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DEPARTMENT: WATER AFFAIRS AND FORESTRY

Directorate: Water Resources Planning

BERG
WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

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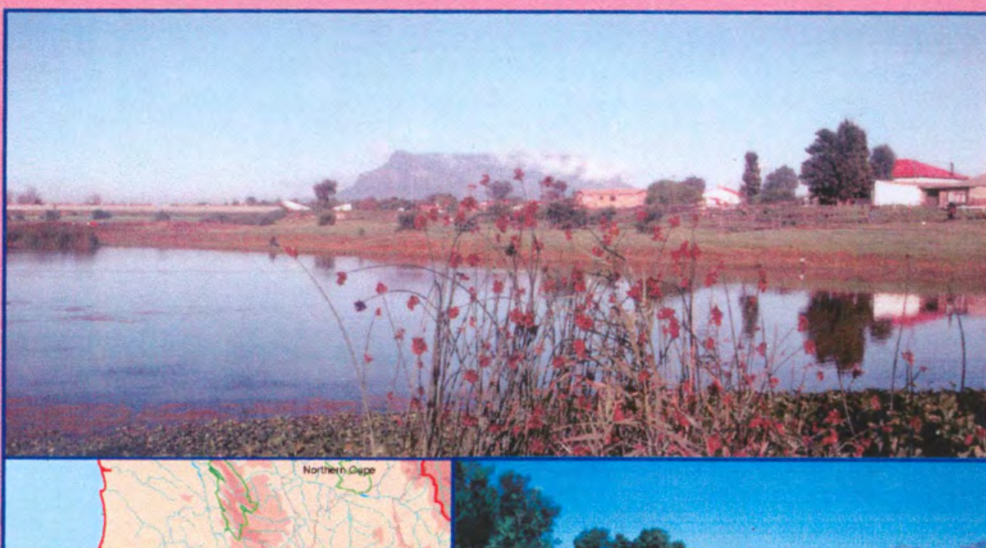

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BERG WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT

OVERVIEW

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reserve for various ecological management classes that correspond to those determined previously for the rivers throughout the country.

SYNOPSIS

1. INTRODUCTION

1.1 PURPOSE OF THE STUDY

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

The Department of Water Affairs and Forestry (DWAF) has appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database which will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and 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 information gathered in the Water Resources Situation Assessments has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Berg Water Management Area.

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 to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

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

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

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

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

Information from all the above studies, that is relevant to the Berg Water Management Area, is included in the appropriate sections of this report. The main conclusions drawn from the information are summarised below, followed by a list of requirements for additional data and recommendations on the action needed to obtain the data.

2. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions drawn from the information gathered in this situation assessment are :

(i) The Berg WMA covers an area of 13 000 km^2 in which the mean annual rainfall ranges from a maximum of about 3 200 mm in the high mountains in the north-eastern corner of the WMA to less than 300 mm in the north-west. The rainfall occurs mainly during the winter months.

(ii) The geology of the WMA is dominated by compact sedimentary strata of the Cape Supergroup with Table Mountain Sandstone forming the mountains along the eastern boundary, the mountains of the Cape Peninsula, and a few smaller outcrops of high ground. Sand dune areas, mainly underlain by Malmesbury shales, occur along parts of the western and southern coasts, and the rolling hills of the central area consist mainly of Malmesbury shales. Surface water originating from runoff from the Table Mountain Sandstone areas is of low natural salinity, while that from areas where Malmesbury shales occur is moderately saline. Groundwater is similarly affected by the geological strata.

(iii) Water quality in the Lourens River, the lower reaches of the Cape Peninsula rivers, and the Diep River, is adversely affected by wash-off from urban areas and return flows of water carrying waste. Water quality in the middle and lower reaches of the Berg River is adversely affected by nutrients from agricultural land.

(iv) For purposes of determining the ecological flow requirements of the rivers of the WMA, most catchments have been allocated a PESC of Class D : largely modified, with low ecological flow requirements. The lower Berg River and its tributaries, the lower Diep River, the Steenbras River and the Cape Peninsula rivers have been given PESCs of Class C : moderately modified, with higher ecological flow requirements.

(v) The population of the WMA in 1995 was approximately 3 247 000 people. About 95% of the population lived in urban areas.

(vi) The GGP of the WMA in 1997 was R63,8 bn with the most important economic sectors, in terms of their contributions to GGP being Manufacturing (25,4%), Transport (20,6%), Financial Services (17,6%) and Government (15,0%). Transport has a high comparative advantage relative to other WMAs.

(vii) Land-use is predominantly for rough grazing for livestock, about 75% of the surface area of the WMA being used for this purpose. The remainder is used for urban areas (4%), dryland farming (12%), irrigated agriculture (4%), nature reserves (4%), and afforestation (1%).

(viii) There were about 296 000 head of livestock in the WMA in 1995, with sheep making up 68% of the livestock numbers and cattle and pigs each accounting for 15% of the numbers.

(ix) Water related infrastructure for urban, irrigation, and rural domestic requirements is well developed.

(x) The combined capacities of regional potable water supply schemes and individual town schemes totalled 333 million m^3/a in 1995 and provided water to an estimated 95% of the population of the WMA.

(xi) A total of 20 dams, both large and small provide water for the town supplies and some of these provide water for irrigation as well. Nineteen of the dams are in the Berg WMA and one, Theewaterskloof, is in the Breede WMA. The 19 dams in the Berg WMA have a capacity of 297 million m^3 and a 1:50 year yield of approximately 263 million m^3/a.

(xii) Because most of the rainfall, and hence most of the flow in the rivers, occurs between the winter months of May and October each year, infrastructure for irrigation has been developed to store runoff that occurs during the winter months and distribute it to irrigated lands during the remainder of the year.

(xiii) Two Government Water Supply Schemes, namely the Berg River/Riviersonderend Government Water Scheme and the Voëlvlei Government Water Scheme provide large volumes of water for irrigation as well as for urban supplies. In addition, farm dams with a combined capacity of 104 million m^3 store water for irrigation.

(xiv) Allocations of water for irrigation from Government Water Supply Schemes totalled 142 million m^3/a in 1995, which was 41% of the average irrigation water requirement of the whole WMA of 345 million m^3/a. In normal years, only about 60% of the water allocated is used for irrigation. This amounts to about 25% of the total irrigation requirement of the WMA and the remainder is provided from excess winter water, pumped from the main rivers, and from the farmers' own sources.

(xv) Water requirements in the WMA in 1995 were estimated to total 839 million m^3, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sectors were the urban and rural domestic sector, which accounted for 43% of the total consumptive requirement (i.e. the requirement excluding the ecological Reserve) and the agricultural sector which accounted for 42%. The next biggest water user was alien vegetation (10%), followed by afforestation (3%), with river losses and bulk water use making up the remaining 2%. With the requirements of the ecological Reserve added, the total water requirement becomes 960 million m^3.

(xvi) The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, is 705 million m^3/a. The estimates of the impacts on yield are at low levels of confidence.

(xvii) There is scope for reducing urban water requirements by means of a water conservation and demand management programme. There is also scope for improving the efficiency of agricultural water use, particularly by reducing conveyance losses.

(xviii) The natural MAR of the Berg WMA was 1 407 million m^3, and the yield developed from surface water resources in 1995 was 409 million m^3/a at 1:50 year assurance. Some 44% of the developed surface water yield was from farm dams and run-of-river abstractions, and 56% from major dams. In addition, boreholes with an estimated yield of 57 million m^3/a had been developed, bringing the total developed yield to 466 million m^3/a at 1:50 year assurance.

(xix) Comparison of the equivalent 1:50 year assurance water requirements of 705 million m^3/a with the developed yield of 466 million m^3/a, shows a deficit of 239 million m^3/a, but re-usable return flows of 49 million m^3/a reduce the deficit to 190 million m^3/a. Imports of water of 171 million m^3/a from the Breede WMA further reduce the deficit to 19 million m^3/a. The deficit of 19 million m^3/a is equal to the estimated impact of the ecological Reserve on the 1:50 year yield of the water resources of the WMA. This is to be expected as the ecological Reserve was not implemented in 1995 and the shortfall between the yield of the water resources of the Berg WMA and the water requirements was met by imports from the Breede WMA.

(xx) The maximum 1:50 year potential yield of the water resources of the WMA is estimated to be 719 million m^3/a, which is 253 million m^3/a more than the developed 1:50 year yield in 1995. The proportion of this amount that will be available for consumptive water use after the ecological Reserve has been provided for is uncertain because of a lack of reliable information on the ecological flow requirements of the rivers and the Berg River estuary.

(xxi) Studies carried out as part of the Skuifraam Dam, Skuifraam Supplement, Voëlvlei Scheme, Eerste River and Lourens River diversions show that additional yield of 137 million m^3/a could be developed in large schemes in the Berg WMA, while groundwater appears to have the potential to provide an additional 116 million m^3/a, mainly in small diffuse schemes.

(xxii) The cost of developing an additional 253 million m^3/a of yield to utilise the full potential of the water resources of the Berg WMA is roughly estimated to be R1 978 million at year 2000 price levels, including VAT.

(xxiii) A further yield of 62 million m^3/a from treated wastewater effluent, is also possible. Currently 135 million m^3/a of effluent is not re-used. However, of this, only 62 million m^3 has been considered to be cost effectively re-usable.

