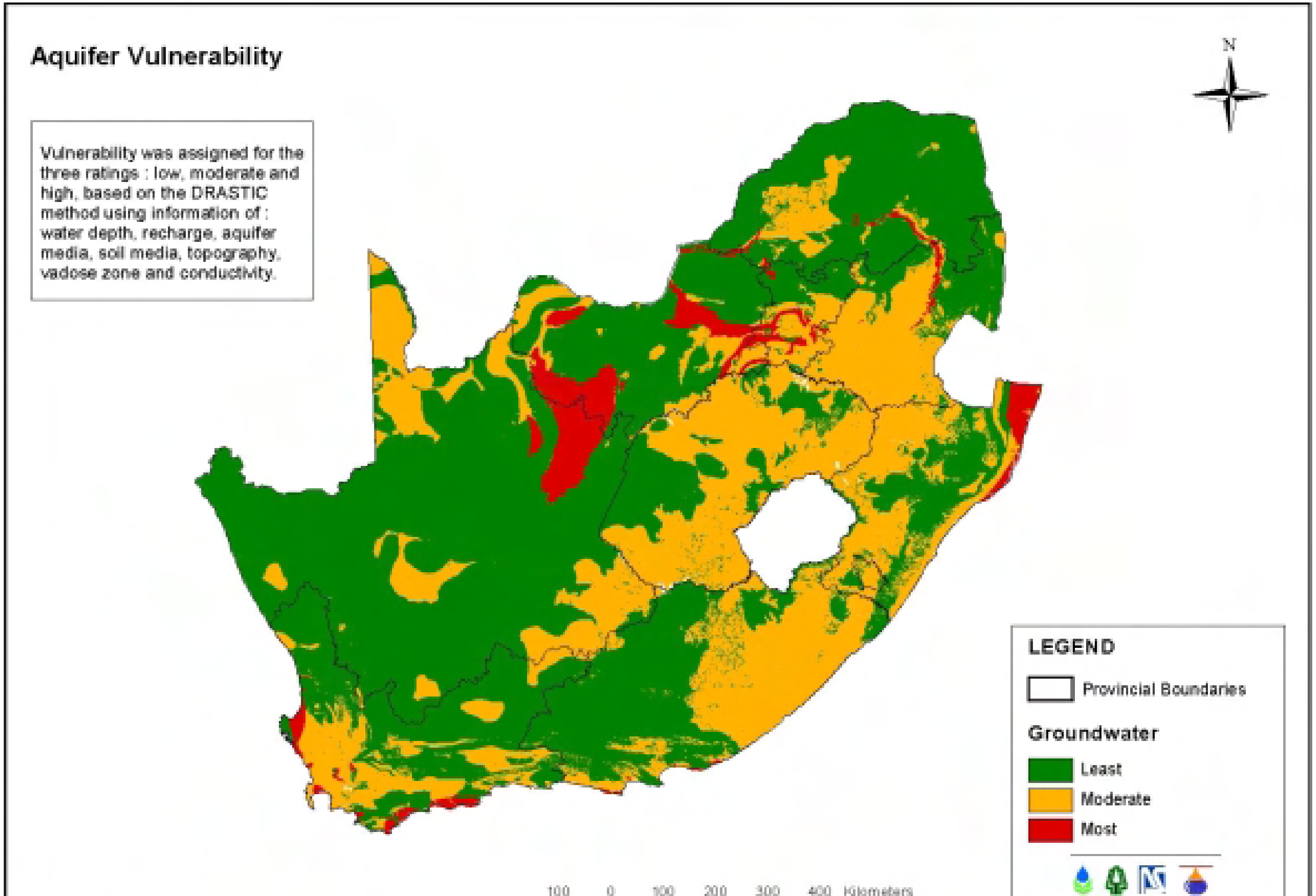

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
LEGEND
Provincial Boundaries
Groundwater
Least
Moderate
Most
(Parsons and Conrad, 1998)
100 0 100 200 300 400 Kilometers

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.

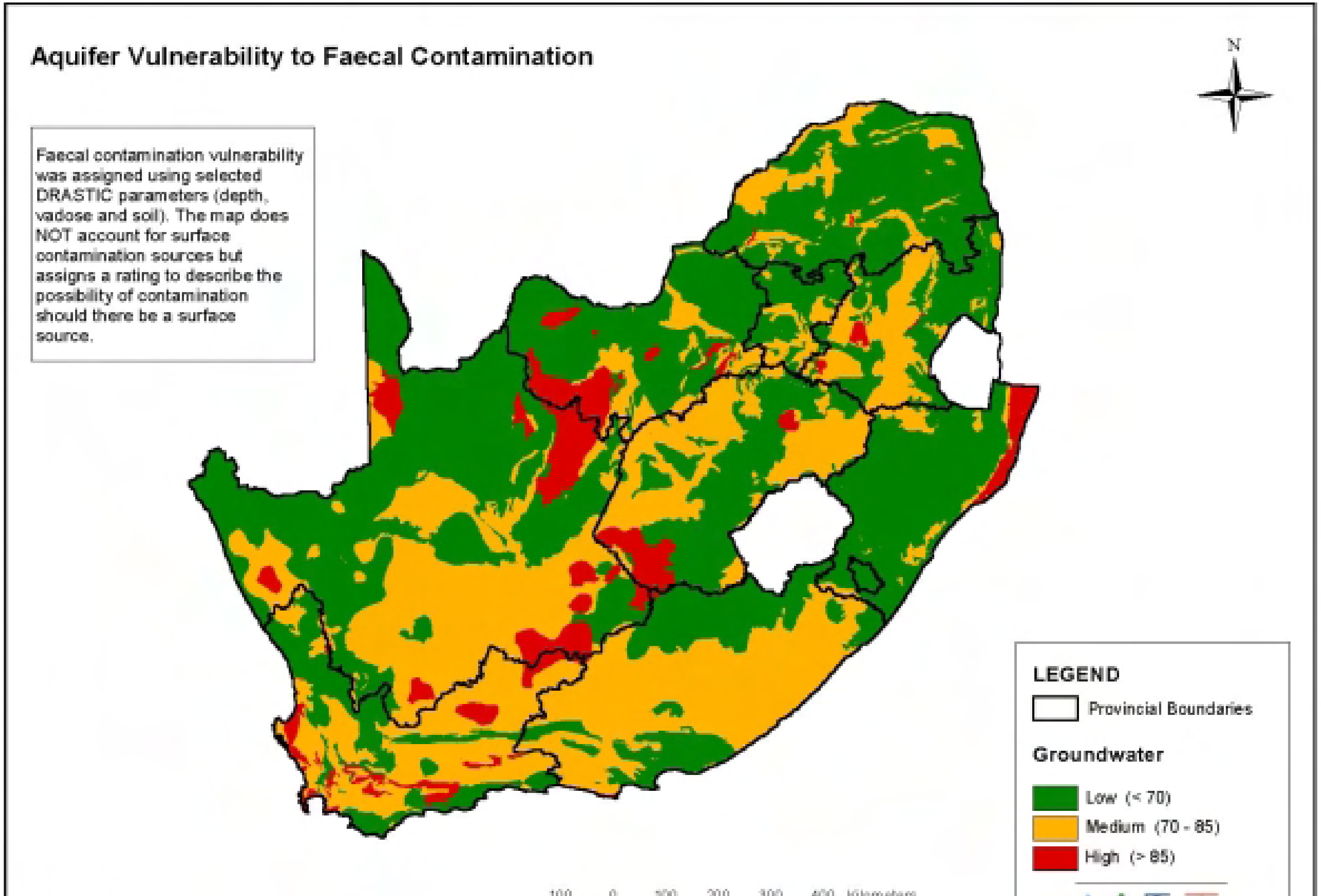
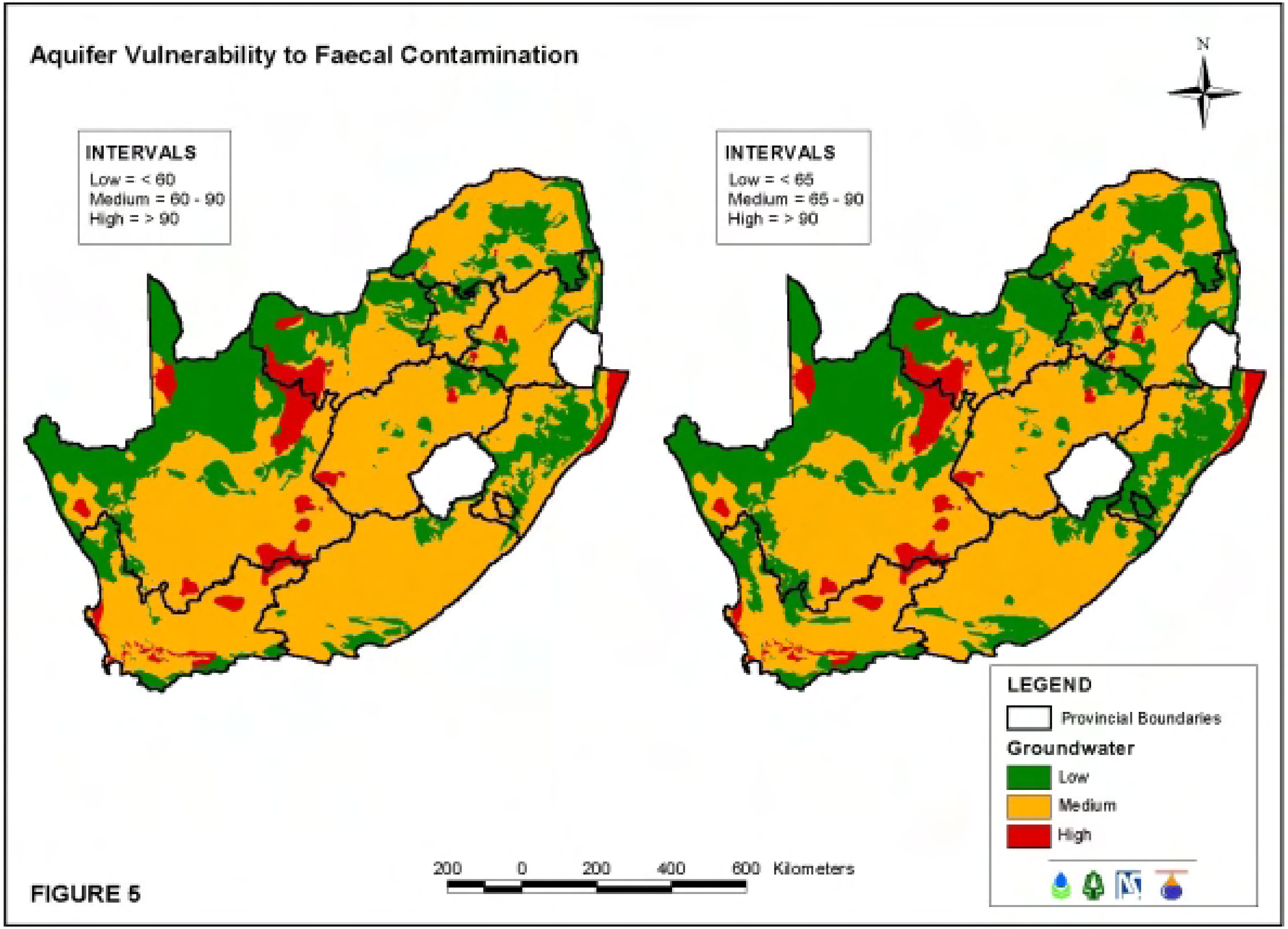
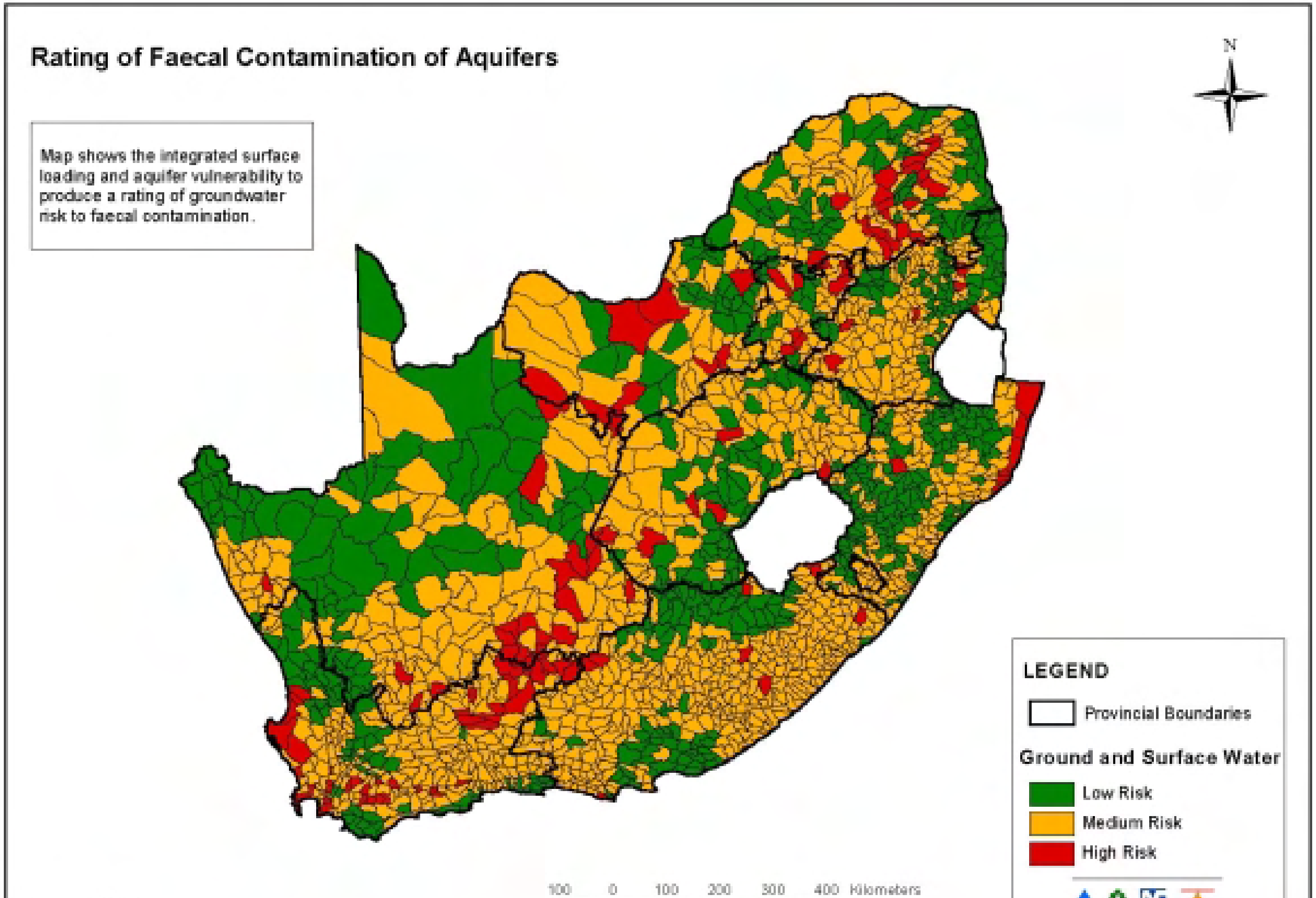