(xxiv) The requirements of the Cape Metropolitan Area for water for urban use exceed the quantity that can be provided by the water resources owned by the City of Cape Town and the allocations of water from State owned dams that have been made to it. The shortfall is made up at present by providing the City of Cape Town with additional water from State owned dams that has been allocated to agriculture, but not yet used, because the farmers have not fully utilised their water allocations.

This assessment has indicated that if irrigation allocations were fully utilised and the currently estimated requirements of the ecological Reserve were fully implemented, the water resources of the Berg WMA would be stressed in terms of the levels of assurance at which the required quantities of water could be provided to consumers.

(xxv) As it is known that the urban water requirements of both the Cape Metropolitan Area and the Vredenburg/Saldanha area have continued to grow steadily since 1995, and irrigation water requirements are also increasing as farmers develop more land and use the water allocations that they have previously acquired, it is clear that the assurance at which the water resources as developed in 1995 can meet requirements will diminish steadily.

(xxvi) To counter this, imports of water via the Palmiet Scheme began in 1997 and planning for the construction of a new dam on the Berg River at Skuifraam is well advanced. However, even if the rate of growth in urban water requirements is substantially reduced as a result of the successful implementation of water conservation and demand management, but existing water allocations for agriculture are all utilised, it will be necessary to construct additional schemes to keep pace with continuing growth in water requirements.

(xxvii) As the level of development of the water resources approaches their full potential yield it will become increasingly important to have accurate information on the amounts of abstractions of water from the streams and rivers of the catchments to be developed. This will be required to derive the reliable information on streamflow at the sites of the proposed new schemes that is needed to ensure that they are economically designed.

It is apparent from the above conclusions that the available data on the following aspects is inadequate :

- The quantity of water abstracted for irrigation from farmers' own sources and from excess winter flow in the main rivers.

- The ecological Reserves for the rivers of the WMA and the Berg River estuary, and their impacts on the utilisable yields of the rivers.

- The impacts of alien vegetation and afforestation on the availability of water to meet other requirements.

The following actions are recommended to obtain the additional data :

- Compulsory licensing of water use for irrigation should be implemented in the catchments of the Berg, Eerste and Lourens Rivers in order to accurately determine irrigation water requirements.

- New aerial photography of the same catchments should be obtained and used to determine irrigated areas in each quaternary catchment for purposes of verifying the licensing process, and also used to determine areas of alien vegetation.

- Detailed work that has been carried out in separate studies on the ecological flow requirements of some river reaches should be used to derive monthly flow sequences of ecological flow requirements.

- In the quaternary sub-catchments of the Berg, Eerste and Lourens Rivers where more detailed work has not been done, the ecological river classifications determined in this study should be verified by limited field work, and monthly sequences of ecological flow requirements determined using the simulation model that has been developed for this purpose.

- A determination of the ecological freshwater flow requirements of the Berg River Estuary should be made at the intermediate level and monthly flow sequences developed.

- The information obtained as described above should be used to configure the Water Resources Yield Model to determine :

    - total irrigation water requirements in each quaternary catchment,
    - the quantity of water that would be required by irrigators from Government Water Schemes during severe droughts,
    - the quantity of water available in the rivers for the development of additional yield after allowing for the effects of afforestation and alien vegetation.

In terms of priorities for carrying out this work, the Berg River catchment should take precedence over the other catchments in this WMA because further development of the yield of its water resources will be required sooner.

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DIAGRAMS

ABBREVIATIONS AND ACRONYMS

AEMC	Suggested Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
d/s	downstream
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TMG	Table Mountain Group (of geological strata)
TRC	Transitional Regional Council
u/s	upstream
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
m^3	cubic metre
$10^6 m^3$	million cubic metres
$10^6 m^3/a$	million cubic metres per year
%	percent

GLOSSARY OF TERMS

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.
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 ClassA (highly sensitive, no risks allowed) to ClassD (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.

ECOSYSTEM	A unit made up of all the living and non-living components of a particular area that interact and exchange materials with each other.
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.
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.
ENVIRONMENTALLY SENSITIVE AREA	A fragile ecosystem which will be maintained only by conscious attempts to protect it.
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 pre-determined quotas to irrigators registered under the scheme.
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	Pertaining to fast running aquatic habitats such as fast flowing streams or rivers.
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 ClassA (largely natural) to ClassF (critically modified).
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.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

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

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

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

In order to facilitate use by future catchment management agencies, the information has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Berg Water Management Area, which is situated in 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 balance model, developed in a separate study (DWAF, 2000a) to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

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

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

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

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

Information from all the above studies, that is relevant to the Berg Water Management Area, is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect of the Berg Water Management Area are presented in the nine chapters that make up the main body of this report, and a number of appendices containing mainly statistics for the quaternary hydrological sub-catchments that make up the water management area. (The system used to divide the area into hydrological sub-catchments is explained in Section 2.1 of the report).

The chapter headings are :

Chapter 1 : Introduction
Chapter 2 : Physical Features
Chapter 3 : Development Status
Chapter 4 : Water Related Infrastructure
Chapter 5 : Water Requirements
Chapter 6 : Water Resources
Chapter 7 : Water Balance

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

CHAPTER 2: PHYSICAL FEATURES

2.1 THE STUDY AREA

The study area comprises the whole of the Berg Water Management Area (WMA) which is shown on Figure 2.1.1. The Berg WMA includes the Berg, Diep and Steenbras River catchments and all the catchments of the smaller rivers draining into Table Bay and False Bay. It also includes Robben Island which is the only inhabited island along the coast of the WMA.

The Berg WMA is bounded in the north by the Olifants/Doring Water Management Area and in the east by the Breede Water Management Area. The topography is mountainous in the southern and eastern portions, where the Berg River basin is narrow. In the west the Berg River basin levels out and widens as shown on Figure 2.1.2.

The WMA has been sub-divided into quaternary catchments (see Figure 2.1.3). These are the basic units of area used in the Surface Water Resources of South Africa, 1990 (Midgley et al, 1994), which is the main source of hydrological data used in this study.

In this system, drainage regions throughout the country are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been selected to have similar runoffs : the greater the runoff volume, the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example G21C, may be interpreted as follows. The letter G denotes Drainage Region G (sometimes referred to as a primary catchment). The number 2 denotes secondary catchment 2 of Drainage Region G. The number 1 shows that the secondary catchment has, in this case, been sub-divided into tertiary catchments and that the tertiary catchment is first in sequence downstream from the head of secondary catchment G2. The letter C shows that the quaternary catchment is the third in the sequence downstream from the head of tertiary catchment G21.

The Berg WMA consists of most of drainage region G. It contains a total of 29 quaternary catchments from this drainage region.

In the description of features of the area that follows, references to quaternary catchments are shown in brackets to assist in locating the approximate position of features on Figure 2.1.1. Many of the features themselves are not shown on the figure because the scale of the mapping is too small.

The Berg Water Management Area covers an area of 13 000 km^2. There are five sub-basins as described below.

- The Berg River Basin consists of twelve quaternary catchments (G10A - G20M). The upper region of the Berg River Basin is surrounded by high mountain ranges (RL 1500 m) to the south, east and west. The river basin is fairly narrow (10 - 15 km) between the source (Groot Drakenstein) and Wellington. North of Wellington the Limietberg continues to bound the valley to the west. In the east the basin levels out and the river basin widens to approximately 25 km.

- The Steenbras River Basin consists of one quaternary catchment (G40A). It consists of the Steenbras River and its tributaries. The Steenbras River is located to the west of the Kogelberg Mountains and is bounded by the Hottentots Holland Mountains to the north and west. The catchment contains numerous small tributaries that drain into the upper and lower Steenbras Dams.

- The Kuils, Eerste, Lourens and Sir Lowry's Pass Basin consists of six quaternary catchments (G22E - G22K). The south-eastern portion of the area is separated from the Steenbras, Palmiet and Riviersonderend Basins by the Hottentots Holland Mountain range and from the Berg River Basin by the Jonkershoek Mountain range. These mountain ranges are the highest parts of the catchment with peaks in both ranges being at an altitude of just over 1 500 m.

  With the exception of the Jonkershoek Valley (situated between the Jonkershoek Mountains and the Stellenboschberg) where slopes are relatively steep, the catchment levels out rapidly towards the False Bay coast.

- The Diep, Modder and Dwars River catchments are sub-divided into six quaternary catchments. The Diep River has its source in the Riebeeck Kasteel Mountains in the north-east of the catchment. It flows in a south-westerly direction through Malmesbury and the wheat producing areas of the Swartland.

  The Diep River Basin is low lying and flat with isolated mountains on its eastern boundary, namely the Perdeberg, Kasteelberg and Paarlberg, and a major mountain range to its east.

  The Diep River has one major tributary, the Mosselbank River, which rises in the Skurweberg Mountains and drains the south-eastern portion of the catchment joining the Diep River approximately two-thirds of the way along its course.

  The Modder and Dwars Rivers drain from the Lower Berg catchment boundary, in a westerly direction into the Atlantic Ocean.

- The Black, Elsies, Lotus and smaller Peninsula rivers occupy the remaining four quaternary catchments (G22A-D) of the Berg Water Management Area.

For purposes of describing the characteristics of the WMA, it was divided into a number of key areas. These are either the catchments of the main rivers within the Berg WMA, or groupings of several minor catchments. The key areas are listed in Table 2.1.1, where the reasons for selecting them are also shown.

TABLE 2.1.1: KEY AREAS WITHIN THE BERG WMA

LOCATION OF KEY AREA				DESCRIPTION
SECONDARY		QUATERNARY		
NO.	DESCRIPTION	NO.	RIVER	
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei Dam	Upper Berg River from Catchment G10A to G10F (Voëlvlei Dam)
		G10G to G10M	Berg River downstream of Voëlvlei Dam	Berg River between G10F and the river mouth in Catchment G10M
G2	Diep River and West Coastal belt	G21A to G21B	Combined West Coast rivers	Small coastal catchments between the Berg and Diep River catchments
		G21C to G21F	Diep River	Diep River catchment
		G22E to G22K	Combined Kuils/Eerste/ Lourens /Sir Lowry Rivers	Catchments draining to the eastern half of False Bay
		G22A to G22D	Combined Cape Peninsula rivers	Cape Peninsula catchments (including the Black River)
G4	Steenbras River	G40A	Steenbras	The Steenbras River catchment

The boundaries of these key areas are shown on Figure 2.1.3 and most of the other figures in the report. The key areas are also used in many of the tables.

2.2 CLIMATE

Temperature

Climatic conditions can vary considerably within the Berg Water Management Area as a result of the variation in the topography. The mean annual temperature ranges between 16º C in the east central to 18º C towards the west coast, with an average of 16º C for the WMA as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Table 2.2.1 below summarises temperature data for the Berg Water Management Area.

TABLE 2.2.1: TEMPERATURE DATA

MONTH	TEMPERATURE (ºC)	AVERAGE	RANGE
January	Mean temperature	21,8	13 - 26
	Maximum temperature	29,4	18 - 34
	Minimum temperature	14,1	7 - 18
	Diurnal range	15,3	8 - 19
July	Mean temperature	10,8	15 - 16
	Maximum temperature	17,1	8 - 22
	Minimum temperature	4,5	-4 - 10
	Diurnal range	12,6	5 - 16

Rainfall

The Berg WMA lies within the winter rainfall region, with the majority of rainfall occurring between the months of May and September. The rainfall is frontal in nature with cold fronts moving from the Atlantic Ocean over the Western Cape. The mean lightning flash density is 0 - 1 per km^2 per annum.

As a result of the orographical influence of the mountains, a large spatial variability in the mean annual precipitation (MAP) is experienced (see Figure 2.2.1). In the high lying areas of the Hottentots Holland mountains (in the east of the WMA), the maximum MAP is approximately 3 200 mm, reducing to 500 mm in the north-east. The average co-efficient of variation ranges from 20% to 35%.

For the driest year in five (80% exceedance probability), the annual rainfall for the northern half of the WMA is 400 mm, but can be as low as 100 mm. For the southern half, the annual rainfall is 200 mm but can be as high as 1 000 mm in places. For the wettest year in five (20% exceedance probability), the annual rainfall in the northern half of the WMA is 600 mm, but can be as low as 200 mm. For the southern half, the annual rainfall is 800 mm but can be as high as 1 200 mm in places.

Humidity and Evaporation

In accordance with the rainfall pattern, the relative humidity is higher in winter than in summer. Humidity is generally highest in June (the daily mean over the Berg WMA ranges from 75% in the west to 68% in the east) and the lowest in January (the daily mean over the Berg WMA ranges from 68% in the west to 62% in the east).

The average potential mean annual evaporation (as measured by Symons-pan) for the WMA ranges from 1 700 mm in the north to 1 400 mm in the southern parts (Midgley *et al*, 1994) (see Figure 2.2.2). The highest Symons-pan evaporation is in January (range 256 mm to 206 mm) and the lowest evaporation in July (30 mm to 42 mm).

2.3 GEOLOGY

The geology of the area is shown in simplified form on Figure 2.3.1. It is dominated by compact sedimentary strata of the Cape Supergroup. In the north-west and along the Cape Flats, porous unconsolidated to semi-consolidated sediments are found.

The Cape Peninsula Mountain Chain (G22A - G22D) and the mountains along the eastern boundary of the Berg WMA consist of Table Mountain Sandstone. Granite occurs as an underlying layer in the Cape Peninsula. An outcrop of sandstone occurs at Kasteelberg, west of Riebeeck-West (G10F, G21C).

Sand dune areas, mainly underlain by Malmesbury shales extend across the Cape Flats (G21E, G22C - G22E, G22H) and up the West Coast between Blaauberg and the Berg River estuary (G10M, G21A, G21B, G21F). These areas are all characterised by sandy aquifers.

The central region comprises rolling hills, mainly underlain by Malmesbury shales of marine origin. There are a few massive granite outcrops, of which Paarl Mountain (G10C) is the largest.

2.4 SOILS

Figure 2.4.1 shows a generalised soils map of the WMA based on 7 broad soil groupings. The figure was obtained from the report on the Surface Water Resources of South Africa, 1990 (Midgley *et al*, 1994). In that report, 16 groupings were derived by the Department of Agricultural Engineering of the University of Natal, using a national base map which was divided into 82 soil types. These soil types were then analysed according to features most likely to influence hydrological response, viz. depth, texture and slope.

The following soil types occur in the Berg WMA :

- Moderate to deep sandy soils occur in flat terrain extending from Cape Town up the west coast. This coastal strip is approximately 20 to 30 km wide, expanding to 120 km wide along the lower reaches of the Berg River (G10M) and to 75 km wide in the Cape Peninsula (G22A - G22E).

- Moderate to deep clayey loam over an undulating terrain is found across the greater part of the remaining area.

- Along the eastern and south-eastern boundary of the WMA, moderate to deep sandy loam over steep terrain is found.

2.5 NATURAL VEGETATION

2.5.1 Introduction

Some 20 000 different plant species occur throughout South Africa. These are however not randomly distributed with the region but are organised into distinct communities, largely dependent on the prevailing climatic (especially rainfall) and edaphic (soil) conditions. For the purposes of identifying and managing the heterogenous arrange 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 (Table 2.5.1.1). These "simplified" Acocks veld type categories are used for the purposes of this report, and accordingly the description of the natural vegetation types occurring within the WMA is rather broad.

TABLE 2.5.1.1: A LIST OF THE DETAILED AND SIMPLIFIED ACOCKS VELD TYPES (Acocks, 1988)

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Coastal Forest and Thornveld	1	**Coastal Tropical Forest**
Alexandria Forest	2	
Pondoland Coastal Plateau Sourveld	3	
Knysna Forest	4	
'Ngongoni Veld	5	
Zululand Thornveld	6	
Eastern Province Thornveld	7	
North-eastern Mountain Sourveld	8	**Inland Tropical Forest**
Lowveld Sour Bushveld	9	
Lowveld	10	**Tropical Bush and Savanna**
Arid Lowveld	11	
Springbok Flats Turf Thornveld	12	
Other Turf Thornveld	13	
Arid Sweet Bushveld	14	
Mopani Veld	15	
Kalahari Thornveld	16	
Kalahari Thornveld invaded by Karoo	17	
Mixed Bushveld	18	
Sourish Mixed Bushveld	19	
Sour Bushveld	20	
False Thornveld of Eastern Cape	21	**False Bushveld**
Invasion of Grassveld by Acacia karoo	22	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Valley Bushveld	23	**Karoo and Karroid**
Noorsveld	24	
Succulent Mountain Scrub	25	
Karroid Broken Veld	26	
Central Upper Karoo	27	
Western Mountain Karoo	28	
Arid Karoo	29	
Central Lower Karoo	30	
Succulent Karoo	31	
Orange River Broken Veld	32	
Namaqualand Broken Veld	33	
Strandveld	34	
False Arid karoo	35	**False Karoo**
False Upper Karoo	36	
False Karroid Broken Veld	37	
False Central Lower Karoo	38	
False Succulent Karoo	39	
False Orange River Broken Karoo	40	
Pan Turf Veld invaded by Karoo	41	
Karroid Merxmuellera Mountain Veld replaced by Karoo	42	
Mountain Renosterveld	43	
Highveld Sourveld and Dohne Sourveld	44	**Temperate and Transitional Forest and Scrub**
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	53	
Turf Highveld to Highland Sourveld Transition	54	
Bakenveld to Turf Highveld Transition	55	
Highland Sourveld to Cymbopogon – Themeda Veld	56	
North-eastern Sandy Highveld	57	
Themeda – Festuca Alpine Veld	58	
Stormberg Plateau Sweetveld	59	
Karroid Merxmuellera Mountain veld	60	
Bankenveld	61	**False Grassveld**
Bankenveld to Sour Sandveld Transition	62	
Piet Retief Sourveld	63	
Northern Tall Grassveld	64	
Southern Tall Grassveld	65	
Natal Sour Sandveld	66	
Pietersburg Plateau False Grassveld	67	
Eastern Province Grassveld	68	
Fynbos	69	**Sclerophyllous Bush**
False Fynbos	70	**False Sclerophyllous Bush**

2.5.2 Natural Vegetation Types within the Berg WMA

The Berg WMA is located within the Western Cape, and the vegetation within this province is dominated by Karoo and Karroid Types, Temperate and Transitional Forest and Scrub Types, and Sclerophyllous Bush Types. The veld types occurring within the Berg WMA are described in more detail below and illustrated in Figure 2.5.2.1.

Karoo and Karroid Bushveld
Within the Berg WMA, a narrow but continuous band of this vegetation type occurs along the western coastline, from the Cape Peninsula to St Helena Bay. The flora is characteristically low, typically less than 1 m in height, and includes scrub, bushes, dwarf trees and a few grasses. Rainfall within this vegetation type typically ranges between 150 mm and 500 mm, but reaches a maximum of up to 900 mm in some of the river valleys. Karoo and Karroid Bushveld occurs at any altitude from sea level to 1 700 m above mean sea level (MSL).