Aquifer Vulnerability to Faecal Contamination
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
N
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
N
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
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

SEDIMENTATION

APPENDIX G.5

LOWER ORANGE WMA – SEDIMENTATION

Quaternary Catchment	WR90 Area (km²)	Area (drgn-quat-geo) (km²)	WR90 Sediment yield (t/a)	Sediment volume at 50 year density (m³/a)	Sediment volume after 25 years (10^6 m³/a)	Naturalised MAR (10^6 m³/a)	Potential Sediment accumulation after 25 years (% MAR)
C92C	1 956.34	1 804.80		0	0.00	10.18	0.00%
D42A	10 296.83	9 243.70	0	0	0.00	5.01	0.00%
D42B	3 203.63	2 896.90	0	0	0.00	0.52	0.00%
D42D	14 130.47	12 878.20	0	0	0.00	1.21	0.00%
D42E	4 213.80	3 869.10	0	0	0.00	0.28	0.00%
D51A	796.38	762.50	64 000	45 345	1.68	9.45	17.77%
D51B	873.67	833.60	56 000	39 539	1.46	3.68	39.78%
D51C	522.50	497.10	17 000	11 968	0.44	0.66	67.14%
D52A	375.55	359.70	30 000	21 263	0.79	4.48	17.57%
D52B	659.86	630.50	48 000	33 940	1.26	4.22	29.78%
D52C	465.67	443.70	27 000	19 037	0.70	0.74	95.26%
D52D	636.60	606.60	41 000	28 910	1.07	2.99	35.80%
D52E	608.64	578.80	26 000	18 297	0.68	1.00	67.75%
D52F	1 145.08	1 086.40	74 000	51 954	1.92	1.11	173.31%
D53A	1 940.93	1 803.50	58 000	39 881	1.48	5.61	26.32%
D53B	1 715.39	1 590.10	51 000	34 984	1.30	5.72	22.65%
D53C	1 901.74	1 762.60	57 000	39 094	1.45	4.32	33.51%
D53D	1 844.08	1 712.30	70 000	48 098	1.78	3.06	58.20%
D53E	826.95	765.00	25 000	17 114	0.63	1.52	41.69%
D53F	8 039.74	7 520.10	556 000	384 847	14.25	3.11	458.19%
D53G	4 751.41	4 414.50	172 000	118 255	4.38	2.59	169.06%
D53H	1 591.45	1 473.30	48 000	32 883	1.22	2.32	52.48%
D53J	455.53	420.70	14 000	9 568	0.35	0.72	49.20%
D54A	1 519.42	1 430.10	63 000	43 879	1.62	4.31	37.70%
D54B	4 055.38	3 813.30	151 000	105 070	3.89	14.79	26.30%
D54C	1 343.60	1 261.40	65 000	45 157	1.67	2.43	68.81%
D54D	5 075.28	4 746.10	220 000	152 241	5.64	13.08	43.10%
D54E	3 328.88	3 130.60	148 000	102 997	3.81	7.15	53.34%
D54F	3 812.68	3 568.40	173 000	119 818	4.44	7.67	57.84%
D54G	4 507.93	4 200.40	142 000	97 911	3.63	10.72	33.82%
D55A	1 866.92	1 779.50	151 000	106 508	3.94	5.95	66.28%
D55B	1 257.84	1 198.30	79 000	55 693	2.06	2.23	92.47%
D55C	759.00	721.00	61 000	42 880	1.59	3.78	42.00%

Quaternary Catchment	WR90 Area (km²)	Area (drgn-quat-geo) (km²)	WR90 Sediment yield (t/a)	Sediment volume at 50 year density (m^3/a)	Sediment volume after 25 years (10^6 m^3/a)	Naturalised MAR (10^6 m^3/a)	Potential Sediment accumulation after 25 years (% MAR)
D55D	1 890.26	1 793.10	128 000	89 851	3.33	6.17	53.92%
D55E	2 240.07	2 132.70	78 000	54 953	2.03	3.01	67.60%
D55F	2 633.46	2 488.20	82 000	57 333	2.12	6.53	32.51%
D55G	1 293.93	1 225.80	53 000	37 155	1.38	2.91	47.28%
D55H	1 152.19	1 091.90	35 000	24 545	0.91	1.88	48.34%
D55J	2 000.12	1 891.10	60 000	41 980	1.55	3.56	43.66%
D55K	1 248.02	1 185.30	37 000	26 004	0.96	2.04	47.20%
D55L	1 242.74	1 177.60	43 000	30 152	1.12	1.94	57.55%
D55M	1 814.29	1 713.60	84 000	58 710	2.17	2.08	104.51%
D56A	508.93	488.20	41 000	29 104	1.08	3.64	29.61%
D56B	515.91	494.70	42 000	29 802	1.10	2.56	43.11%
D56C	920.31	880.90	54 000	38 249	1.42	3.25	43.58%
D56D	621.20	592.70	21 000	14 827	0.55	0.87	63.10%
D56E	663.70	635.10	54 000	38 238	1.42	3.01	47.04%
D56F	1 038.82	991.70	46 000	32 496	1.20	2.51	47.94%
D56G	651.66	620.80	20 000	14 099	0.52	1.18	44.24%
D56H	447.62	426.30	14 000	9 867	0.37	0.46	79.42%
D56J	931.56	885.30	28 000	19 691	0.73	1.40	52.08%
D57A	854.13	803.60	53 000	36 900	1.37	0.64	213.48%
D57B	2 276.12	2 142.30	68 000	47 362	1.75	2.97	59.05%
D57C	637.24	598.40	49 000	34 050	1.26	0.48	262.66%
D57D	4 448.75	4 156.90	316 000	218 499	8.09	6.89	117.42%
D57E	1 959.75	1 825.30	73 000	50 314	1.86	3.60	51.75%
D58A	763.93	724.40	25 000	17 543	0.65	0.48	135.32%
D58B	1 130.47	1 070.00	82 000	57 434	2.13	1.12	189.88%
D58C	2 520.99	2 377.60	190 000	132 603	4.91	1.28	383.59%
D61A	1 460.87	1 384.40	113 000	79 243	2.93	4.36	67.30%
D61B	1 197.09	1 131.50	73 000	51 060	1.89	3.42	55.28%
D61C	1 169.54	1 105.40	48 000	33 572	1.24	2.32	53.58%
D61D	648.11	614.40	43 000	30 165	1.12	1.20	93.08%
D61E	1 087.38	1 031.20	79 000	55 440	2.05	2.62	78.35%
D61F	871.32	825.90	70 000	49 100	1.82	1.32	137.73%
D61G	743.94	704.10	44 000	30 816	1.14	1.39	82.09%
D61H	1 086.16	1 027.00	62 000	43 381	1.61	2.61	61.54%
D61J	1 558.86	1 471.10	52 000	36 314	1.34	2.87	46.85%

Quaternary Catchment	WR90 Area (km²)	Area (drgn-quat-geo) (km²)	WR90 Sediment yield (t/a)	Sediment volume at 50 year density (m³/a)	Sediment volume after 25 years (10^6 m³/a)	Naturalised MAR (10^6 m³/a)	Potential Sediment accumulation after 25 years (% MAR)
D61K	1 608.29	1 515.30	48 000	33 466	1.24	3.62	34.23%
D61L	1 015.44	956.80	30 000	20 918	0.77	2.82	27.47%
D61M	942.57	888.00	28 000	19 520	0.72	3.11	23.24%
D62A	2 242.75	2 104.90	67 000	46 533	1.72	4.01	42.97%
D62B	3 117.32	2 923.00	93 000	64 530	2.39	6.14	38.91%
D62C	2 126.56	2 003.90	77 000	53 693	1.99	5.90	33.70%
D62D	2 397.10	2 255.80	82 000	57 103	2.11	8.79	24.05%
D62E	1 922.06	1 801.50	58 000	40 228	1.49	4.98	29.91%
D62F	1 699.06	1 589.10	53 000	36 682	1.36	5.53	24.56%
D62G	2 548.23	2 379.30	76 000	52 512	1.94	8.71	22.32%
D62H	2 063.17	1 928.40	62 000	42 883	1.59	3.72	42.68%
D62J	2 200.41	2 049.40	66 000	45 488	1.68	5.12	32.90%
D71A	1 209.40	1 120.00	36 000	24 671	0.91	5.69	16.05%
D71B	2 875.27	2 653.60	86 000	58 734	2.17	20.01	10.87%
D71C	1 592.20	1 477.30	48 000	32 957	1.22	4.75	25.69%
D71D	1 714.10	1 589.50	51 000	34 997	1.30	4.96	26.13%
D72A	1 397.62	1 301.70	42 000	28 947	1.07	3.09	34.69%
D72B	2 571.19	2 388.50	77 000	52 931	1.96	12.70	15.43%
D72C	2 778.45	2 576.90	83 000	56 965	2.11	10.76	19.60%
D73B	3 528.03	3 256.80	0	0	0.00	26.34	0.00%
D73C	2 435.14	2 247.50	0	0	0.00	26.34	0.00%
D73D	3 788.41	3 494.30	0	0	0.00	30.07	0.00%
D73E	3 388.03	3 114.90	0	0	0.00	15.30	0.00%
D73F	4 636.42	4 276.40	0	0	0.00	13.29	0.00%
D81A	2 313.62	2 135.20	0	0	0.00	9.62	0.00%
D81B	852.27	784.60	0	0	0.00	2.74	0.00%
D81C	2 685.92	2 460.00	0	0	0.00	0.65	0.00%
D81D	1 828.21	1 686.20	0	0	0.00	2.53	0.00%
D81E	1 291.72	1 191.90	0	0	0.00	2.00	0.00%
D81F	1 842.35	1 704.50	0	0	0.00	0.82	0.00%
D81G	2 008.57	1 860.90	0	0	0.00	0.93	0.00%
D82A	-9 999.00	0.00	0	0	0.00	0.85	0.00%
D82A	1 917.64	0.00	0	0	0.00	0.28	0.00%
D82B	4 872.63	4 537.20	0	0	0.00	0.83	0.00%
D82C	3 995.63	3 708.30	0	0	0.00	0.78	0.00%

Quaternary Catchment	WR90 Area (km²)	Area (drgn-quat-geo) (km²)	WR90 Sediment yield (t/a)	Sediment volume at 50 year density (m³/a)	Sediment volume after 25 years (10^6 m³/a)	Naturalised MAR (10^6 m³/a)	Potential Sediment accumulation after 25 years (% MAR)
D82D	2 965.30	0.00	0	0	0.00	1.72	0.00%
D82E	943.20	871.80	0	0	0.00	0.66	0.00%
D82F	1 037.64	959.30	0	0	0.00	0.89	0.00%
D82G	593.56	548.00	0	0	0.00	0.18	0.00%
D82H	820.48	756.40	0	0	0.00	0.09	0.00%
D82J	1 382.52	1 269.80	0	0	0.00	0.01	0.00%
D82K	915.02	841.10	0	0	0.00	0.01	0.00%
D82L	751.34	691.90	0	0	0.00	0.02	0.00%
F10A	459.11	423.20	0	0	0.00	0.04	0.00%
F10B	1 086.40	1 002.70	0	0	0.00	0.09	0.00%
F10C	1 172.53	1 082.70	0	0	0.00	0.05	0.00%
F20A	1 118.41	1 035.40	0	0	0.00	0.53	0.00%
F20B	513.14	475.80	0	0	0.00	0.18	0.00%
F20C	611.84	566.20	0	0	0.00	0.13	0.00%
F20D	451.82	418.60	0	0	0.00	0.06	0.00%
F20E	432.02	401.30	0	0	0.00	0.15	0.00%
F30A	1 952.00	1 825.60	0	0	0.00	2.84	0.00%
F30B	1 461.65	1 361.90	0	0	0.00	0.47	0.00%
F30C	1 653.13	1 543.30	0	0	0.00	3.75	0.00%
F30D	974.73	908.50	0	0	0.00	1.42	0.00%
F30E	1 258.78	1 169.20	0	0	0.00	1.49	0.00%
F30F	1 466.40	1 362.20	0	0	0.00	0.56	0.00%
F30G	978.32	910.20	0	0	0.00	0.26	0.00%
F40A	1 014.99	946.90	0	0	0.00	0.36	0.00%
F40B	403.74	376.80	0	0	0.00	0.21	0.00%
F40C	607.36	567.80	0	0	0.00	0.92	0.00%
F40D	739.19	691.10	0	0	0.00	0.32	0.00%
F40E	1 063.07	996.40	0	0	0.00	2.08	0.00%
F40F	680.50	638.10	0	0	0.00	0.25	0.00%
F40G	347.68	326.50	0	0	0.00	0.47	0.00%
F40H	512.92	481.90	0	0	0.00	0.14	0.00%
F50A	1 304.63	1 225.40	0	0	0.00	2.11	0.00%
F50B	603.12	566.50	0	0	0.00	1.65	0.00%
F50C	438.59	412.80	0	0	0.00	0.46	0.00%
F50D	686.63	647.00	0	0	0.00	0.20	0.00%

Quaternary Catchment	WR90 Area (km²)	Area (drgn-quat-geo) (km²)	WR90 Sediment yield (t/a)	Sediment volume at 50 year density (m³/a)	Sediment volume after 25 years (10^6 m³/a)	Naturalised MAR (10^6 m³/a)	Potential Sediment accumulation after 25 years (% MAR)
F50E	486.55	456.30	0	0	0.00	2.49	0.00%
F50F	574.75	540.40	0	0	0.00	0.31	0.00%
F50G	774.10	728.70	0	0	0.00	0.12	0.00%
Namibia							
Z10A						12.00	0.00%
Z10G						1.40	0.00%
Z10H						8.10	0.00%
Z10J						0.60	0.00%
Z20A						483.90	0.00%
Z20B						7.80	0.00%
Z20C						0.60	0.00%
Z20D						1.50	0.00%
Z20E						0.60	0.00%
Z20F						0.10	0.00%

APPENDIX H

WATER BALANCE

APPENDIX H.1

WATER SITUATION ASSESSMENT MODEL :

REVISED METHODOLOGY

FOR YIELD ASSESSEMENT

WATER BALANCE MODEL: REVISED METHODOLOGY FOR YIELD ASSESMENT

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ABSTRACT

The Department of Water Affairs and Forestry has initiated the development of a Water Balance Model for use at a national scale. The development takes advantage of the fact that decades of hydrological modelling have given rise to a situation in which the hydrology of each quarternary catchment in the country has been modelled with varying degrees of success. The gross yield potential of each catchment can be described using storage - draft - frequency curves which are derived from the flow files.

By using such curves it is possible to develop a water balance model which can be rapidly processed at a national scale for all quarternary catchments in the country.

The implementation of these curves in water balance modelling is subject to some debate. This paper outlines some of the problems associated some of the initial conceptual ideas, explains the revised method developed for implementation in the model and presents some of the initial results of studies undertaken to test the approach.

Initial results indicate that the “method of accounting for upstream storage”, in the determination of the total yield at the outlet of a system, or sub-system, provides a reasonable approximation (within 5 %) of results obtained by means of monthly hydrological models. The main benefit of the technique presented in this paper is that it facilitated the development of the Water Balance Model by overcoming some of the uncertainties associated with the initial proposals made for it’s development.