Temperate and Transitional Forest and Scrub
This veld type dominates within the Berg WMA, occupying some 80% of its area. As the name implies, this veld type is typical of relatively temperate habitats. This general veld type includes areas of forest, grassland and fynbos. Temperate and Transitional Forest and Scrub occurs from sea level to up to 1 350 m. Rainfall is typically high, ranging from 650 mm to 1 150 mm per annum, although it may be somewhat lower within the coastal renosterveld and fynbos elements of this veld type, where it typically ranges between 300 mm to 500 mm per annum.

Sclerophyllous Bush
Occurs in a broad band along the western border of this WMA. Moreover, Sclerophyllus Bush predominates on the Cape Peninsula and isolated patches occur in the central reaches and towards the northern border of the WMA. This vegetation type, also referred to as Fynbos, contains a bewildering array of species which are characteristically small leafed (hence the term Sclerophyllous bush). No single species dominates and there is a tremendous spatial turnover in species composition. The areas occupied by the Sclerophyllous Bush veld type are typically fairly mesic, receiving in excess of 500 mm, and up to 1 500 mm, of rainfall per annum.

2.6 ECOLOGICALLY SENSITIVE SITES

2.6.1 Sensitive Ecosystems

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

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

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

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

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

The procedure for establishing the Reserve requires each water resource to be classified and the resource quality objectives to be set as initial steps towards determining the Reserve.

As estimates of the quantity of water required for the ecological component of the Reserve are an essential requirement if a meaningful assessment of water resources is to be carried out, and the process of classifying all the water resources has not yet been completed, rapid preliminary classifications were made and used to make rough estimates of the Reserve for purposes of the situation assessments.

The procedure followed to classify the rivers is described in Section 2.6.2, below, and the use of the classifications to make rough estimates of the quantity of water required for the ecological component of the Reserve for each of the quaternary catchments in the WMA is described in Section 5.2.

2.6.2 River Classification

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

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

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

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

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

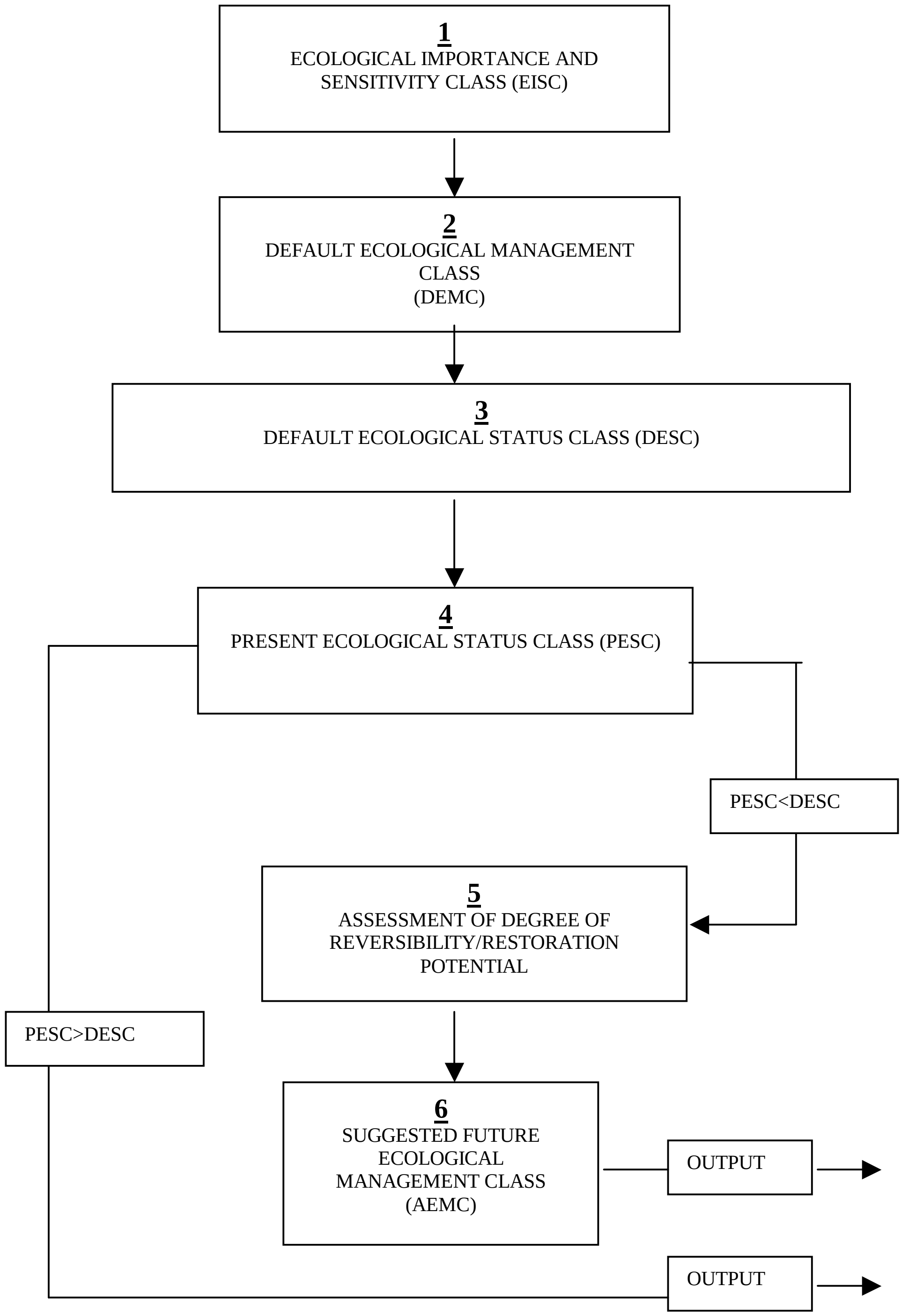

Diagram 2.6.2.1: Procedure followed to determine the river classifications

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

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

→: indicates relationship.

──▶: indicates possible direction of desirable change.

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

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

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

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

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

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

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

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

- The riparian zone has 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 also species diversity were 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.

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

Suggested Future Ecological Management Class (AEMC)
The potential to improve the ecological conditions was assessed only in terms of the present flow regime. Degradation of the system purely because of non-flow related changes was ignored.

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

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

2.6.3 Aquatic Ecosystems of Concern to the Study

It is important to recognise that within the context of the current report sensitive ecosystems refer specifically to ecosystems which are sensitive with respect to possible changes in water quantity and quality. Other sensitive ecosystems, specifically protected areas, are discussed in Section 2.6.4 below.

The Berg WMA derives its name from the Berg River which is the dominant river system within the WMA. The ecological significance/conservation importance of the river systems falling within the Berg WMA, as exemplified by their Ecological Importance and Sensitivity Classes (EISC), is summarised in Figures 2.6.3.1 to 2.6.3.3. These show respectively for each quaternary catchment, the default ecological management class, the present ecological status class, and the suggested future ecological management class. As outlined in Section 2.6.2, the EISC of a river is an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from the disturbance once it has occurred. The EISC leads to the DEMC shown on Figure 2.6.3.1. As evident from Figure 2.6.3.1, the river reaches within the Berg WMA exhibit the full range of EISCs from "low" to "very high" and the associated range of DEMCs. Some reaches of the Berg River (G10A, G10B, G10G, G10K) (Figure 2.6.3.1), are still in a relatively good condition, and accordingly exhibit a "high" EISC corresponding to a DEMC of Class B : largely natural. In particular, the communities of aquatic invertebrates in these reaches are of conservation significance, and consequently human manipulation of this system would require very strong motivation. In contrast, the lower reaches of the Berg River (G10C, G10F, G10J, G10L, G10M) and the coastal strip G21A-G21F have become considerably modified, and thus exhibit an EISC of "moderate" to "low" and have been allocated DEMCs of Class C : moderately modified or Class D : largely modified. The following modifications are evidently the most important in the degradation of the habitat integrity of the Berg River:

- Modification of the flow regime in the upper reaches due to an inter-basin transfer from the Theewaterskloof Dam. During summer this is also associated with a decrease in flow variability.
- A decrease in the summer flows in some reaches, also associated with an increase in flow variability.
- Deterioration in water quality due to farming, urban activities and inter-basin transfers.
- Destruction and modification of riparian zone by farming activities.
- Massive invasion by exotic riparian vegetation.
- Extensive modification of the stream bed due to farming activities in some reaches.
- Modification of stream channel by farming activities and exotic vegetation.

Another significant river system within the Berg WMA is the Diep River (G21C to G21F, Figure 2.6.3.1), which rises in the Riebeeck Kasteel area north-east of Cape Town, and flows into Table Bay via the Rietvlei Wetland Protected Natural Environment. The Diep River system is of metropolitan significance, and although moderately modified (as exemplified by its "low" EISC score and a DEMC of Class C : moderately modified), with some loss or change of natural habitat and biota, the basic ecosystem functioning is still intact. Accordingly, the system is recognised as a "core river earmarked for conservation" (Southern Waters, 1999) and is probably one of the most ecologically significant riverine systems within the Cape Metropolitan Area. The Rietvlei Wetland is a wetland of particular ecological significance, especially in terms of its avifauna as exemplified by its pending recognition as a RAMSAR wetland site and as a Provincial Nature Reserve.

The Cape Peninsula rivers (G22A and G22B) the upper reaches of the Eerste River (G22F) and the Steenbras River (G40A) are relatively unspoiled with DEMCs of Class A : unmodified, natural.

This overview of the ecological significance and conservation importance of the river systems within the Berg WMA is of necessity superficial. However, the assessment of the EISC and Default Ecological Management Classes for the various Quaternary Catchments (outlined in Section 2.6.2) involved the consideration of a range of ecological determinants, including : rare and endangered biota, unique biota, intolerant biota, species richness, diversity of habitat types or features, refuge value of habitat types, sensitivity to flow changes, sensitivity to water quality changes, migration route/corridor for instream and riparian biota and presence of conservation or natural areas. This information is summarised within the DWAF EcoInfo database, and accordingly this database should be consulted as a matter of course at the onset of any water utilisation and development projects, to provide insight into the ecological sensitivity of the environment which is likely to be impacted by the proposed project, particularly with respect to sensitive habitats and rare and endangered species.

The ecological sensitivity of aquatic systems other than rivers, including lakes, wetlands and groundwater systems, has to date not been assessed within the Berg WMA. Similarly, the estuarine systems are generally not well studied, but could be ecologically important and sensitive to reduced flows and changes in water quality, especially salinity. In this regard, the Berg River estuary is of major conservation importance, particularly from an avifaunal perspective. The habitat functioning depends to a great extent on floods inundating the flood plain that is adjacent to the estuary. The freshwater requirements of the estuary have been investigated (DWAF, 1994a) and the following recommendations made with regard to the necessary water release pattern flowing into the estuary :

- A constant base flow of 0,6 m^3/s. This translates to a volume of 1,5 million m^3 entering the estuary at the head of the tidal effect every month.
- A medium size flood between May and July of 200 m^3/s peak. This corresponds to a volume of 25 million m^3.
- A small flood in August or September of 50 m^3/s. This corresponds to a total volume of 15 million m^3.
- A large, uncontrolled flood expected once every five years with a peak of 600 m^3/s. This corresponds to a total volume of 70 to 100 million m^3.

Given its considerable ecological value, it is imperative that if any future development of the water resources in the Berg River catchment is considered, these freshwater requirements of the estuary be taken into account when ascertaining the environmental acceptability of the development.

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 Berg 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 Berg WMA. All water resource development and utilisation 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.

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 that he or she is familiar with the most recent status of protected areas within the Berg WMA.

TABLE 2.6.4.1: PROTECTED NATURAL AREAS AND NATURAL HERITAGE SITES WITHIN THE BERG WMA

AREA NAME	CATEGORY	GRID REFERENCE
Assegaaibosch Nature Reserve	Habitat and Wildlife Management Areas	33º57'S 18º54'E
Bainskloof	National Monument	33º35'S 19º08'E
Blouberg Nature Reserve	Habitat and Wildlife Management Areas	-
Cape Peninsula National Park	National Parks and Equivalent Reserves	34º05'S 18º25'E
Dassen Island	Scientific Reserves and Wilderness Areas	33º24'S 18º04'E
De La Fontaine	Natural Heritage Site	33º22'S 18º56'E
Divisie HK (Ou 6BKD)	Natural Heritage Site	33º53'S 18º32'E
Duikerklip (Hout Bay)	Habitat and Wildlife Management Areas	34º03'S 18º19'E
Duthie Reserve	Natural Heritage Site	33º55'S 18º53'E
Edith Stephen Nature Reserve	Natural Monuments and Areas of Cultural Significance	33º00'S 18º33'E
Elandsberg	Natural Heritage Site	33º27'S 19º03'E
Forest Hill	Natural Heritage Site	34º02'S 18º22'E
Groot Winterhoek State Forest	Habitat and Wildlife Management Areas	33º05'S 19º00'E
Groot Winterhoek Wilderness Area	Habitat and Wildlife Management Areas	33º05'S 19º00'E
Grootvadersbosch State Forest	Habitat and Wildlife Management Areas	-
Harmony Flats Nature Reserve	Habitat and Wildlife Management Areas	34º08'S 18º51'E
Helderberg Nature Reserve	Habitat and Wildlife Management Areas	34º00'S 18º52'E
Hottentots Holland Nature Reserve	Habitat and Wildlife Management Areas	34º00'S 19º00'E
Jacob's Rock	Natural Monuments and Areas of Cultural Significance	32º57'S 17º51'E
J N Bries-Louw Nature Reserve	Habitat and Wildlife Management Areas	33º45'S 18º49'E
Joostenberg Hill	Natural Heritage Site	33º46'S 18º47'E
Kirstenbosch National Botanical Garden	Natural Monuments and Areas of Cultural Significance	34º59'S 18º26'E
Klawer Valley	Natural Heritage Site	34º12'S 18º26'E
Klipheuwel Radio station	Natural Heritage Site	33º41'S 18º43'E
Koeberg Nature Reserve	Natural Heritage Site	33º39'S 18º26'E
Langebaan	RAMSAR Site	33º09'S 18º04'E
Langebaan - Jutten Island	RAMSAR Site	33º05'S 17º57'E
Langebaan - Malgas Island	RAMSAR Site	33º03'S 17º55'E
Langebaan - Marcus Island	RAMSAR Site	33º02'S 17º58'E
Lobster Sanctuary	Habitat and Wildlife Management Areas	33º50'S 18º25'E
Muldersvlei	Natural Heritage Site	33º49'S 18º49'E
Paarenberg Conservation Area	Natural Heritage Site	33º35'S 18º48'E
Paternoster Rocks	Natural Monuments and Areas of Cultural Significance	32º44'S 17º53'E
Plattekloof 430	Natural Heritage Site	33º52'S 18º33'E
Riverlands Nature Reserve	Habitat and Wildlife Management Areas	33º28'S 18º34'E
Robben Island	Natural Heritage Site	33º48'S 18º22'E
Robbesteen Nature Reserve	Natural Monuments and Areas of Cultural Significance	33º38'S 18º24'E
Saldanha Rock Lobster Sanctuary	Habitat and Wildlife Management Areas	33º02'S 17º58'E
Seal Island (False Bay)	Habitat and Wildlife Management Areas	34º08'S 18º34'E
Silverboomkloof	Natural Heritage Site	34º03'S 18º51'E
Silwerfontein	Natural Heritage Site	33º21'S 19º04'E
Steenboksberg	Natural Heritage Site	33º31'S 19º07'E
Tienie Versveld Nature Reserve	Natural Monuments and Areas of Cultural Significance	33º20'S 18º16'E
Voëlvlei Nature Reserve	Habitat and Wildlife Management Areas	33º21'S 19º00'E
Vondeling Island (Saldanha Bay)	Habitat and Wildlife Management Areas	33º09'S 17º58'E
Waterval Natural Heritage Site	Natural Heritage Site	33º15'S 19º00'E
Wemmershoekvlei	Natural Heritage Site	33º52'S 19º04'E
West Coast National Park	National Parks and Equivalent Reserves	33º12'S 18º08'E

2.7 CULTURAL AND HISTORICAL SITES

The purpose of this section is to highlight the need to take cognisance of any cultural or historical sites which may be present within the Berg WMA and accordingly could influence the further development and utilisation of water resources within this WMA. Cultural and historical sites can be broadly defined as natural or manmade areas that are associated with human activity and history, and which carry social, cultural, religious, spiritual or historic significance. Furthermore, sites of palaeontological significance contain fossilised human or animal remains. The National Heritage Resources Act (No. 25 of 1999) provides automatic protection for palaeontological, archaeological and historical sites and materials older than 60 years, and a permit is required before any alterations can be made to such artefacts.

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

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The water related infrastructure in the Berg WMA has been mainly developed to meet the water supply needs of the city of Cape Town and progressively for multi-purpose use, including the supply of small towns and supplies to farmers for irrigation.

Initially, Cape Town was dependent on the springs and streams on the slopes of Table Mountain and various wells scattered through the Municipality until 1852, when the De Waal Park reservoir was built. In 1890, a water treatment plant using water from Albion Spring was brought into operation. Later, in 1896, the Molteno Reservoir was built to store runoff from Table Mountain. The further development of the infrastructure in the Berg WMA is outlined below:

1897 - 1910	Construction of the five dams on Table Mountain for the Municipality of Cape Town.
1921	Completion of the construction of Steenbras Dam and the Steenbras pipeline conveying water to Molteno Reservoir.
1924	Raising of Steenbras Dam and laying of a second pipeline.
1934	The Constantia Nek Water Treatment Plant became operational, treating water from the Victoria, Alexandra and De Villiers Dams.
1948	Second raising of Steenbras and laying of a third pipeline.
1953 - 1958	Construction of Wemmershoek Scheme.
1956	Construction of the Berg River/Swartland Scheme.
1972	Construction of the Voëlvlei Scheme.
1978	Construction of the Berg/Saldanha Scheme.
1980	Construction of the Riviersonderend/Berg River Scheme.
1982	The Blackheath Water Treatment Plant came into operation, treating water from the Riviersonderend/Berg River Scheme.
1988	Construction of the Palmiet Scheme for water supply and hydro electricity. However only the hydro electricity scheme was in operation prior to 1999 when the first transfers of water for urban use were made.
1995	Construction of the Faure Water Treatment Works and associated pipelines from Steenbras Dam and from the Stellenbosch mountain tunnel outlet.
1997	The Palmiet Transfer Scheme was commissioned.