1. INTRODUCTION

The Department of Water Affairs and Forestry, together with the Water Research Commission have initiated several projects over the last few decades. As a result of these studies the hydrology of all catchments in the country has been simulated with varying degrees of success. Significant contributions to these simulations have come from Basin Study Reports and the reports on the Surface Water Resources of South Africa (Midgley, Pitman and Middleton, 1999). The latter reports produced flow files for all quarternary catchments in the country as well as a set of storage - draft - frequency curves for all hydrological zones in the country. Storage - draft - frequency curves provide an opportunity with which it is possible to conduct Water Balance studies for scenarios of water resource developments without having to resort to complex mathematical modelling. This does not imply that complex mathematical modelling is no longer **relevant** for water resource modelling. It does however imply that initial water resource planning scenarios can be tested rapidly without having to resort to complex modelling approaches. In order to exploit this opportunity, the Department of Water Affairs and Forestry initiated conceptual studies for the development of a National Water Balance Model (Pitman, Barta and Watson, 1998). Model development and the collection of appropriate data for the model has subsequently been initiated. Due to the need to include drainage systems that are shared with neighbouring states, the model is now simply referred to as the “Water Balance Model.” The main consultants involved in updating the hydrological and water use algorithms are **GIBB Africa** and **WRP** with some inputs from BKS, Eric Hall and Associates, Loxton Venn and the IWR, Rhodes University.

The method of implementation of storage-draft-frequency curves within the Water Balance Model has been subject to some debate. This paper outlines some of the problems associated with the initial conceptual ideas, explains the revised method developed for implementation in the model and some of the initial results of studies undertaken to test the approach.

2. LIMITATIONS OF ORIGINAL CONCEPTUAL MODEL

The approach proposed in the conceptual model (Pitman et al., 1998) involved conducting a “mass balance” to determine the mean annual flow in the river and then conducting a “yield balance” to determine the deficit or surplus in water supply for the 1:50 year return period. For purposes of this paper the storage - draft - frequency curve for gross yields for a given return period will simply be referred to as the gross yield curve. The curve as used in the model is presented in its dimensionless form. This is achieved by expressing the storage and yield values as percentages of the MAR. The conceptual model focussed on determining changes in gross yield as a result of changes in the MAR. Weaknesses in this approach are associated largely with uncertainties in the representativeness of the MAR for altered flow conditions and sudden changes in yield curve characteristics as cumulative flows are moved from one hydrological zone to another. The main difficulties are listed below.

- The flows in the river are highly modified and therefore the method of determining yields for developed conditions by altering the MAR and applying this to a gross yield curve based on highly variable natural flows is uncertain.

- In the conceptual report the flow in the river is split into several portions to represent exploitable and unexploitable flows from upstream and local catchments. Exploitable spillages and unexploitable spillages from upstream and local catchments are further complicated by other exploitable contributions to flows from imported water, return flows and water being transferred via the river to downstream catchments. The unexploitable flow portions due to extreme floods are ignored in the determination of yields. However, these flow portions are included in the MAR of the natural flow used in deriving the gross yield curve for the model.

- A separate gross yield curve is provided for each hydrological zone (Midgley et al, 1994). The implication of this is that as rivers pass from one hydrological zone to another, the yield for the cumulative flow suddenly takes on the characteristics of the new hydrozone. Suggestions were made to weight the yield curves to account for upstream yield characteristics but a methodology was not devised as part of the conceptual study to do this.

- A crucial problem associated with the method is that if a given volume of water is released at a uniform rate to supplement a downstream yield, then the corresponding yield increment (excluding losses) should be the same. This value must therefore be added to the yield and not to the MAR.

Due to these uncertainties, it was decided that alternative approaches should be explored for incorporating yield curves in the Water Balance Model.

3. GROSS YIELD ACCOUNTING

The natural variability of flow is reflected in the non-linearity of yield curves. Because of non-linearity and changes in flow characteristics in a downstream direction, the accounting of yields for multiple dams cannot simply involve accumulating their storage for downstream use in yield curves to derive accumulated gross yields. The purpose of this section is to outline a preferable methodology developed for yield accounting in a downstream direction. It presents the equations used, explains the "method of accounting for upstream storage" and summarises the manner in which it is incorporated in the Water Balance Model.

3.1 Yield Equations

Natural flow conditions for each quarternary catchment have been derived as part of the SWR90 project (Midgley et al, 1994). Some of the flow files have been updated (Görgens, 1999) to account for a new algorithm developed by the CSIR for estimating the effects of afforestation on runoff (Scott and Le Maitre, 1999). The flows used in the National Water Balance Model are based on cumulative natural flow conditions derived from updated SWR90 flows for incremental quarternary catchment conditions. These flow files have been further processed by de Jager and van Rooyen (1999), using stochastic techniques to generate 1 000 sequences of 70 years each from which gross yield curves have been produced for the outlet of each quarternary catchment. This production of separate cumulative yield curves for each catchment has helped to minimise initial problems associated with sudden changes in yield curve characteristics when moving from one hydrological zone to another.

Due to the large number of quarternary catchments, approximately 2 000, the number of yield curves actually derived using stochastic flow sequences was reduced to key points separating hydrozones between which yield results were proportionally incremented. The results were given in terms of coefficients describing the storage-draft-frequency relationships for cumulative flows. The yield curve is presented in its dimensionless form. The dimensionless form is obtained by expressing storage and yield values as percentages of the cumulative natural (virgin) MAR.

$$Yield = \left(\frac{vMRTo}{100}\right) * \left(fYCAi * \left\{ Storage * \left(\frac{100}{vMRTo}\right) \right\}^{fYCBi} + fYCCi \right) \tag{1}$$

Where:	vMRTo	=	(cumulative natural mean runoff)
	fYCAi	=	constant describing the storag
			e yield curve
	fYCBi	=	exponent describing the storage yield curve
	fYCCi	=	constant describing the storage yield curve
And:	vLRLi	=	average river loss for quaternary catchment
	fLRLi	=	river loss actor to reduce average river losses to drought flow loss conditions. Representative of 1:50 year condition (default for fLRLi=0.7)

In the methods given below for accounting for upstream storage at downstream dams, it is often necessary to also accommodate situations where the yield is known and used to derive a storage value. Under these conditions the storage is estimated as follows:

$$Storage = \frac{dMRTo}{100} * YCB\sqrt{\left[\frac{Yield * 100}{dMRTo * fYCAi}\right] - \frac{fYCCi}{fYCAi}} \qquad (2)$$

3.2 Method of Accounting for Upstream Storage

The gross yield is sensitive to the variability and amount of flow as well as the size of the dam. Land and water use activities influence flow characteristics and hence the yield of a dam. If these influences alter the quantity of natural flow without significantly altering the natural variability, then the impact on the yield can be calculated using adjusted MAR values in the dimensionless yield curves. Impacts involving uniform flow rates must, however, be accounted for by direct adjustment of the yield and not by altering the MAR. Distinguishing between activities associated with relatively uniform flow rates and those affecting naturally varying quantities of flow forms an important part of the upgrading of the Water Balance Model.

The “method of accounting for upstream storage“ was derived as part of the development of this model. It is used to determine the total gross yield at the outlet of a system combined with that of the gross yields of the upstream dams. The method can also be applied to dams at outlets of sub-catchments within the flow system. The yield curves used in the system must be representative of the cumulative natural flows at each dam. The accounting procedure is summarized as follows:

> The gross yield contribution of upstream dams, towards the total gross yield of the combined system, can be deduced by plotting the total yield of the upstream dams on the yield curve for the outlet of the system. In this way, the equivalent storage benefit that the upstream dams have towards the system at its outlet can be derived. The storage of the dam at the outlet is then added to the equivalent storage benefit of the upstream dams. This sum represents the equivalent storage that a single dam at the outlet would need to provide a gross yield equal to that of all the dams in the system. This equivalent total storage is plotted on the yield curve for the dam at the outlet of the system in order to derive the total gross yield of the system. The incremental gross yield for the dam at the outlet is the difference between the total yield of system and the combined yields of the upstream dams.

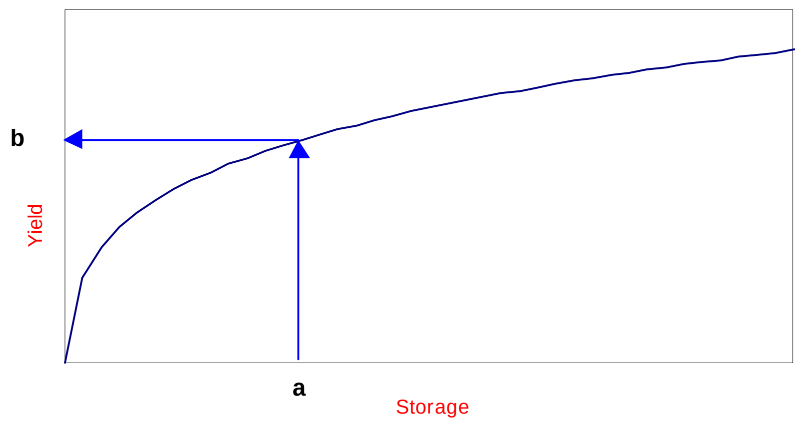
In practice it is necessary to accommodate configurations of multiple dams by accumulating incremental yields while applying the process to dams or sub-catchments in a downstream direction. The method is described in more detail below.

3.2.1 Implementation in Water Balance Model

Gross yield relationships have been established for the cumulative natural flows of all quarternary catchments in South Africa. The incremental and cumulative gross yield totals can therefore be estimated in a downstream sequence using actual dam sizes. If several dams exist within a catchment, their storage values are summed to represent a single hypothetical dam at the catchment outlet. If no dams exist in a quarternary catchment, the storage of the outlet dam is assigned a value of zero and the same procedure is used computationally in the model.

The "method of accounting for upstream storage" is described below by making reference to graphical plots of yield curves. In the model the approach follows the same sequence but equations (1) and (2) are used instead to derive values for yields or equivalent storages as required. The approach is as follows:

(i) Commence at a headwater catchment and, as shown in the diagram below, determine the gross yield (b**)** from the known storage (a) by plotting the values on the graph.



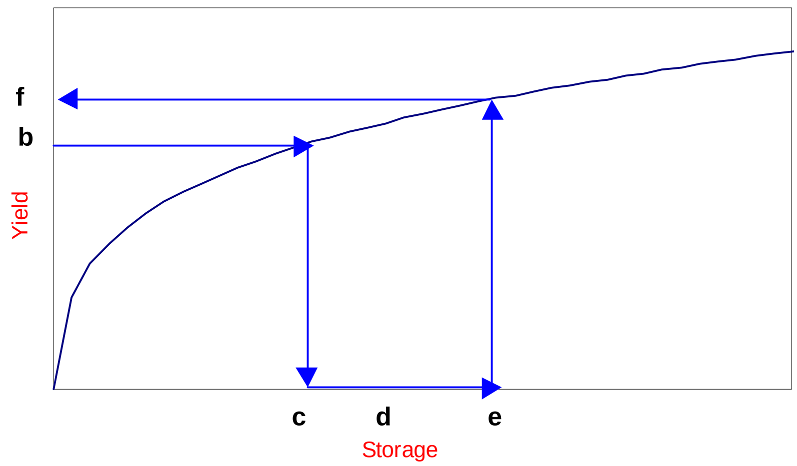
(ii) For the next catchment downstream, combine the yields (b) of all upstream catchments that flow into this catchment.

i.e. $$\mathbf{b} = \mathbf{b_1} + \mathbf{b_2} + \mathbf{b_3} \ldots\ldots\ldots\ldots\ldots \tag{3}$$

Where b = combined gross yields of all upstream quarternary catchments.

b_i = Individual upstream catchment yields.

(iii) Plot yield (b**)** of the upstream dams on the graph for the gross yield of the downstream catchment dam (i.e. outlet dam) to get the equivalent storage (c) of the upstream dam at the downstream dam site. Add the storage (d) of the downstream dam to (c) to get the total effective storage (e) of both dams and use this value to get the total effective yield (f) of the downstream dam combined with that of the upstream dams. The incremental yield of the downstream dam is **f** – **b**.



The process described in steps (ii) and (iii) above is repeated for successive catchments in a downstream direction.

4. YIELD BALANCE

The above method can be used to obtain cumulative and incremental gross yields based on actual dam sizes using "variable" flows from natural surface conditions or from developed surface conditions. The next step in water accounting is to use these yields in a mass balance to account for the additional impacts of activities related to "uniform" flow types. The water balance model is therefore structured to distinguish between:

- those activities that impact directly on surface runoff components whose variability and quantity is reflected in the shape of the yield curve and

- those activities that are associated with relatively uniform flow rates

The method for determining gross yields based on “variable” flows is summarised in figure 1. The gross yield calculated in this figure is further applied in the yield balance as explained in an accompanying paper for this symposium by Watson et al, 1999. In that paper the effects of uniform flow rates on the yield balance are described.

The main inputs shown on figure 1 are the cumulative yields and flows from upstream catchments, the incremental runoff of the catchment under consideration, the reservoir characteristics, the magnitude of the impacts on flow due to of streamflow reduction activities and those of runoff enhancement activities. The relevant calculations involve adjusting incremental flows to account for activities that impact on the amounts of “variable” flow, determining the cumulative mean annual runoff at the dam site and then performing calculations to determine yields in accordance with the “method of accounting for upstream storage”.

The resultant yields and flows are then used in a mass balance to account for all other water demand factors as described in the accompanying paper by Watson et al (1999). The relevant software is described by Wolff-Piggott et al (1999).

Additional details of the modelling procedure and the algorithms describing the hydrology, the water demands, the streamflow reduction activities and runoff enhancement due to urbanisation are included in the User Manual for the Water Balance Model (Watson, Schultz, De Jager, and contributing authors, 1999).

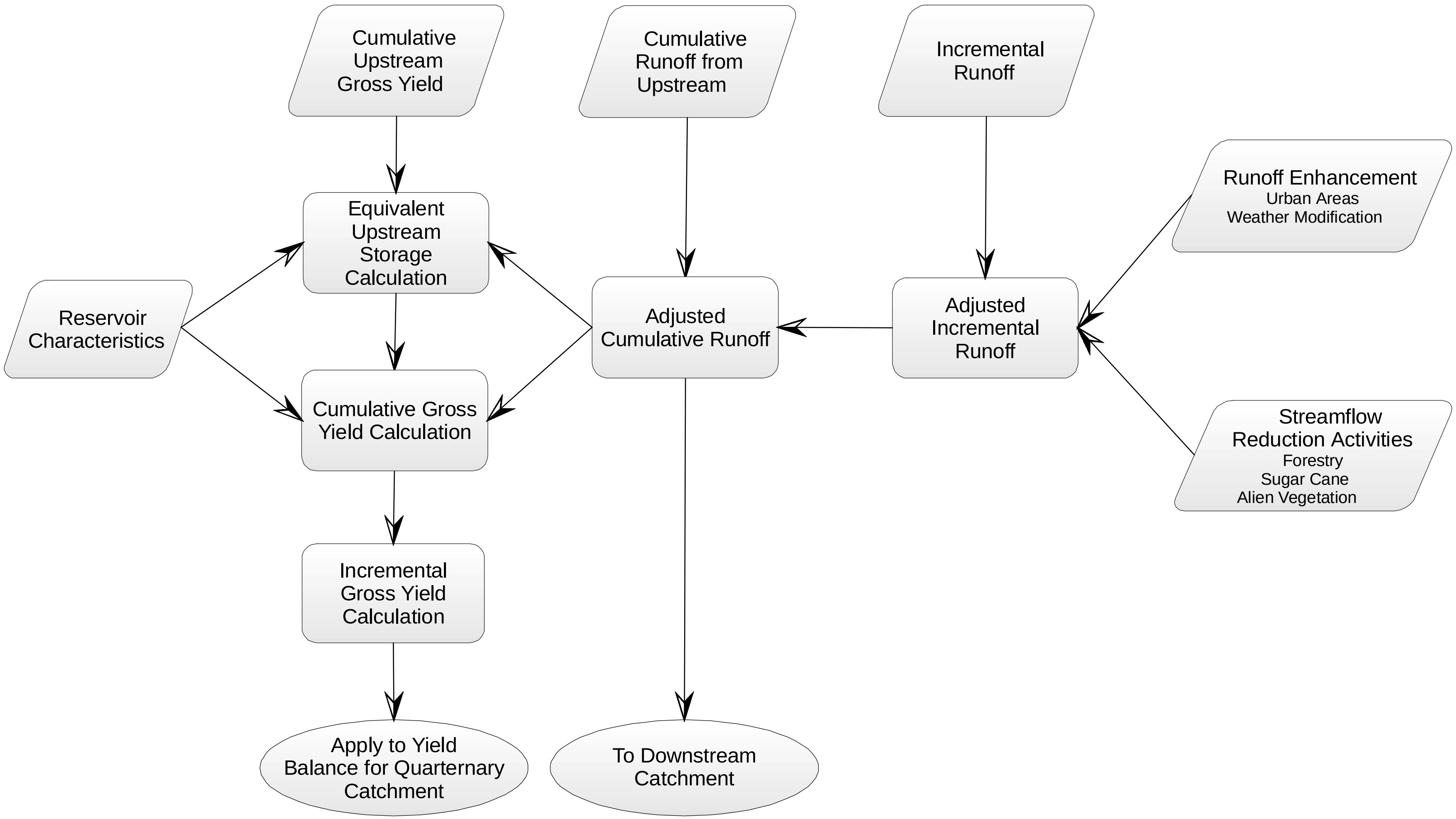


Figure 1: Simplified Flow Diagram for Gross Yield Calculation in Water Balance Model

5. ASSESSMENT OF GROSS YIELD ESTIMATION TECHNIQUE

The method of accounting for the effects of upstream storage, as developed for this project, has never been attempted before by the authors and it is uncertain if it has been attempted elsewhere. Testing was therefore essential prior to implementation of the technique in the model. In order to assess the approach it was necessary to first create sets of yield results which could be assumed to be correct and which would form a basis for comparison.

The WRSM90 model was therefore set up using selected flow files from the SWR90 reports (Midgley et al, 1994). Flow systems were structured to represent a range of hydrological zones between hypothetical dam sites. Yield curves were output from the WR90 model for cumulative natural flow conditions at each dam site. Simulations were then repeated using realistically selected dam sizes and abstracting the full gross yield from each dam. All other losses and land and water use impacts were set at zero in the model inputs. Rainfall onto and evaporation from the dam surfaces was also set at zero. Selected results are given in Table 1 for six hypothetical dams located in the Upper Tugela River Drainage System (Region V11).

Table 1. Comparison of Gross Yield estimates based on the "method of accounting for upstream storage" with results from the WRSM90 Model.

Dam no.	Dam size	Cumulative	Dam size	Cumulative Yield		
		MAR		WRSM90 method	"Method of accounting for upstream Storage"	Differ-ence
	(Mm$^{3)}$	(Mm^3)	(% Cum. MAR)	(Mm^3/a)	(Mm^3/a)	%
1	120	228.6	52.5	129.4	129.6	0.19
2	120	201.8	59.5	135.2	135.2	-0.03
3	600	539.5	111.2	431.9	446.4	3.36
4	800	825.2	96.9	741.0	752	1.48
5	300	901.3	33.3	824.6	813.6	-1.34
6	800	916.0	87.3	871.0	864	-0.80

The results indicate that the "method of accounting for upstream storage" does not precisely duplicate the results of hydrological models. The results for cumulative gross yields are however very similar. "Errors" or "differences" between the two methods are generally more noticeable when dam sizes involve combinations of small and large dams. At this stage a working version of the model forms a basis for further testing prior to finalisation of the method and the algorithms to be used.

6. CONCLUSIONS

Yield curves encompass the results of mathematical simulations of several years of hydrological data. They provide a simple basis from which a mass balance of water resource availability can be done for all catchments in the country. The accuracy is affected by the methodology used to account for upstream impacts. For the "method of accounting for upstream storage" the results are generally within 5% of values produced by hydrological models for simple catchment configurations and results of less than 2% are common. These discrepancies are considered to lie within the accuracy constraints of curve fitting techniques, available hydrological data and the limitations of land and water use information.

The main advantage of the approach is that it provides a basis for summarising, by means of yield curves, the results of several years of hydrological modelling into a single Water Balance Model depicting approximately 2000 catchments.

The methodology developed to account for the effects of upstream dams on the yield of a downstream dam and the strategy of distinguishing between uniform flow rates and variable flow rates is considered to have reduced the main uncertainties associated with the initial proposals for model development.

7. ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank the Department of Water Affairs and Forestry for commissioning the study and for permission to present this paper at the symposium.

8. REFERENCES

DE JAGER FGB and VAN ROOYEN, PG (1999) *Assessment of Storage-Draft-Frequency Characteristics for the Water Balance Model*. Draft report for the Department of Water Affairs and Forestry, Pretoria, South Africa.

GÖRGENS A (1999) *Adjustment of WR90 Naturalised Flows to Allow for Streamflow Reductions Based on the CSIR's Streamflow Reduction Model*. Report for the Department of Water Affairs and Forestry, Pretoria, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994a) *Surface Water Resources of South Africa, Volume I, Drainage Regions A, B - Limpopo-Olifants*, Appendices and Book of Maps. Report No. 298/1.1/94, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994b) *Surface Water Resources of South Africa, Volume II, Drainage Region C - Vaal*, Appendices and Book of Maps. Report No. 298/2.1/94, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994c) *Surface Water Resources of South Africa, Volume III, Drainage Regions D, F – Orange Namaqualand*, Appendices and Book of Maps. Report No. 298/3.1/94, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994d) *Surface Water Resources of South Africa, Volume IV, Drainage Regions E, G, H, J, K – Western Cape*, Appendices and Book of Maps. Report No. 298/4.1/94, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994e) *Surface Water Resources of South Africa, Volume V, Drainage Regions M, N, P, Q, R, S, T – Eastern Cape*, Appendices and Book of Maps. Report No. 298/5.1/94, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

MIDGLEY DC, PITMAN WV and MIDDLETON BJ (1994f*) Surface Water Resources of South Africa, Volume VI, Drainage Regions U, V, W, X – Eastern Escarpment, Appendices and Book of Maps. Report No. 298/6.1/94*, Water Research Commission, University of Witwatersrand, Johannesburg, South Africa.

PITMAN WV, BARTA B and WATSON MD (April, 1998) *National Water Balance Model*. Proposal by SSI to the Department of Water Affairs and Forestry, Pretoria, South Africa.

SCOTT, DF and LE MAITRE, DC (1994) *A Synthesis of Afforestation Impacts on Streamflow*. Report for the Department of Water Affairs and Forestry, Pretoria, South Africa.

WATSON MD, DE JAGER FGB, MCKENZIE RS and SCHULTZ CB (1999) *Water Balance Model: Overview of Latest Development.* Department of Water Affairs and Forestry, Pretoria, South Africa.

WATSON MD, SCHULTZ CB, DE JAGER FGB and CONTRIBUTING AUTHORS (1999) *National Water Balance Model: User Manual.* Department of Water Affairs and Forestry, Pretoria, South Africa.

WATSON MD, PITMAN WV and BARTA B (1997) *National Water Balance Model.* 8th South African National Hydrological Symposium, Pretoria, South Africa.

WOLFF-PIGGOTT B, STRYDOM CJ, DE VILLIERS E, and WATSON MD (1999) *Water Balance Model : Software Structure Design and Development.* Paper for the Ninth South African Hydrology Symposium: 29 –30 November 1999, University of the Western Cape, Cape Town.

APPENDIX H.2

DATA SOURCES AND DEFAULT VALUES USED IN THE WRSA REPORTS

APPENDIX H.2

DATA SOURCES

Data Type	Responsible Organisation
Afforestation	CSIR
Alien vegetation	CSIR
Industrial, urba 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 - Efficency and losses - Evapotraspiration and crop factors	 WRSA Consultant WRSA Consultant WRP
Storage-draft-frequency curves	WRP

DATA DEFAULT VALUES USED IN THE WRSA REPORT

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**

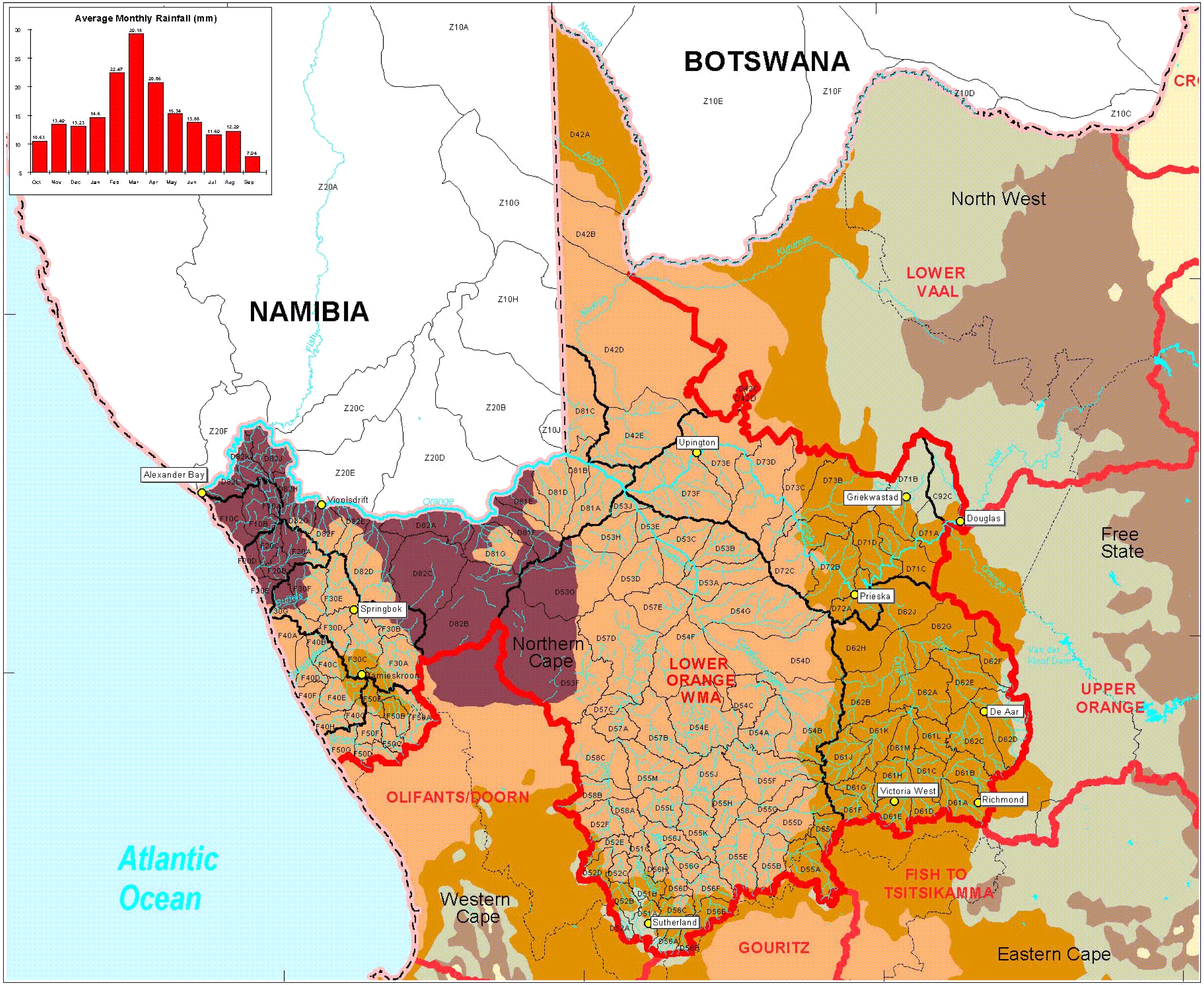
FIGURES

BOTSWANA
NAMIBIA
LIMPOPO
Northern Province
CROCODILE(WEST) AND MARICO
OLIFANTS
Mpumalanga
Gauteng
LOWER VAAL
North West
MIDDLE VAAL
UPPER VAAL
THUKELA
Free State
Kwazulu Natal
LOWER ORANGE
Northern Cape
UPPER ORANGE
LESOTHO
MVOTI TO UMZIMKULU
MZIMVUBU TO KIESKAMMA
Eastern Cape
FISH TO TSITSIKAMMA
GOURITZ
Western Cape
BERG
OLIFANTS/DOORN
Atlantic Ocean
Indian Ocean
Lichtenburg
Coligny
Germiston
Balfour
Heidelberg
Klerksdorp
Orkney
Amersfoort
Kuruman
Kroonstad
Welkom
Christiana
Bethlehem
Harrismith
Upington
Kimberley
Ficksburg
Griekwastad
Douglas
Bloemfontein
Alexander Bay
Pofadder
Maseru
Springbok
Prieska
Fauresmith
De Aar
Aliwal-North
Victoria West
Richmond
Sutherland
Orange
Molopo
Nossob
Kuruman
Harts
Vaal
Riet
Modder
Fish
Caledon
Kraai
Sak
Brak
Seekoei
19°
24°
29°
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
Quaternaries inside Orange R. catchment
Study Area
GIS COV:
Newtownspes
Intebnd2
Prov0897
OVC_boundary
WMA_new
WMA_new
OVC_Mainriv
OVC_catch
lowma
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 5 000 000
N
50 0 50 100 Kilometers
TITLE:
LOWER ORANGE WMA
ORANGE RIVER WATERCOURSE
Prepared by: S. Schwabe
Date: September 2001
Data Type: PVO24044_ch2_1.apr
Figure 2.1.1


BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Richtersveld
Alexander Bay
Springbok
Augrabies
Kakamas
Upington
Groblershoop
Boegoeberg
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Molopo
Kuruman
Vaal
Hartbees
Brak
Ongers
Carnarvonleegte
Sak
Fish
Buffels
Swartlintjies
Spoeg
Groen
Renoster
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Rivers in Order of Size
1
2
3
4
5
6
7
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
Rivall
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
THE STUDY AREA
Prepared by: S. Schwabe
Date: February 2002
Data Type: PVO24044_ch2_1.apr
Figure 2.1.2

NAMIBIA
BOTSWANA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
GOURITZ
FISH TO TSITSIKAMMA
Eastern Cape
Atlantic Ocean
Alexander Bay
Richtersveld
Springbok
Augrabies
Kakamas
Upington
Groblershoop
Boegoeberg
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Elevation (m)
0 - 400
401 - 800
801 - 1200
1201 - 1600
1601 - 2000
2001 - 2400
2401 - 2800
Endoreic Areas
Local
Global
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
TOPOGRAPHY AND RIVER CATCHMENTS
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch2_1.apr
Figure 2.1.3

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
Western Cape
Eastern Cape
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Atlantic Ocean
Alexander Bay
Richtersveld
Springbok
Augrabies
Kakamas
Upington
Groblershoop
Boegoeberg
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Vaal
Molopo
Kuruman
Sak
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Secondary Catchment Areas
Vaal
Molopo
Sak
Ongers / Brak
Orange
Orange Downstream
Holgat
Kamma
Buffels
Swartlintjies
Groen
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
HYDROLOGICAL SUB-CATCHMENTS
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch2_1.apr
Figure 2.1.4



LOCALITY MAP:

BASE MAP LEGEND:

- Main Towns
- International Boundaries
- Provincial Boundaries
- WMA Boundaries
- Secondary Catchments
- Quaternary Catchments
- Rivers

Mean Annual Precipitation

- < 100 mm
- 100 - 200 mm
- 200 - 300 mm
- 300 - 400 mm
- 400 - 500 mm
- 500 - 600 mm
- 600 - 700 mm

GIS COV:

Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
Rivall
Rip

NOTE: The high rainfall in the Kamiesberg is not shown due to the map scale.