The Wemmershoek Dam was the last major dam constructed purely for water supply to Cape Town. Since then, the new dams constructed by the State or municipalities have been incorporated into multi-purpose schemes for the supply of urban centers, small towns and irrigation.

Numerous privately owned farm dams, with a combined storage capacity of about 104 million m^3 have been constructed to store water that is available during the wet winter months so that it can be used for irrigation during the dry summers. The earliest registered farm dam was constructed near Paarl in 1897, but the numbers remained fairly small until about 1950, when expanding opportunities for the export of fruit and wine resulted in a steady increase in the number of farm dams. The growth in the numbers of farm dams continued into the 1990s, but has almost stopped in recent years as a result of a decline in the fruit export market.

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

3.2.2 Methodology

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

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

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

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

- Household counts from the sampling database held by one of the participating consultants.
- Previous census results from 1970 onwards, including former homeland censuses.
- Estimates obtained from very large surveys such as that of the SAARF.

- The database of villages of the Directorate : Water Services of the Department of Water Affairs and Forestry.

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

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

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

3.2.3 Historical Population Growth Rate

Accurate historical population data for the WMA as a whole is not readily available. The reason for this is that the main sources of data are the national population censuses, for which published figures are available in terms of magisterial districts. As the boundaries of the latter do not coincide with the boundaries of the WMA, the population of the WMA can only be roughly estimated. Nevertheless, this information can be use to obtain an indication of the trends in population growth.

It appears from data extracted from population censuses and published by the Development Bank of Southern Africa (DBSA, 1991), that the average growth rate of the population in the Berg WMA between 1980 and 1990 was about 3,2% per year. The urban populations increased at 3.4% per year and the rural population at 1,4% per year.

3.2.4 Population Size and Distribution in 1995

In 1995, approximately 3 247 000 people lived in the Berg WMA. Of these, it is estimated that approximately 3 077 000 people lived in the urban or peri-urban areas and the rest in rural areas. The distribution of the population is shown in Table 3.2.4.1, where it can be seen that the population is concentrated in the Cape Peninsula, where 83% of the total population live. Only 5% of the population live in the Berg River catchment downstream of Voëlvlei (G10G to G10M), even though this region accounts for 51% of the total land area in the WMA. On Figure 3.2.4.1 the distribution and proportions of urban and rural population are shown by means of a pie diagram for each key area.

TABLE 3.2.4.1: POPULATION IN 1995

CATCHMENT				POPULATION IN 1995		
SECONDARY		TERTIARY / QUATERNARY		URBAN	RURAL	TOTAL
No.	Description	No.	Description			
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	164 142	53 156	217 298
		G10G to G10M	Berg River downstream of Voëlvlei	125 987	25 997	151 984
Sub-total (Berg River)				290 129	79 153	369 282
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	730	9 858	10 588
		G21C to G21F	Diep River	37 299	34 065	71 364
		G22E to G22K	Combined Kuils /Eerste/Lourens/ Sir Lowry Rivers	64 585	40 209	104 794
		G22A to G22D	Combined Cape Peninsula Rivers	2 684 687	5 764	2 690 451
Sub-total (Diep River and West Coast belt)				2 787 301	89 896	2 877 197
G4	Steenbras River	G40A	Steenbras catchment	0	563	563
TOTAL IN BERG WMA				**3 077 430**	**169 612**	**3 247 042**

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 Berg WMA in terms of the following aspects:

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

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

3.3.2 Data Sources

The information presented has been derived from a database of macroeconomic indicators that was prepared by Urban-Econ: Development Economists from a number of sources, including the Development Bank of Southern Africa. **Appendix B.2** contextualises each WMA economy in terms of its significance to the national economy, as derived from the national economic database. Only gross geographic product (GGP) and labour data are analysed. A brief description of the database of macro-economic indicators and associated economic information system is given in **Appendix B4.**

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

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

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

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

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

3.3.3 Methodology

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

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

- **Trade and Community Services**
  To take account of the subdivision of local authority areas by MD or WMA boundaries, the number of enumerator areas (EAs) falling within each subdivision of a local authority area, as a proportion of the total number of EAs in a local authority area, was determined. This proportion was applied to the latest population figure (1996 census) of each local authority area. As EAs are of approximately equal population size, these proportions were used to calculate the approximate population for that part of a local authority area which falls within each MD, as they are subdivided by WMA boundaries. The population of each MD segment, as a proportion of the total MD population, was used to calculate the proportion of a GGP figure which should be allocated to each segment of a MD, so that theses figures could be totalled up within the WMA boundaries.

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

3.3.4 Status of Economic Development

The GGP of the Berg WMA was R63,8 bn in 1997. The most important magisterial districts in terms of contribution to GGP in the Berg WMA are shown below :

- Cape 49,8%
- Bellville 14,8%
- Wynberg 9,3%
- Goodwood 5,5%
- Paarl 4,4%
- Malmesbury 4,3%
- Other 11,9%

Economic Profile
The composition of the Berg WMA economy is shown in Diagram 3.3.4.1. The most important sectors in terms of contribution to GGP are shown below :

- Manufacturing 25,4%
- Transport 20,6%
- Financial Services 17,6%
- Government 15,0%
- Other 21,4%

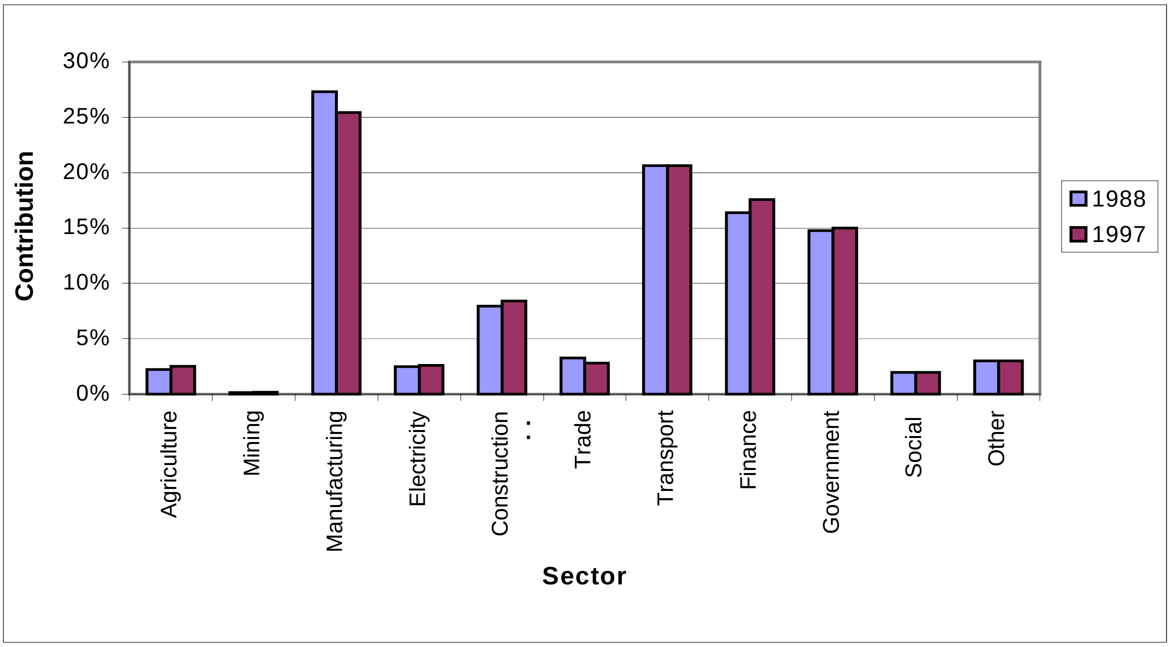

Diagram 3.3.4.1: Contribution by sector to economy of Berg Water Management Area, 1988 and 1997 (%)

The manufacturing sector has been undergoing structural changes over the past decade, moving from more labour intensive industries, such as food, textiles and clothing towards capital intensive industries such as paper and printing, chemicals and high-tech products. This can be ascribed to a number of factors such as difficulties with respect to adapting to the global market where products can now be imported at far more competitive prices. Manufacturing activities, however, still include some clothing and textile industries, and in addition, bottling, leather, fruit packaging and distribution. Iskor has recently brought a steel mill into operation at Saldanha Bay.

The importance of the transport sector can be attributed to the harbour and the import and export activities related to the harbour. The movement to and from provinces of goods also contributes to the importance of the transport sector.

The importance of the finance sector can be attributed to the increase and growth in the property market. It is also considered that the University of Stellenbosch and the associated financial services support the finance sector in this region. Finally, it should be noted that there is a strong linkage between the agricultural and finance sectors with respect to the financing of equipment and resources. The strong agricultural sector therefore has a positive impact on the finance sector.

The government services sector is strong due to the presence of a number of national, provincial, regional and local government institutions. This sector has, however, shown signs of decline in the previous decade.

Economic Growth

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

- Agriculture : 2,8%
- Mining : 2,9%
- Finance and Government : 2,2%
- Transport : 2,1%

Growth in the finance sector can be ascribed to the location of a number of corporate headquarters in the winelands region, such as Rembrandt, Medi-Clinic Corporation, Distillers Corporation, Stellenbosch Farmers Winery, Bonita Holdings, Sekunjalo Investments, KWV Investments, SASKO, Boland PKS, SA Dried Fruit and the Western Cape Agriculture Union.