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TEL NO (012) 460-1606

CLIENT:

Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE: 1: 3 500 000

40 0 40 80 Kilometers

N

TITLE:

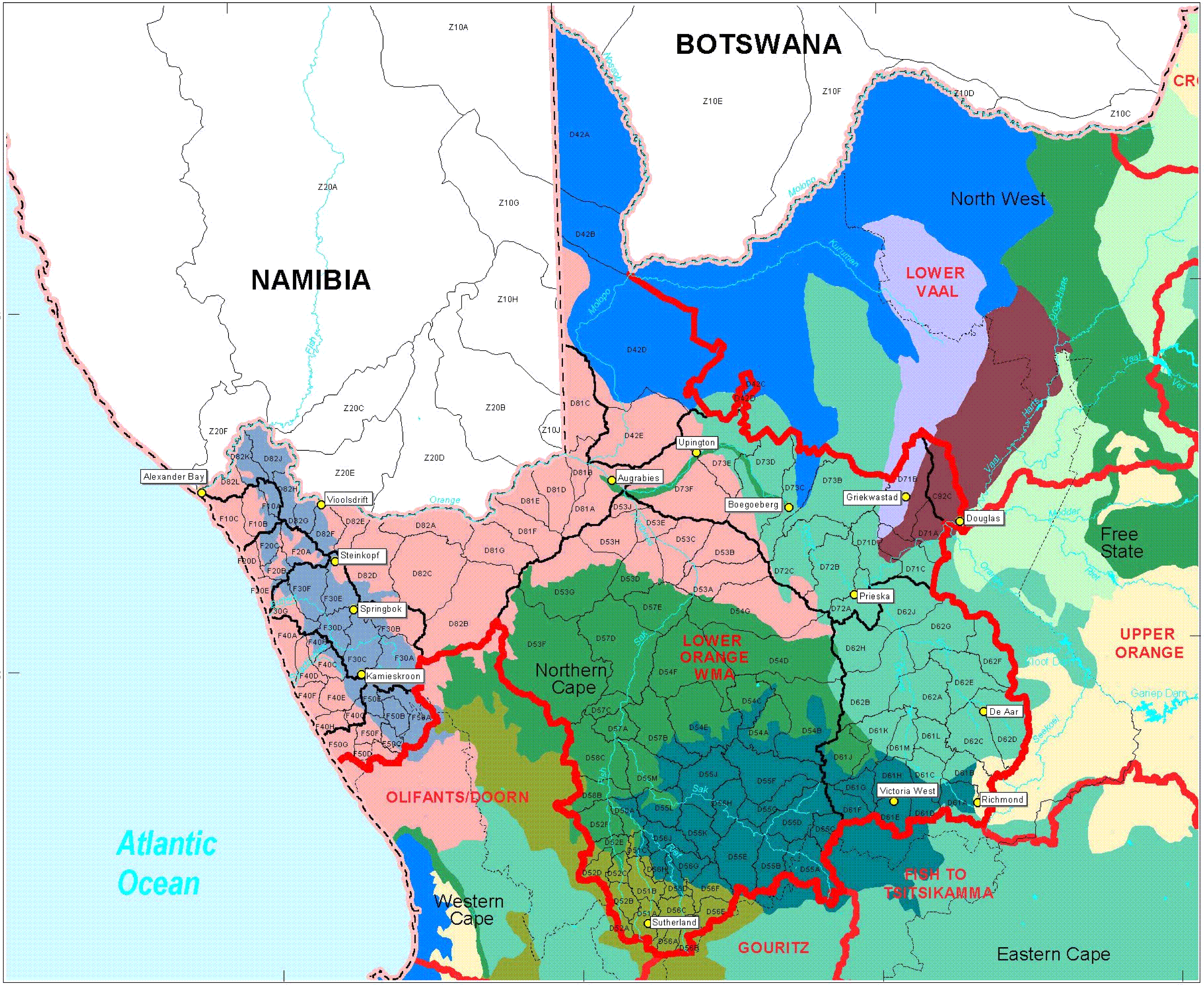
LOWER ORANGE WMA

MEAN ANNUAL PRECIPITATION

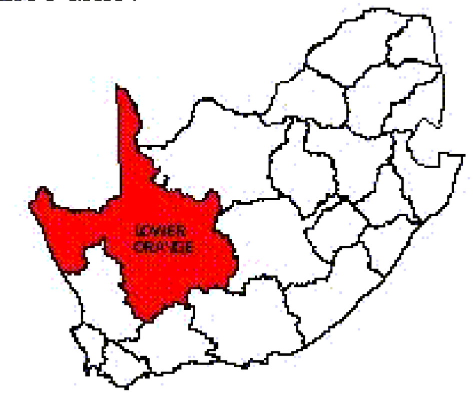
Prepared by:	S. Schwabe	Figure 2.2.1
Date:	February 2002	
Data Type:	PVO24044_ch2_2.apr	

NAMIBIA
BOTSWANA
Atlantic Ocean
North West
Free State
Northern Cape
Western Cape
Eastern Cape
LOWER VAAL
LOWER ORANGE WMA
UPPER ORANGE
OLIFANTS/DOORN
GOURITZ
FISH TO TSITSIKAMMA
Alexander Bay
Springbok
Upington
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Evaporation Contours
Mean Annual Evaporation (S-Pan)
1600 - 1700
1700 - 1800
1800 - 2000
2000 - 2200
2200 - 2400
> 2600
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
MEAN ANNUAL EVAPORATION
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch2_2.apr
Figure 2.2.2

NAMIBIA
BOTSWANA
North West
LOWER VAAL
CROCO
UPPER ORANGE
Free State
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Port Nolloth
Springbok
Upington
Griekwastad
Douglas
Kimberley
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
Molopo
Nossob
Vaal
Fish
Buffels
Hartbees
Sak
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Geology
Acid and intermediate lavas
Acid, intermediate or alkaline intrusives
Assemblage of compact sedimentary and extrusive rocks
Assemblage of compact sedimentary extrusive and intrusive rocks
Compact arenaceous and argillaceous strata
Compact sedimentary strata
Compact, dominantly arenaceous strata
Compact, dominantly argillaceous strata
Dolomite, chert and subordinate limestone
Mafic / basic lavas
Mainly compact tillite and shale. (Dwyka Formation and Ecca Group)
Mainly compact tillite, shale and sandstone. (Dwyka Formation and Ecca Group)
Mainly compact tillite. (Dwyka Formation)
Porous unconsolidated to semi-consolidated sediment
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Geoll
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
GEOLOGY
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch2_2.apr
Figure 2.3.1



LOCALITY MAP:



BASE MAP LEGEND:	GIS COV:
Main Towns	Newtownspes
International Boundaries	Intebnd2
Provincial Boundaries	Prov0897
Lower Orange WMA	WMA_new
Secondary Catchments	Drgnsnd
Quaternary Catchments	Drgnquat
Main Rivers	OVC_Mainriv
Dams	Ndams
Soils	Soilgrps

	Depth	**Texture**	**Relief**
B	Moderate to Deep	Sandy	Undulating
C	Moderate to Deep	Sandy	Steep
D	Shallow	Sandy	Flat
I	Moderate to Deep	Clay Loam	Undulating
J	Moderate to Deep	Clay Loam	Flat
K	Moderate to Deep	Sandy Loam	Steep
L	Moderate to Deep	Sandy Loam	Undulating
M	Moderate to Deep	Sandy Loam	Flat
N	Shallow	Sandy Loam	Undulating
P	Shallow	Sandy	Undulating
Q	Moderate to Deep	Sandy	Flat

PREPARED BY:

V3 CONSULTING ENGINEERS
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PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606

CLIENT:

Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE: 1: 3 500 000

50 0 50 100 Kilometers

N

TITLE:

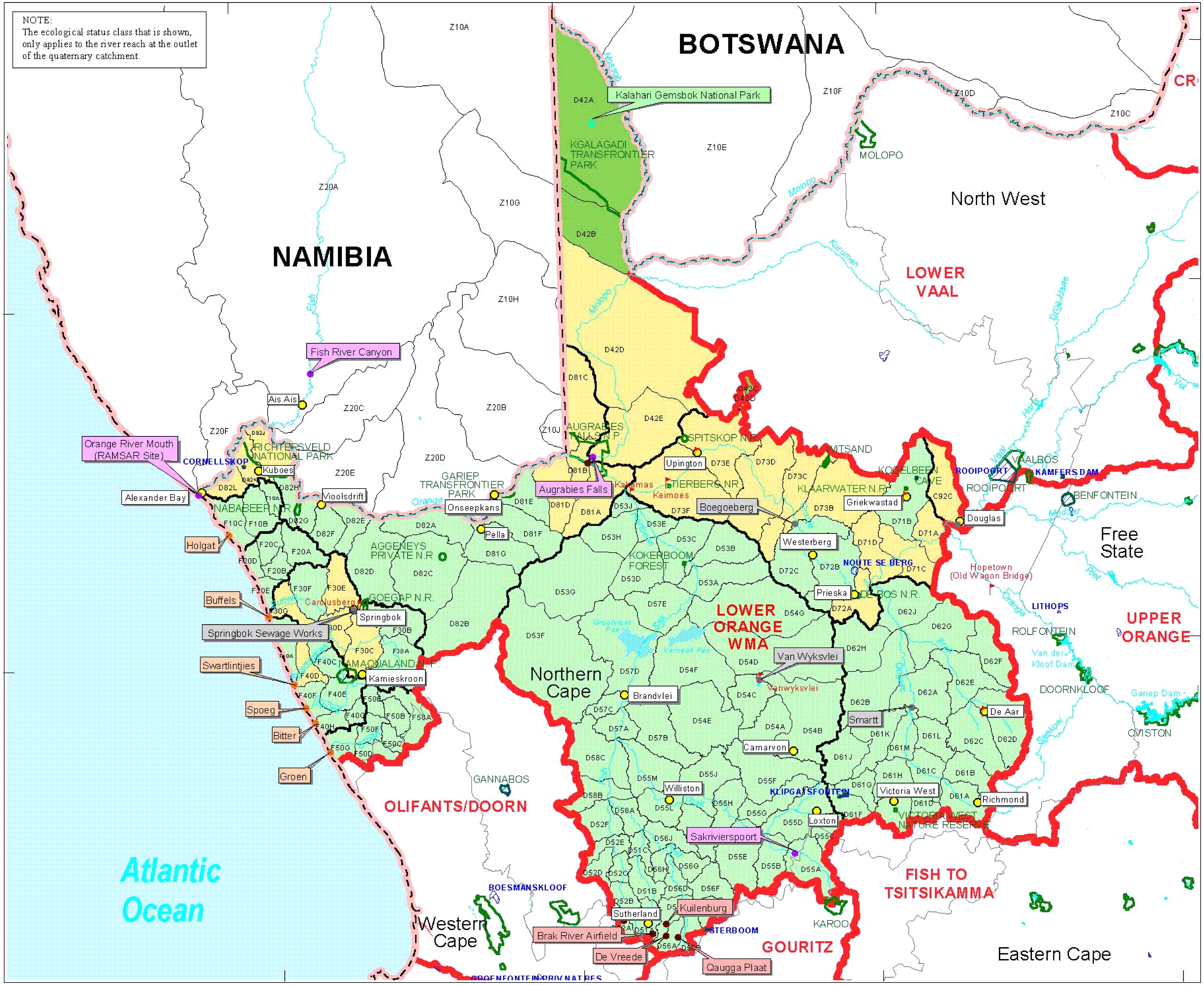
LOWER ORANGE WMA

SOILS

Prepared by:	S. Schwabe	**Figure 2.4.1**
Date:	September 2001	
Data Type:	PVO24044_ch2_2.apr	


BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
Western Cape
Eastern Cape
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
CR
Atlantic Ocean
Upington
Griekwastad
Douglas
Prieska
Alexander Bay
Springbok
Garies
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Vaal
Kuruman
Molopo
Nossob
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Natural Vegetation
False Karoo
Karoo and Karroid
Sclerophyllous Bush
Tropical Bush and Savanna
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Acocks
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
50 0 50 100 Kilometers
N
TITLE:
LOWER ORANGE WMA
NATURAL VEGETATION
Prepared by: S. Schwabe
Date: September 2001
Data Type: PVO24044_ch2_5.apr
Figure 2.5.2.1


BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Springbok
Upington
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
Vaal
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Nature Reserve Boundaries
Default Ecological Management Class
Class B: Largely Natural
Class C: Moderately Modified
Class D: Largely Modified
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Consgeo
NOTE:
The ecological management class that is shown, only applies to the river reach at the outlet of the quaternary catchment.
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
N
Kilometers
TITLE:
LOWER ORANGE WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Prepared by: S. Schwabe
Date: March 2002
Data Type: PVO24044_ch2_5.apr
Figure 2.6.3.1



LOCALITY MAP:

BASE MAP LEGEND:

	GIS COV:
Main Towns	Newtownspes
International Boundaries	Intebnd2
Provincial Boundaries	Prov0897
Lower Orange WMA	WMA_new
Secondary Catchments	Drgsnd
Quaternary Catchments	Drgnquat
Rivers	OVC_Mainriv
Dams	Ndams

Present Ecological Status Class

- Class A: Unmodified, Natural
- Class B: Largely Natural
- Class C: Moderately Modified

Ecologically Sensitive Sites

- Lacustrine
- Riverine
- Palustrine
- Estuarine
- Manmade
- Sites of Historical and Cultural Interest
- Heritage Sites
- Pans
- Nature Reserve Boundaries — Consgeo

PREPARED BY:

V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606

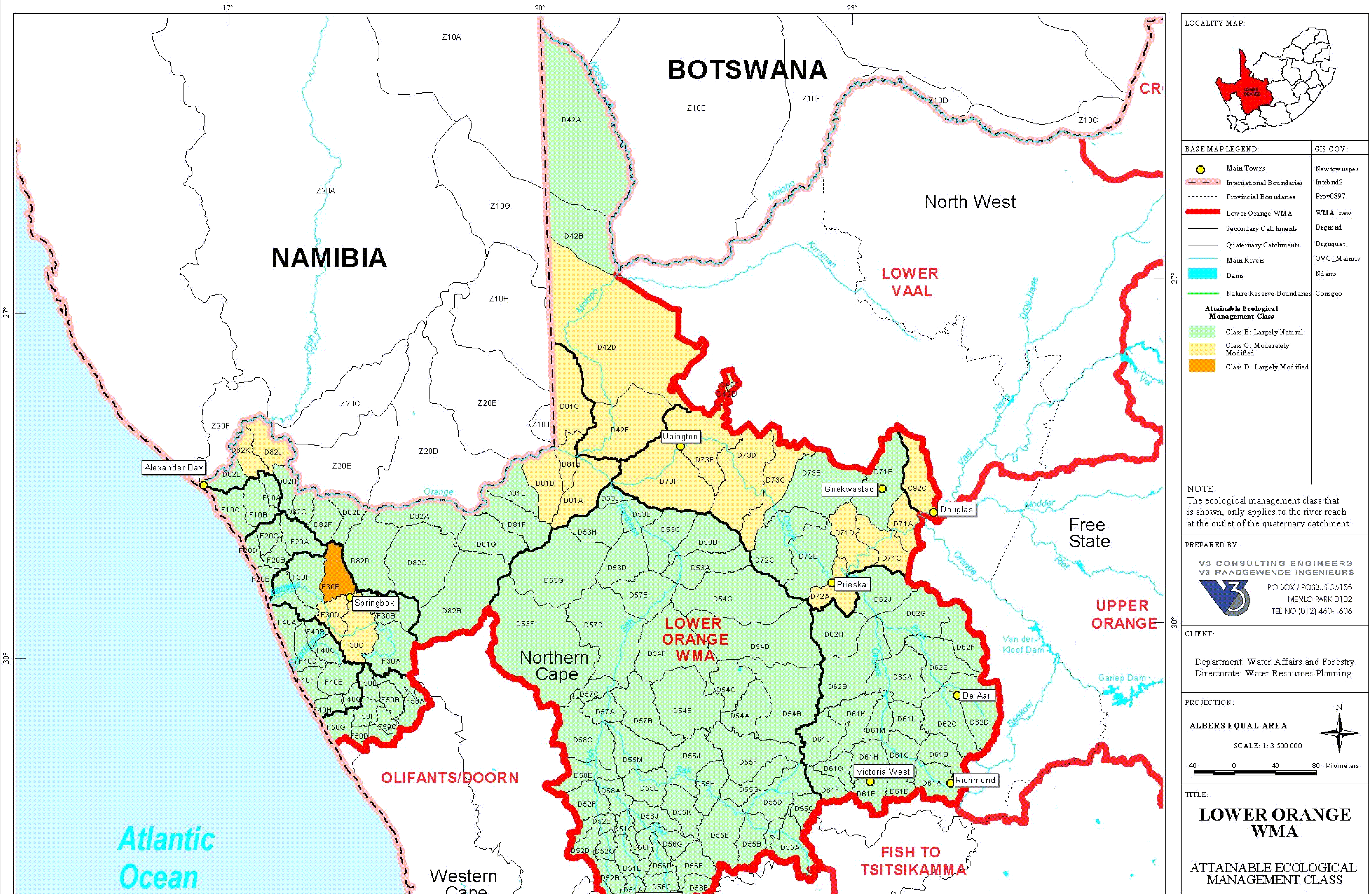
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:3 500 000
40 0 40 80 Kilometers

TITLE:
LOWER ORANGE WMA

PRESENT ECOLOGICAL STATUS CLASS, ECOLOGICALLY SENSITIVE SITES AND SITES OF HISTORICAL AND CULTURAL INTEREST

Prepared by:	S. Schwabe	**Figure 2.6.3.2**
Date:	February 2002	
Data Type:	PVO24044_ch2_5.apr	



TITLE:

LOWER ORANGE WMA

ATTAINABLE ECOLOGICAL MANAGEMENT CLASS

Prepared by:	S. Schwabe
Date:	March 2002
Data Type:	PVO24044_ch2_5.apr

Figure 2.6.3.3


BOTSWANA
NAMIBIA
Namibia
Nossob-Molopo
North West
LOWER VAAL
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Ongers
Sak-Hartbees
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Karasburg
Aussenkehr
Alexander Bay
Vioolsdrift
Onseepkans
Port Nolloth
Kleinsee
Springbok
Aggeneys
Pofadder
Kamieskroon
Garies
Augrabies
Kakamas
Upington
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Vaal
Kuruman
Molopo
Nossob
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Drainage Areas
Sak-Hartbees
Ongers
Neusberg
Vioolsdrift
Alexander Bay
Nossob-Molopo
Boegoeberg
Coastal
Namibia
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
DRAINAGE AREAS
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_1.apr
Figure 3.1.1

BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Ongers
Sak - Hartbees
LOWER ORANGE WMA
LOWER VAAL
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Upington
Groblershoop
Griekwastad
Douglas
Prieska
Hopetown
Alexander Bay
Springbok
Okiep
Aggeneys
De Aar
Victoria West
Richmond
Sutherland
Orange
Vaal
Molopo
Nossob
Kuruman
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Dams
Main Rivers
Population
Urban
Rural
Population Size
50 000
100 000
150 000
GIS COV:
Newtowrspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
Lowma_drainage
Ndams
OVC_Mainriv
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
N
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
POPULATION DISTRIBUTION BY DRAINAGE AREA
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_2.apr
Figure 3.2.4.1


BOTSWANA
NAMIBIA
Atlantic Ocean
North West
Northern Cape
Western Cape
Eastern Cape
Free State
KALAHARI
BENEDE-ORANJE
DIAMANTVELD
NAMAQUALAND
HANTAM
BO-KAROO
LOWER VAAL
LOWER ORANGE WMA
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Alexander Bay
Springbok
Namaqualand
Upington
Gordonia
Kenhardt
Griekwastad
Hay
Douglas
Kimberley
Herbert
Jacobsdal
Barkly West
Hartswater
Taung
Postmasburg
Kuruman
Kudumane
Ganyesa
Vryburg 1
Molopo
Prieska
Hopetown
Faursmith
Philipstown
De Aar
Britstown
Colesberg
Hanover
Noupoort
Richmond
Victoria West
Middelburg
Murraysburg
Graaff-Reinet
Aberdeen
Beaufort West
Fraserburg
Sutherland
Williston
Carnarvon
Calvinia
Van Rhynsdorp
Vredendal
Clanwilliam
Piketberg
Van der Kloof Dam
Gariep Dam
Orange
Molopo
Z10A
Z10C
Z10D
Z10E
Z10F
Z10G
Z10H
Z10J
Z20A
Z20B
Z20C
Z20D
Z20E
Z20F
17°
20°
23°
26°
27°
30°
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
District Council Seats
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Magisterial District Boundaries
Newtowrupes
Newtown
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Mag96ge
Nesadc2
1995 District Councils
BENEDE-ORANJE
BO-KAROO
DIAMANTVELD
HANTAM
KALAHARI
NAMAQUALAND
NOTE:
The District Council Boundaries shown here are those prior to the current boundaries which took effect from July 2000
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS (1995)
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_2.apr
Figure 3.4.9.1

BOTSWANA
NAMIBIA
Atlantic Ocean
North West
Northern Cape
Western Cape
Eastern Cape
Free State
SIYANDA
KGALAGADI
FRANCES BAARD
NAMAKWA
KAROO
LOWER VAAL
LOWER ORANGE
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Upington
Alexander Bay
Springbok
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Gordonia
Kenhardt
Postmasburg
Kuruman
Kudumane
Ganyesa
Vryburg 1
Molopo
Taung
Hartswater
Barkly West
Kimberley
Jacobsdal
Herbert
Hay
Hopetown
Fauresmith
Prieska
Philipstown
Britstown
De Aar
Colesberg
Hanover
Carnarvon
Victoria West
Richmond
Noupoort
Middelburg
Murraysburg
Graaff-Reinet
Beaufort West
Aberdeen
Fraserburg
Sutherland
Williston
Calvinia
Van Rhynsdorp
Vredendal
Clanwilliam
Piketberg
Namaqualand
Orange
Molopo
Kuruman
Harts
Vaal
Z10A
Z10E
Z10F
Z10D
Z10C
Z20A
Z10G
Z10H
Z20C
Z20B
Z20F
Z10J
Z20D
Z20E
17°
20°
23°
26°
27°
30°
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Rivers
Dams
Magisterial District Boundaries
Newtowrspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
Rivall
Ndams
Mag96ge
New District Councils
Siyanda
Frances Baard
Kgalagadi
Karoo
Namakwa
Note:
The new District Council boundaries do not necessarily coincide with the magisterial district boundaries as was the case in 1995
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
N
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS (CURRENT)
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_2.apr
Figure 3.4.9.2

BOTSWANA
NAMIBIA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Kalahari West WB
Karos-Geelkoppen WB
Pella WB
Namakwa WB
RICHTERSVELD
Alexander Bay
STEINKOPF
CONCORDIA
Springbok
KOMAGGAS
LELIEFONTEIN
PELLA
POFADDER
KENHARDT
GROBLERSHOOP
Upington
UPINGTON
GORDONIA
Griekwastad
Douglas
NIEKERKSHOOP
MARYDALE
Prieska
STRYDENBURG
BRITSTOWN
De Aar
VAN WYKSVLEI
VOSBURG
BRANDVLEI
CARNARVON
Victoria West
Richmond
LOXTON
WILLISTON
FRASERBURG
Sutherland
Onseepkans Irrigation Area
Namakwaland Irrigation Area
Kakamas Irrigation Area
Upington Irrigation Area
Boegoeberg Dam Irrigation Area
Lower Vaal Irrigation Area
Middle Orange Irrigation Area
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
GIS COV:
Main Towns — Newtownspes
International Boundaries — Intebnd2
Provincial Boundaries — Prov0897
WMA Boundaries — WMA_new
Secondary Catchments — Drgnsnd
Quaternary Catchments — Drgnquat
Main Rivers — OVC_Mainriv
Dams — Ndams
Waterboard Boundaries — Waterb
Transitional Local Council — Ncsalc2
Transitional Regional Council — sarc_geo
Irrigation Areas
Waterboard Areas — Waterb
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_2.apr
Figure 3.4.10

BOTSWANA
NAMIBIA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
CROCO AND
Upington
Alexander Bay
Griekwastad
Douglas
Prieska
Springbok
De Aar
Victoria West
Richmond
Calvinia
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
District Council Seats
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Dams
Main Rivers
Land Use
Afforestation
Dryland
Sugar Cane
Irrigation
Total Land Use (km²)
30 km²
150 km²
300 km²
NOTE:
Refer to Figure 3.7.1 for the location of active mines
GIS COV:
Newtownspes
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
drainage_lowma
Ndams
OVC_Mainriv
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
LAND USE
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_5.apr
Figure 3.5.1.1

BOTSWANA
NAMIBIA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Upington
Griekwastad
Douglas
Prieska
Springbok
De Aar
Victoria West
Richmond
Sutherland
Alexander Bay
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Rivers
Dams
Livestock
Game
Livestock and Game Quantity (ELSU's)
50 000
150 000
250 000
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
LIVESTOCK AND GAME NUMBERS
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch3_5.apr
Figure 3.5.4.1


BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
Western Cape
Eastern Cape
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Atlantic Ocean
Upington
Griekwastad
Douglas
Prieska
Springbok
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Kuruman
Molopo
Nossob
Orange
Vaal
Modder
Riet
Seekoei
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Drainage Areas
Main Rivers
Dams
Condensed Areas of Alien Vegetation (km²)
30
350
700
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
drainage_lowma
OVC_Mainriv
Ndams
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
ALIEN VEGETATION INFESTATION
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_5.apr
Figure 3.5.6.1

NAMIBIA
BOTSWANA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
ALEXKOR MINE (alluvial diamonds)
BLACK MOUNTAIN MINE (lead)
Springbok
O'OKIEP COPPER MINE
KLEINZEE DIAMOND MINE
HONDEKLIPBAAI MINE (alluvial diamonds)
Upington
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
Molopo
Kuruman
Nossob
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Mines
Active Mines
Mines of economic importance to the region
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Note:
Small alluvial diamond mines are found along the Orange River.
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
MINES
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch3_5.apr
Figure 3.7.1

NAMIBIA
BOTSWANA
Namibia
Nossob - Molopo
North West
LOWER VAAL
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
LOWER ORANGE WMA
Northern Cape
Free State
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Sendelingsdrift
Alexander Bay
Aussenkehr
Port Nolloth
Kleinsee
Steinkopf
Springbok
Nababeep
Okiep
Garies
Aggeneys
Pofadder
Onseepkans
Mier
Upington
Kakamas
Keimoes
Kenhardt
Griekwastad
Douglas
Kimberley
Prieska
Hopetown
Brandvlei
Carnarvon
Williston
Fraserburg
Sutherland
Victoria West
Richmond
De Aar
Karos-Geelkoppen Rural WSS
Kalahari West Rural WSS
Pelladrift WSS
Springbok Regional WSS
Vioolsdrift - Noord Oewer
Vioolsdrift Irrigation Area
Namakwaland Irrigation Area
Onseepkans Irrigation Area
Kakamas Irrigation Area
Upington Irrigation Area
Boegoeberg Dam
Boegoeberg Dam Irrigation Area
Douglas Irrigation Area
Middle Orange Irrigation Area
Alexander Bay Irrigation Area
Van der Kloof Dam
Gariep Dam
Smartt Syndicate Dam
Loxton
Orange
Molopo
Nossob
Kuruman
Vaal
Modder
Riet
Seekoei
Hartbees
Sak
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Main Rivers
Dams
Water Supply Schemes
Canal
Pipelines
Irrigation Areas
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
WATER RELATED INFRASTRUCTURE
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch4.apr
Figure 4.1.1

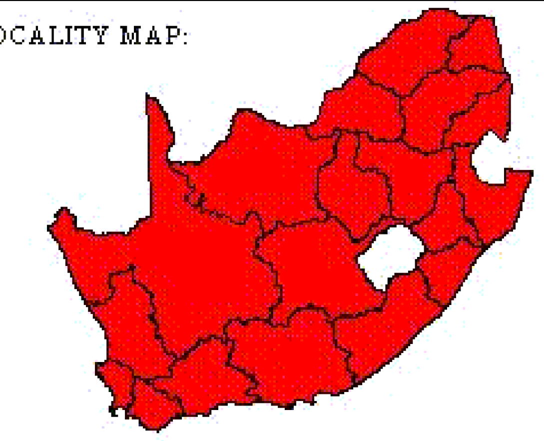
BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Coastal
Vioolsdrift
Neusberg
Boegoeberg
Ongers
Sak - Hartbees
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
Western Cape
Eastern Cape
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
CROCO AND
Atlantic Ocean
Sendelingsdrift 9.200
Noord Oewer 31.400
Alexander Bay to Port Nolloth 0.670
Vioolsdrift 22.400
Pelladrift WSS 3.000
Pelladrift WSS 1.286
Pelladrift WSS 0.874
Springbok Regional WSS 0.080
Springbok Regional WSS 0.190
Springbok Regional WSS 0.615
Springbok Regional WSS 1.850
Neusberg North 234.900
Neusberg South 214.800
Kalahari West Rural WSS 0.420
Karos - Geelkoppen Rural WSS 0.042
Gariep Settlement 63.070
Noord Oranje Irrigation Board 63.070
Upington Main 312.2
Rouxville West Scheme 12.620
Boegoeberg-Karos 84.520
Rosh Pinah
Aussenkehr
Karasburg
Onseepkans
Pofadder
Aggeneys
Springbok
Kleinsee
Port Nolloth
Kamieskroon
Upington
Kakamas
Augrabies
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Main Rivers
Dams
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
drainage_lowma
OVC_Mainriv
Ndams
Total Water requirements at 1:50 Year Assurance ($10^6m^3/a$)
0.01 - 0.5
0.5 - 2
2 - 5
5 - 10
10 - 50
50 - 100
100 - 250
Water Transfers
Irrigation
Mine Bulk User
Urban
Name 12.620
Name of Transfer Units in $10^6m^3/a$
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
TOTAL EQUIVALENT WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE 1995
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch5_1.apr

Figure 5.1.1

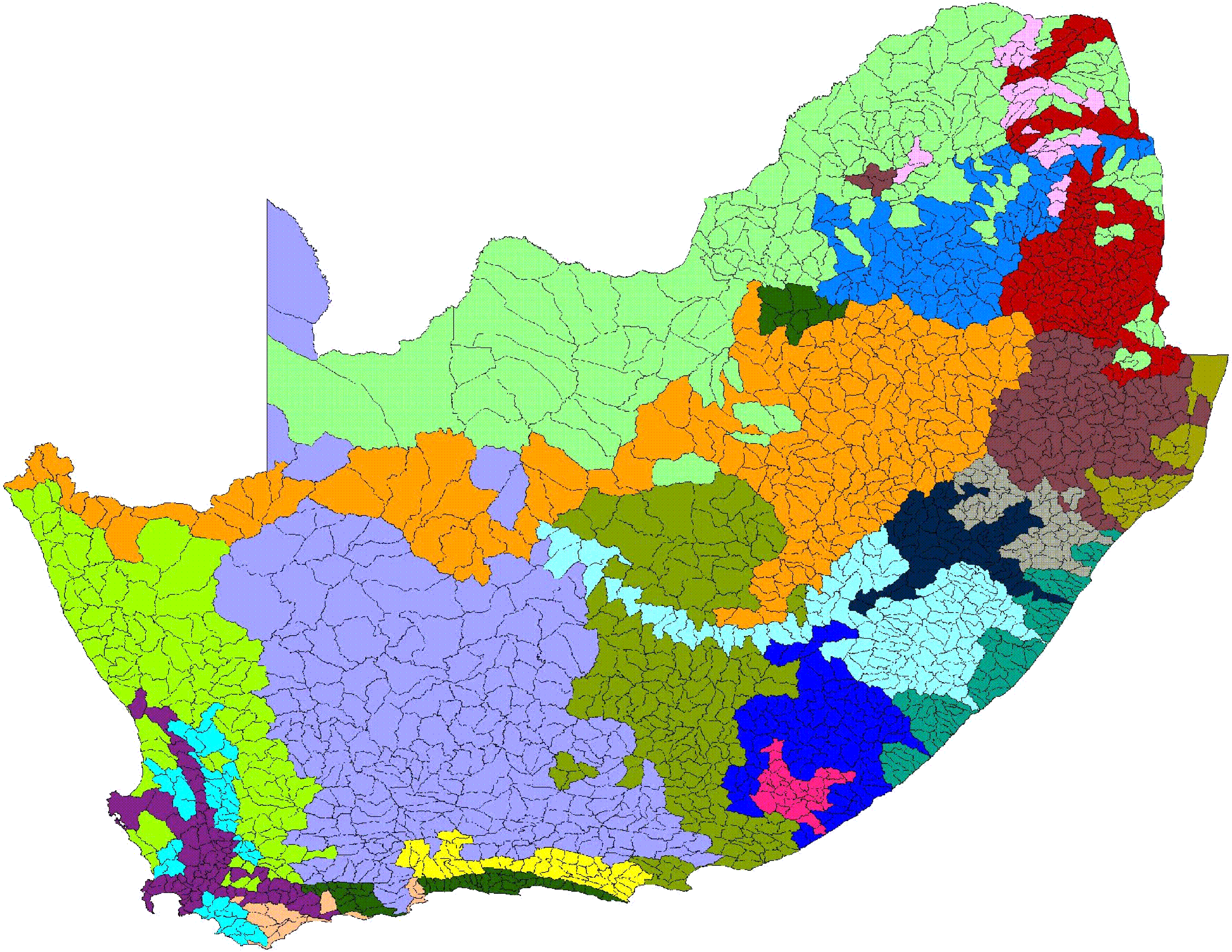

BOTSWANA
NAMIBIA
Atlantic Ocean
North West
Free State
Northern Cape
Western Cape
Eastern Cape
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Onseepkans
Karasburg
Port Nolloth
Kleinsee
Springbok
Aggeneys
Pofadder
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Kuruman
Orange
Vaal
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Water Use (10⁶m³/a)
0 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
2 - 4
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgmsnd
Drgmquat
OVC_Mainriv
Ndams
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
WATER USE BY ALIEN VEGETATION IN 1995
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch5_9.apr
Figure 5.11.1

LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Darinage Areas
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
User Groups
Water Transfers
Alien Vegetation
Irrigation
Bulk
Ecological Reserve
River Losses
Domestic
Total Water Requirements
50
250
500
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
WATER REQUIREMENTS AT EQUIVALENT ASSURANCE PER USER SECTOR 1995
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch5_1.apr
Figure 5.1.2
BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
North West
Free State
Northern Cape
Western Cape
Eastern Cape
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Atlantic Ocean
Rosh Pinah
Karasburg
Aussenkehr
Alexander Bay
Vioolsdrift
Onseepkans
Pofadder
Aggeneys
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Orange
Kuruman
Molopo
Nossob
Vaal
Van der Kloof Dam
Gariep Dam

LOCALITY MAP:



BASE MAP LEGEND: GIS COV:



LEGEND

- 1: Western Cape (wet)
- 2: Western Cape (dry)
- 3: Western Karoo
- 4: Eastern Karoo
- 5: Southern Cape (dry)
- 6: Southern Karoo
- 7: Southern Cape (wet)
- 8: Eastern Cape (arid)
- 9: Eastern Cape
- 10: Amatole
- 11: T Drainage Region
- 12: T Drainage Region (coast)
- 13: Drakensberg
- 14: Southern Natal
- 15: Northern Natal
- 16: Zululand
- 17: Eastern Escarpment
- 18: Lowveld
- 19: Eastern Foothills
- 20: Vaal
- 21: Olifants

Map Courtesy of DWAF

PREPARED BY:

V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606

CLIENT:

Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE: 1: 6 000 000

N

(coast)

TITLE:

LOWER ORANGE WMA

DESKTOP RESERVE PARAMETER REGIONS

Prepared by:	
Date:	January 2002
Data Type:	PVO24044_ch5_1.apr

Figure 5.2.1.1


BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Ongers
Sak - Hartbees
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Karasburg
Rosh Pinah
Aussenkehr
Onseepkans
Pofadder
Aggeneys
Vioolsdrift
Alexander Bay
Port Nolloth
Springbok
Kleinsee
Kamieskroon
Garies
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns — Newtownspes
International Boundaries — Intebnd2
Provincial Boundaries — Prov0897
Lower Orange WMA — WMA_new
Drainage Areas — drainage_lowma
Secondary Catchments — Drgnsnd
Quaternary Catchments — Drgnquat
Main Rivers — OVC_Mainriv
Dams — Ndams
Ecological Reserve Requirements for Present Ecological Status Class (% of MAR)
0 - 5%
5 - 10%
10 - 15%
15 - 20%
20 - 25%
25 - 50%
Note:
The indicated Reserve Requirements only apply to the river reaches at the outlets of the Quaternaries.
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch5_1.apr
Figure 5.2.4.1

LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Rivers
Dams
Urban & Rural Total Water Requirements ($10^6m^3/a$)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
10 - 30
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Deptartment: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
URBAN AND RURAL DOMESTIC WATER REQUIREMENTS IN 1995
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch5_3.apr
Figure 5.3.1.1
NAMIBIA
BOTSWANA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Onseepkans
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Pofadder
Aggeneys
Springbok
Port Nolloth
Kleinsee
Kamieskroon
Garies
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Rosh Pinah
Aussenkehr
Karasburg
Alexander Bay
Vioolsdrift
Onseepkans
Upington
Augrabies
Kakamas
Pofadder
Aggeneys
Port Nolloth
Springbok
Kleinsee
Kamieskroon
Garies
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Orange
Molopo
Nossob
Kuruman
Vaal
Modder
Riet
Buffels
Hartebees
Sak
Brak
Ongers
Fish
Seekoei
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Drainage Areas
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
GIS COV:
Newtownspes
Intebnd2
Prov0897
Waterman
drainage_lowma
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Water Requirements ($10^6 m^3/a$)
0 - 1
1 - 5
5 - 10
10 - 20
20 - 50
>50
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Deptartment: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
IRRIGATION WATER REQUIREMENTS IN 1995
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch5_3.apr
Figure 5.6.1


BOTSWANA
NAMIBIA
Atlantic Ocean
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Onseepkans
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Aggeneys
Pofadder
Augrabies
Kakamas
Upington
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Water Use (10⁶m³/a)
0 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
2 - 4
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
WATER USE BY ALIEN VEGETATION IN 1995
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch5_9.apr
Figure 5.11.1


BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Rosh Pinah
Sendelingsdrif
9.200
Alexander Bay
Alexander Bay to Port Nolloth 0.670
Port Nolloth
Kleinsee
Springbok Regional WSS 0.190
Springbok Regional WSS 0.615
Springbok
Springbok Regional WSS 1.850
Springbok Regional WSS 0.080
Noord Oewer 31.400
Vioolsdrift 22.400
Vioolsdrift
Pelladrift WSS 3.000
Pelladrift WSS 1.286
Pelladrift WSS 0.874
Onseepkans
Aggeneys
Pofadder
Neusberg North 234.900
Neusberg South 214.800
Kalahari West Rural WSS 0.420
Upington
Upington Main 312.2
Kakamas
Rouxville West Scheme 12.620
Boegoeberg-Karos 84.520
Karos - Geelkoppen Rural WSS 0.042
Gariep Settlement 63.070
Noord Oranje Irrigation Board 63.070
Griekwastad
Douglas
Kimberley
Prieska
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Boegoeberg Dam
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Water Transfers
Irrigation
Mine Bulk User
Urban
Name 12.620
Name of Transfer
Units in $10^6 m^3/a$
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
N
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
WATER TRANSFER SCHEMES
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch5_9.apr
Figure 5.14.1

BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
LOWER ORANGE WMA
LOWER VAAL
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
CRO
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Karasburg
Alexander Bay
Aussenkehr
Vioolsdrift
Onseepkans
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Pofadder
Aggeneys
Port Nolloth
Springbok
Kleinsee
Kamieskroon
Garies
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Kuruman
Molopo
Nossob
Fish
Orange
Vaal
Harts
Riet
Sak
Ongers
Seekoei
Droë Harts
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
LOWER ORANGE
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Drainage Areas
Main Rivers
Dams
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
drainage_lowma
OVC_Mainriv
Ndams
Total Water Resources (10⁶m³/a)
10
50
100
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE AS DEVELOPED IN 1995
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_1.apr
Figure 6.1.1

BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Ongers
Sak - Hartbees
LOWER ORANGE WMA
LOWER VAAL
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Karasburg
Aussenkehr
Alexander Bay
Vioolsdrift
Onseepkans
Pofadder
Aggeneys
Port Nolloth
Springbok
Kleinsee
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Molopo
Nossob
Kuruman
Vaal
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Drainage Areas
Rivers
Dams
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA-new
Drgnsnd
Drgnquat
drainage_lowma
Rivall
Ndams
Total Water Resources
100
200
300
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCES IF DEVELOPED TO FULL POTENTIAL
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_1.apr
Figure 6.1.2

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Onseepkans
Pofadder
Aggeneys
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
Orange
Molopo
Nossob
Kuruman
Vaal
Harts
Modder
Riet
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Harvest Potential (mm/a)
<1 mm
1.0 - 2.5 mm
2.5 - 4.0 mm
4.0 - 6.0 mm
6.0 - 10.0 mm
10.0 - 15.0 mm
15.0 - 25.0 mm
25.0 - 50.0 mm
50.0 - 100.0 mm
>100.0 mm
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
GROUNDWATER HARVEST POTENTIAL
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch6_2ch.apr
Figure 6.2.1

BOTSWANA
NAMIBIA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Prieska
De Aar
Richmond
Victoria West
Carnarvon
Brandvlei
Sutherland
Springbok
Kamieskroon
Garies
Port Nolloth
Kleinsee
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Onseepkans
Pofadder
Aggeneys
Karasburg
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Exploitation Potential (mm/a)
<1 mm
1.0 - 2.5 mm
2.5 - 4.0 mm
4.0 - 6.0 mm
6.0 - 10.0 mm
10.0 - 15.0 mm
15.0 - 25.0 mm
25.0 - 50.0 mm
50.0 - 100.0 mm
>100.0 mm
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
GROUNDWATER EXPLOITATION POTENTIAL
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch6_2ch.apr
Figure 6.2.2

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Onseepkans
Pofadder
Aggeneys
Augrabies
Kakamas
Upington
Griekwastad
Douglas
Westerberg
Prieska
De Aar
Richmond
Victoria West
Carnarvon
Brandvlei
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Impact of Groundwater Abstraction on Surface Water
NEGLIGABLE
LOW
MODERATE
HIGH
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
IMPACT OF GROUNDWATER ABSTRACTION ON SURFACE WATER
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch6_2ch.apr
Figure 6.2.3

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Upington
Alexander Bay
Griekwastad
Douglas
Prieska
Springbok
De Aar
Victoria West
Richmond
Sutherland
Port Nolloth
Kleinsee
Kamieskroon
Brandvlei
Carnarvon
Augrabies
Kakamas
Pofadder
Aggeneys
Onseepkans
Vioolsdrift
Aussenkehr
Karasburg
Rosh Pinah
Westerberg
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Total Use (mm/a)
<1 mm
1.0 - 2.5 mm
2.5 - 4.0 mm
4.0 - 6.0 mm
6.0 - 10.0 mm
10.0 - 15.0 mm
15.0 - 25.0 mm
25.0 - 50.0 mm
50.0 - 100.0 mm
>100.0 mm
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
Kilometers
TITLE:
LOWER ORANGE WMA
GROUNDWATER USE IN 1995
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch6_2ch.apr
Figure 6.2.4