Agricultural products from the Winelands are in demand across the world and it is expected that the situation will become even more favourable once trade agreements with the European Union have been finalised.

With respect to the manufacturing sector, small, medium and micro enterprise (SMME) activities are growing rapidly and are absorbing a fairly large portion of retrenched workers. The favourable government attitude towards SMME activities would possibly play a role in the promotion and strengthening of this component of manufacturing activities. It is also expected that growth will occur in this sector due to the expected increase in local and international demand for fruit and wine products from this region.

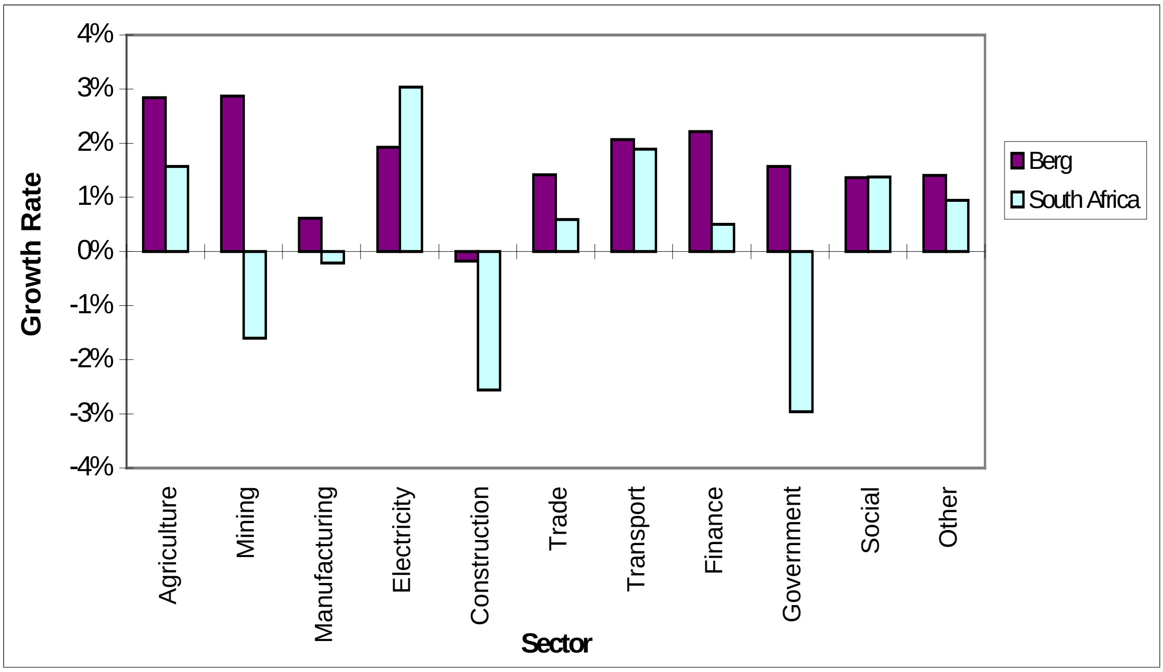

Diagram 3.3.4.2: Compound annual economic growth by sector of Berg Water Management Area and South Africa, 1988-1997

Labour

Of the total labour force of 1,3m in 1994, 19% were unemployed, which is lower than the national average of 29,3%. Sixty two percent (62%) were active in the formal economy. Thirty percent (30%) of the formally employed labour force worked for government. The second largest percentage, 26,1%, were involved in manufacturing, and 13,9% in trade.

Employment growth was recorded in the agriculture sector (2,0% per annum); mining sector (5,4% per annum); financial services (4,3% per annum); the government sector (1,8% per annum); manufacturing (1,0% per annum); construction (2,2% per annum) and the trade sector (1,5% per annum).

3.3.5 Comparative Advantages

A comparative advantage of a particular region indicates that the economy poses a relatively more competitive production function for a specific product or service than other regions in the aggregate economy (e.g. South Africa). A comparative advantage may be measured by means of a location quotient, which compares the economic sector's share in gross geographic product (GGP) with its percentage share in some basic aggregate, such as gross national product (GNP). A value of more than one implies that the region has a comparative advantage in a specific production function *vis-à-vis* the rest of South Africa.

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

- Transport : 2,7
- Construction : 2,9
- Finance : 1,4
- Manufacturing : 1,3

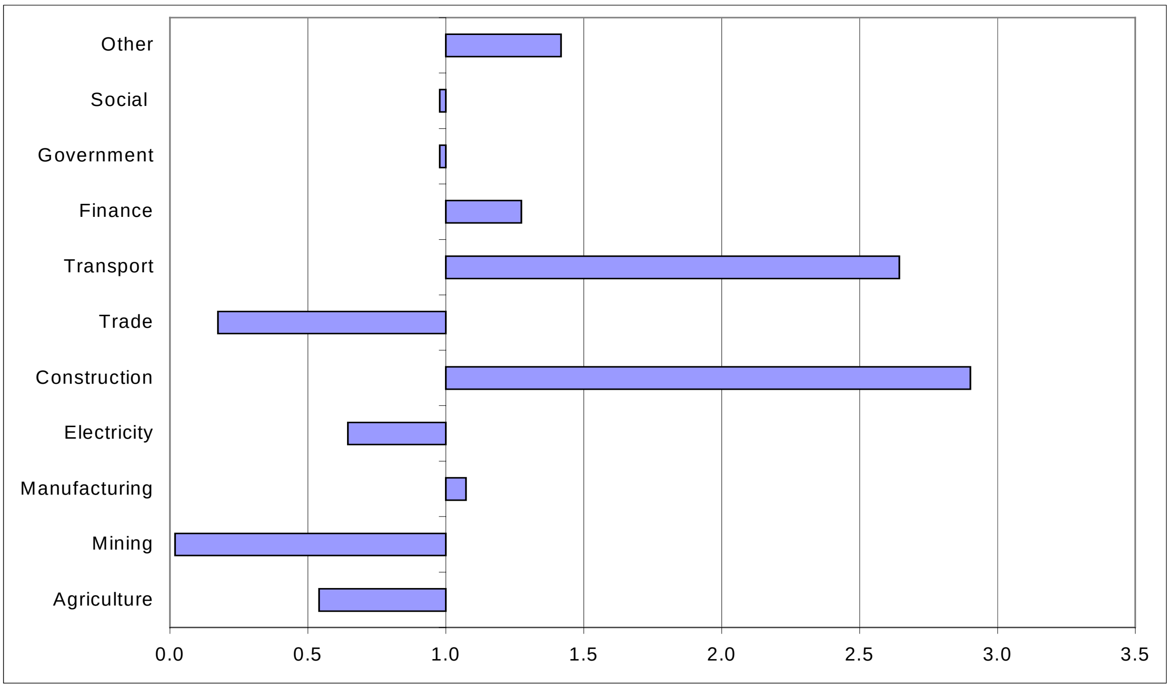

Diagram 3.3.5.1: Berg gross geographic product location quotient by sector, 1997

The finance sector has grown over the past decade due to the Cape Metropolitan Area's comparative advantage as a national financial service centre, its ability to benefit from the global expansion in this sector as well as the migration of finance firms and other business services from Gauteng to the CMA. In addition, the growth in property and insurance markets has contributed to growth in this sector.

The comparative advantages of the transport sector can be attributed to the major national road links feeding into the area, the Cape Town International Airport and Harbour. The transport sector has important forward and backward linkages with other sectors, such as the manufacturing sector. These links are strengthened due to international trade via the airport and harbour and the fact that the CMA accommodates beneficiation plants that serve a sizeable region.

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 of 1956, which also placed a major emphasis on the use of water for irrigation, although other water uses, such as domestic, urban and industrial, also received recognition.

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

3.4.2 National Water Act

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

- The riparian principle is done away with. The nation's water resources become common property, belonging to the nation as a whole. Therefore the previous concept of private ownership in water is done away with;
- The national government, through the Minister of Water Affairs and Forestry, becomes responsible as the public trustee of all water resources to ensure that water resources are protected and water allocated equitably and used beneficially in the public interest. Therefore the NWA reflects the constitutional right of access to sufficient water (Section 27 of the Constitution);
- All right to use water derives from the NWA;
- Water must be available for the Reserve. The Reserve is a new concept and consists of two legs, namely the quantity and quality of water required to satisfy basic human needs as prescribed by the Water Services Act (Act No 108 of 1997) for people who

now or will in future require water and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Thus environmental considerations are anchored in the NWA;

- Setting out in the purposes of the Act that institutions which have appropriate community, racial and gender representation must be developed to give effect to the NWA;
- Shifts the emphasis from the traditional "supply management" approach towards "demand management", that is conservation of the nation's water resources by lessening the demand and providing for an innovative pricing system.
- Providing for extensive public participation. Virtually no decision can be made without public participation;
- The abolishment of the Water Courts and introducing a Water Tribunal where administrative final decisions can be appealed to; and
- Recognition of international obligations.

3.4.3 Strategies

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

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

3.4.4 Environmental Protection

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 (Act No. 108 of 1997).

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

3.4.5 Recognition of Entitlements

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

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

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

3.4.6 Licensing

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

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

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

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

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

Compensation must be claimed from the Water Tribunal.

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

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

3.4.7 Other Legislation

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

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

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

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

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

These Acts are the following :

Physical Planning Act (Act No. 125 of 1991)
Under this act no land use, development or subdivision may be permitted unless in accordance with an approved plan.