BOTSWANA
NAMIBIA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Alexander Bay
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Onseepkans
Pofadder
Aggeneys
Springbok
Port Nolloth
Kleinsee
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
De Aar
Richmond
Victoria West
Carnarvon
Brandvlei
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Estimated Extent of Groundwater Utilisation
OVER-UTILISED
HEAVILY-UTILISED
MODERATELY-UTILISED
UNDER-UTILISED
No Info
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
ESTIMATED EXTENT OF GROUNDWATER UTILISATION IN 1995
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch6_2ch.apr
Figure 6.2.5

BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
LOWER ORANGE WMA
LOWER VAAL
UPPER ORANGE
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Aussenkehr
Karasburg
Onseepkans
Vioolsdrift
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Pofadder
Aggeneys
Springbok
Port Nolloth
Kleinsee
Kamieskroon
Garies
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Orange
Molopo
Nossob
Kuruman
Vaal
Hartbees
Sak
Ongers
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Drainage Areas
Secondary Catchments
Quaternary Catchments
Rivers
Mean Annual Runoff (MAR) (mm/a)
0.01 - 2.5
2.5 - 5
5 - 10
10 - 20
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
drainage_lowma
Drgnsnd
Drgnquat
Rivall
WSAM
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
MEAN ANNUAL NATURALISED RUNOFF
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_3.apr
Figure 6.3.1

BOTSWANA
NAMIBIA
Namibia
Nossob - Molopo
North West
LOWER VAAL
Alexander Bay
Neusberg
Boegoeberg
Vioolsdrift
Coastal
Sak - Hartbees
Ongers
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Western Cape
Eastern Cape
Atlantic Ocean
Rosh Pinah
Aussenkehr
Karasburg
Vioolsdrift
Onseepkans
Pofadder
Aggeneys
Port Nolloth
Springbok
Kleinsee
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Orange
Fish
Molopo
Nossob
Kuruman
Vaal
Modder
Riet
Seekoei
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Drainage Areas
Dams
Main Rivers
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
drainage_lowma
Ndams
OVC_Mainriv
Yield Possible to Secure
(10⁶m³/a)
100
200
300
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
POTENTIAL SURFACE WATER RESOURCE DEVELOPMENT
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_3.apr
Figure 6.3.2


NOTE:
Only quats where there was sufficient data to compile a series of 24 consecutive monthly values have been shaded.
NAMIBIA
BOTSWANA
North West
LOWER VAAL
Free State
UPPER ORANGE
Northern Cape
LOWER ORANGE WMA
Western Cape
Eastern Cape
OLIFANTS/DOORN
GOURITZ
FISH TO TSITSIKAMMA
Atlantic Ocean
Alexander Bay
Springbok
Upington
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
Vaal
Kuruman
Molopo
Nossob
Fish
Harts
Van der Kloof Dam
Gariep Dam
D8H012Q01
D8H003Q01
D8H004Q01
D8H008Q01
D7H005Q01
D7H015Q01
D7H008Q01
D4R002Q01
D8H007Q01
D8H005Q01
D8H006Q01
D8H002Q01
D7H003Q01
D7H004Q01
D7H016Q01
D7H014Q01
D7R001Q01
D7H013Q01
D7H009Q01
D7H002Q01
D7H012Q01
D7H011Q01
D5R001Q01
D5H016Q01
D5H014Q01
D5H017Q01
D5H018Q01
D5H013Q01
D5H021Q01
D5H004Q01
D5H019Q01
D5H015Q01
D5H011Q01
D6H004Q01
D6R002Q01
D6R001Q01
F5H001Q01
F6H001S01
F6H001R01
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns — Newtownspes
International Boundaries — Intebnd2
Provincial Boundaries — Prov0897
Lower Orange WMA — WMA_new
Secondary Catchments — Drgnsnd
Quaternary Catchments — Drgnquat
Main Rivers — OVC_Mainriv
Dams — Ndams
Monitoring Stations with assigned colours for overall TDS values — df_stations
No TDS Data
<260mg/l
260 - 600mg/l
601 - 1800mg/l
1801 - 3400mg/l
>3400mg/l
D7H005Q01 Stations where there was sufficient data to compile a data series of 24 consecutive monthly values.
Quats with assigned colours for overall TDS values
Green
Yellow
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
MINERALOGICAL SURFACE WATER QUALITY
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch6_3.apr
Figure 6.4.1.1

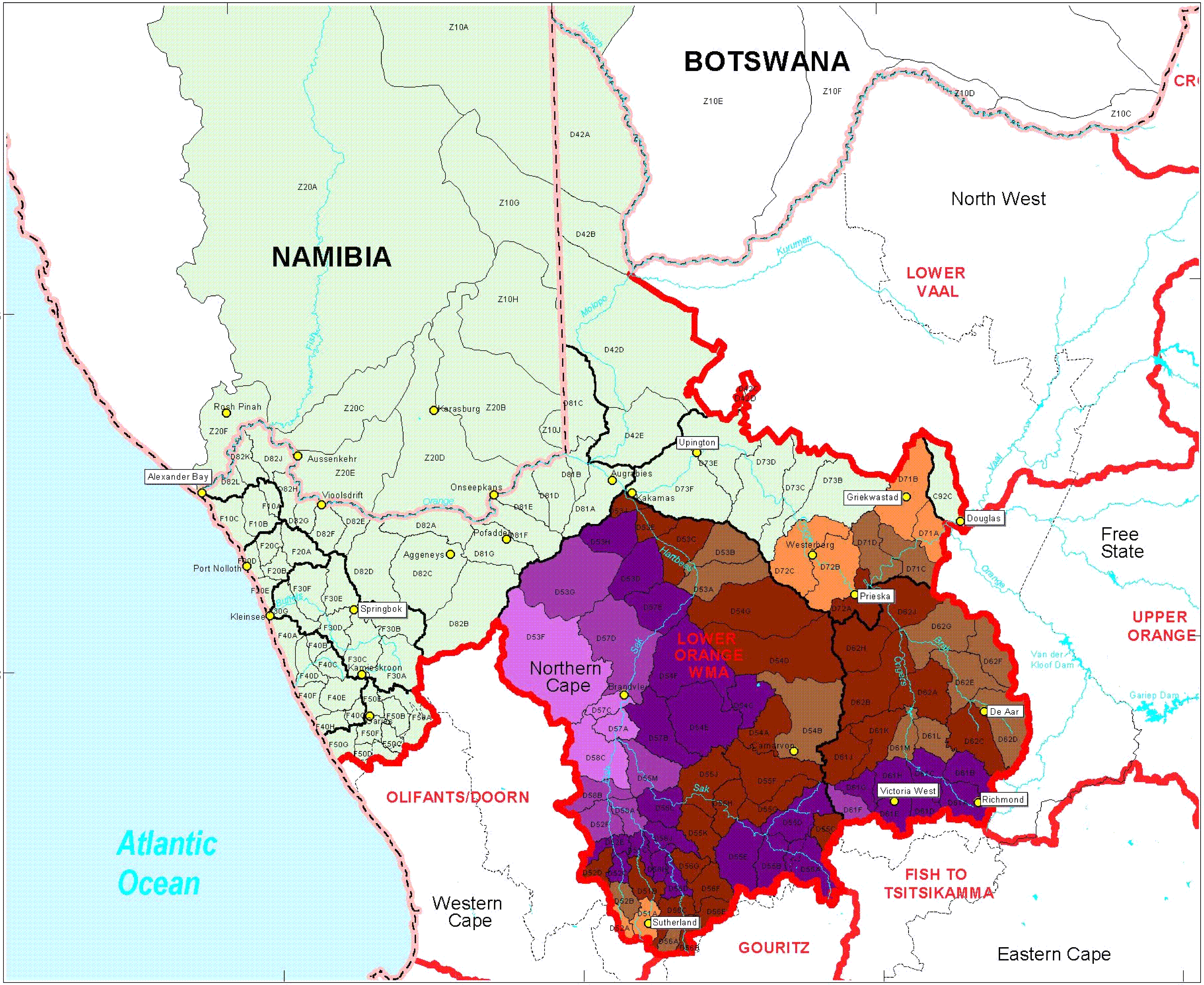

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
GOURITZ
FISH TO TSITSIKAMMA
Eastern Cape
Atlantic Ocean
Alexander Bay
Springbok
Upington
Griekwastad
Douglas
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Mineralogical Groundwater Quality Class (MeanTDS)
Class 0 < 260mg/l
Class 1 261 - 600mg/l
Class 2 601 - 1800mg/l
Class 3 1801 - 3400 mg/l
Class 4 > 3400 mg/l
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
MINERALOGICAL GROUNDWATER QUALITY
Prepared by: S.Schwabe
Date: January 2002
Data Type: PVO24044_ch6_4.apr
Figure 6.4.2.1

BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Upington
Griekwastad
Douglas
Springbok
Prieska
De Aar
Victoria West
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Percentage Potable Groundwater
< 30 %
30 - 50 %
50 - 70 %
70 - 90 %
> 90 %
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
ESTIMATE OF POTABLE GROUNDWATER
Prepared by: S.Schwabe
Date: February 2002
Data Type: PVO24044_ch6_4.apr
Figure 6.4.2.2


Note:
Map was produced using land use information (population density and degree of sanitation) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Rosh Pinah
Karasburg
Aussenkehr
Alexander Bay
Vioolsdrift
Onseepkans
Port Nolloth
Kleinsee
Springbok
Aggeneys
Pofadder
Kamieskroon
Garies
Upington
Augrabies
Kakamas
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
Victoria West
De Aar
Richmond
Sutherland
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Potential Contamination
No Data
Missing Data
Low
Medium
High
GIS COV:
Newtownspes
Intebnd2
Prov0897
WMA_new
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
swq_quat
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
POTENTIAL FAECAL CONTAMINATION OF SURFACE WATER
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_4.apr
Figure 6.4.3.1


Note:
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Aggeneys
Pofadder
Onseepkans
Augrabies
Kakamas
Upington
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
Victoria West
Richmond
De Aar
Sutherland
Rosh Pinah
Aussenkehr
Vioolsdrift
Karasburg
Van der Kloof Dam
Gariep Dam
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
Lower Orange WMA
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
Risk of Groundwater Contamination
Low Risk
Medium Risk
High Risk
GIS COV:
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER
Prepared by: S.Schwabe
Date: September 2001
Data Type: PVO24044_ch6_4.apr
Figure 6.4.3.2


NAMIBIA
BOTSWANA
North West
Free State
Northern Cape
Western Cape
Eastern Cape
Atlantic Ocean
LOWER VAAL
UPPER ORANGE
LOWER ORANGE WMA
OLIFANTS/DOORN
FISH TO TSITSIKAMMA
GOURITZ
Nutrient enrichment from agricultural runoff and treated sewage effluent cause occasional blooms which cause:
- taste and odour problems in treated drinking water.
- fish kills, as aresult of low dissolved oxygen
- a health and ecololgical risk if toxic algae occur.
Bacteriological contamination of river and irrigation canal water has led to an increase in water borne diseases in the Upington/Kakamas area.
High TDS loading from Vaal River
The Orange River Mouth is regarded as an important estuary in the country. It is also a RAMSAR site.
Minor Concerns about pesticide and herbicide contamination from intensive irrigation agriculture close to the river.
Water temperature fluctuations as a result of hydro power releases is a moderate concern to aquatic biota.
Minor concerns about asbestos fibres from mines in the Prieska area have been raised.
High TDS in the Sak River
Alexander Bay
Port Nolloth
Kleinsee
Springbok
Kamieskroon
Garies
Rosh Pinah
Aussenkehr
Vioolsdrift
Onseepkans
Pofadder
Aggeneys
Augrabies
Kakamas
Upington
Griekwastad
Douglas
Westerberg
Prieska
Brandvlei
Carnarvon
De Aar
Victoria West
Richmond
Sutherland
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Main Towns — Newtownspes
International Boundaries — Intebnd2
Provincial Boundaries — Prov0897
Lower Orange WMA — WMA_new
Secondary Catchments — Drgnsnd
Quaternary Catchments — Drgnquat
Rivers — Rivall
Dams — Ndams
Water Quality Issues
Increase in TDS due to increased effluent return flows
Nutrient enrichment from dam releases or irrigation and urban return flows
Trace metals from mining activities
Increase in TDS due to high natural hydrogeological sources and high evaporation
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460- 606
CLIENT:
Department: Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
TITLE:
LOWER ORANGE WMA
WATER QUALITY ISSUES
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch6_4.apr
Figure 6.4.4.1



LOCALITY MAP:

BASE MAP LEGEND:

	GIS COV:
Main Towns	Newtowns pes
International Boundaries	Intebnd2
Provincial Boundaries	Prov0897
Lower Orange WMA	WMA_new
Secondary Catchments	Drgnsnd
Quaternary Catchments	Drgnquat
Rivers	Rivall
Dams	Ndams

25 Year Sediment Accumulation Potential (% MAR)

- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- 50 - 100
- 100 - 200
- 200 - 500

PREPARED BY:

V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606

CLIENT:

Department: Water Affairs and Forestry,
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE: 1: 3 500 000

40 0 40 80 Kilometers

N

TITLE:

LOWER ORANGE WMA

POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS

Prepared by:	S.Schwabe
Date:	September 2001
Data Type:	PVO24044_ch6_5.apr

Figure 6.5.1


BOTSWANA
NAMIBIA
North West
LOWER VAAL
Free State
UPPER ORANGE
LOWER ORANGE
Northern Cape
OLIFANTS/DOORN
Western Cape
FISH TO TSITSIKAMMA
GOURITZ
Eastern Cape
Atlantic Ocean
Alexander Bay
Springbok
Upington
Griekwastad
Douglas
Prieska
De Aar
Victoria West
Richmond
Sutherland
Orange
Vaal
Kuruman
Molopo
Nossob
Riet
Seekoei
LOCALITY MAP:
BASE MAP LEGEND:
Main Towns
International Boundaries
Provincial Boundaries
WMA Boundaries
Secondary Catchments
Quaternary Catchments
Main Rivers
Dams
GIS COV:
Newtownspes
Intebnd2
Prov0897
Waterman
Drgnsnd
Drgnquat
OVC_Mainriv
Ndams
Water Balance $10^6 m^3/a$
-56 - -20
-20 - -10
-10 - 0
0 - 100
100 - 1000
1000 - 1500
1500 - 2000
2000 - 2500
2500 - 3000
Ecological Reserve
Consumptive Requirement Supplied
River Loss
Water Requirements $10^6 m^3/a$
30
300
600
PREPARED BY:
V3 CONSULTING ENGINEERS
V3 RAADGEWENDE INGENIEURS
PO BOX / POSBUS 36155
MENLO PARK 0102
TEL NO (012) 460-1606
CLIENT:
Department: Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1: 3 500 000
40 0 40 80 Kilometers
N
TITLE:
LOWER ORANGE WMA
WATER BALANCE OVERVIEW 1995
Prepared by: S.Schwabe
Date: March 2002
Data Type: PVO24044_ch7_1.apr
Figure 7.2.1