Development Facilitation Act (Act No. 67 of 1995)
This act prescribes the set of principles with which all development projects and all land use and land use planning should comply, and which will serve as guidelines for the administration of land use and development schemes.

Restitution of Land Rights (Act No. 22 of 1994)
This act is aimed at the restitution of land to those who have been deprived thereof in terms of discriminatory laws. Claims are lodged with the Land Claims Commission. It is because of this act that when a transfer of water entitlements is approved in terms of the NWA an indemnity is required from the transferor that a claim was not lodged against the land in terms of the Restitution of Land Rights Act.

Environmental Conservation Act (Act No. 73 of 1989)
This act provides for the effective protection and control of the environment. It makes provision for the declaration of an environmental conservation policy.

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

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

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

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

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

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

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

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

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

Chapter 7 of this act relates to environmental damage, duty of care, emergencies and remediation.

Conservation of Agriculture Resources Act (Act No. 43 of 1983)
This act is to provide for control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil; the water resources and vegetation and the combating of weeds and invader plants. Except for weeds and invader plants, this act does not apply to land in an urban area.

3.4.8 Institutions Created Under the National Water Act

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

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

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

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

(i) Water Services Authorities, which are municipalities, including district or rural councils, that are responsible for ensuring access to water services.

(ii) Water Boards, which may be established by the Minister of Water Affairs and Forestry, after due consultation with stakeholders, for the primary purpose of providing water services to other water services institutions.

(iii) Water Services Committees, which may be established by the Minister of Water Affairs and Forestry to provide water services to communities within their own service areas where the Water Services Authorities having jurisdiction in the areas in question are unable to provide water services effectively.

(iv) The Provincial Government, which may take over the functions of a Water Services Committee or a Water Board, if requested to do so by the Minister of Water Affairs and Forestry

(v) Advisory Committees, which may be appointed by the Minister of Water Affairs and Forestry to provide advice on matters falling within the scope of the Act.

The municipalities were restructured in the year 2000. As this report deals with the period prior to that, only the institutional arrangements prior to the re-restructuring are reported on here. Thus, the Water Services Authorities prior to the restructuring were:

- Cape Metropolitan Council
- Winelands District Council
- West Coast District Council
- Breede River District Council

The boundaries of the areas of jurisdiction of the District Councils are shown on Figure 3.4.8.1. For general administrative purposes, but not for water supply, the country is subdivided into magisterial districts, the boundaries of which are also shown on Figure 3.4.8.1. Several magisterial districts fall within each District Council area. In the Berg WMA the boundaries of all the magisterial districts do not correspond exactly to the boundaries of the District Councils.

The relevant magisterial districts are:

- Within the Cape Metropolitan Council Area
  - Simon's Town
  - Wynberg
  - Goodwood
  - Cape
  - Bellville
  - Kuils River
  - Mitchells Plain
  - Somerset West
  - Strand
  - Malmesbury (part)
- Within the Wineland District Council Area
  - Paarl
  - Stellenbosch
  - Wellington
  - Bellville (part)
  - Malmesbury (part)
  - Kuils River (part)
  - Somerset West (part)
- Within the West Coast District Council Area
  - Malmesbury
  - Piketberg (part)
  - Hopefield
  - Moorreesburg

  - Vredenburg
- Within the Breede River District Council Area
  - Tulbagh

Within the District Council areas, Transitional Local Councils were responsible for water services to towns and Transitional Regional Councils were responsible for water services in sub-divisions of the rural areas. The boundaries of these areas are shown on Figure 3.4.8.2.

3.5 LAND-USE

3.5.1 Introduction

The Berg WMA covers an area of approximately 13 000 km^2. Figure 2.2.1 shows the spatial variability in mean annual precipitation between the upper and lower Berg River catchments. Both irrigated and dryland cultivation is extensive in this WMA, with the latter being most predominant in the lower Berg River catchments.

Land use is summarised in Table 3.5.1.1, where it can be seen that an estimated 1560 km^2 is used for dryland cultivation. This area was interpreted from land cover maps derived from satellite images (CSIR, 1999). These areas are only indicative of the area cultivated, which can be expected to vary considerably from year to year, depending on climatic conditions.

Table 3.5.1.1 has a column for dryland sugar cane. This crop causes a reduction in river low flows where it is found on a large scale. It is therefore of interest in the analysis of water resources. However, sugar cane is not grown on a commercial scale in the Berg WMA.

Grapes, deciduous fruit, lucerne and pasture are grown on a large scale under irrigation on an estimated 563 km^2.

Commercial timber plantations cover approximately 120 km^2 in the high lying south east mountainous areas.

Urban areas cover approximately 558 km^2, of which 455 km^2 occurs in the Cape Metropolitan Area. The boundaries of the Cape Metropolitan Area are shown on Figure 3.4.8.1.

Several nature reserves have been proclaimed and their boundaries are shown on Figure 3.5.1.1, which also shows the extent of irrigation and afforestation in each key area by means of a pie diagram.

There are no significant mining operations in the Berg WMA.

Land use by district council is shown in Table 3.5.1.2.

TABLE 3.5.1.1: LAND USE BY DRAINAGE AREA

DRAINAGE AREA	IRRIGATION (km^2)	DRYLAND SUGAR CANE (km^2)	OTHER DRYLAND CROPS (km^2)	AFFORESTATION (km^2)	NATURE RESERVES (km^2)	URBAN (km^2)	OTHER (km^2)	TOTAL AREA (km^2)
Berg River upstream of Voëlvlei (G10A-F)	301,3	0	122,6	75,5	110,0	31,6	1606,0	2247,0
Berg River downstream of Voëlvlei (G10G-M)	92,9	0	744,1	1,6	168,0	31,9	5626,5	6665,0
Subtotal Berg River (G10A-M)	**394,2**	**0**	**866,7**	**77,1**	**278,0**	**63,5**	**7232,5**	**8912,0**
Combined West Coast Rivers (G21A &B)	0,0	0	98,6	0,0	75,1	15,2	638,1	827,0
Diep River (G21C-F)	67,8	0	591,1	2,4	0,6	24,5	814,6	1501,0
Combined Kuils/ Eerste/ Lourens/Sir Lowry Rivers (G22E-K)	87,1	0	0,3	20,4	64,9	130,1	575,1	878,0
Combined Cape Peninsula Rivers (G22A-D)	13,9	0	2,5	11,2	142,7	325,0	351,7	847,0
Steenbras River (G40A)	0,0	0	0	8,6	1,4	0,0	62,0	72,0
TOTAL BERG WMA	**563,0**	**0**	**1559,2**	**119,7**	**562,7**	**558,3**	**9674,0**	**13037,0**

TABLE 3.5.1.2: LAND USE BY DISTRICT COUNCIL AREA

TYPES OF LAND USE	CAPE METROPOLITAN COUNCIL (km^2)	WINELANDS DISTRICT COUNCIL (km^2)	WEST COAST DISTRICT COUNCIL (km^2)	BREEDE RIVER DISTRICT COUNCIL (km^2)	OVERBERG DISTRICT COUNCIL (km^2)	TOTAL AREA (km^2)
Irrigation	61	318	135	49	0.0	563
Dryland Sugar Cane	0	0	0	0	0	0
Other Dryland Crops	198	295	1 018	48	0	1 559
Afforestation	30	65	4	20	1	120
Nature Reserves (1)	209	93	228	33	0	563
Urban Areas	440	75	40	3	0	558
Other (2)	1 200	1 471	6 456	547	0	9 674
TOTALS	2 138	2 317	7 881	700	1	13 037

1. Includes National Parks, wilderness areas, etc
2. Includes all other areas

3.5.2 Irrigation

Table 3.5.2.1 shows the distribution of irrigated land within the WMA and an estimate of the average areas of the different types of crops harvested. This information was obtained from earlier studies carried out in the area and from information provided by the Western Cape Province Department of Agriculture, and from DWAF officials who work in the area.

The various sources provided very different figures for the areas of the different types of crops. Consequently, the crop mix suggested in discussions with the DWAF officials has been used. Nevertheless, confidence in the accuracy of the areas of individual crops shown in Table 3.5.2.1 is low and the information should be used with caution. The values for the total irrigated areas are thought to be reasonably reliable. There is little double cropping of irrigated land in the WMA and the area of land irrigated does not vary greatly from year to year because it is governed by the quantity of winter runoff that can be stored at the fairly high assurance of supply required for the high value crops that are widely grown. Therefore, the total irrigated area and the total harvested area are estimated to be equal.

It is generally recognised that the future growth in irrigation will be severely limited by the availability of water and the profitability of the crops grown. This may be further compounded by the need to meet growing requirements of domestic and urban water use, which could lead to increasingly frequent water restrictions. These might adversely affect the quality and quantity of fruit grown for export leading to the loss of overseas markets for the fruit. It will, therefore, be necessary to base decisions on sound economic principles that include the economic return per unit of water. Although acknowledged to be fairly generalised, it is suggested that only three assurance categories of irrigated crops be used for this purpose. These assurance categories also represent an appropriate grouping for the purpose of assurance of irrigation water supply. Table 3.5.2.2. shows the typical crops within each category.

The extent of the irrigation is shown on Figure 3.5.1.1 and in Table 3.5.2.1.

The irrigation methods used for a specific crop type do not vary significantly between different catchments. Sprinkler systems are used on field crops and micro systems on row crops.

TABLE 3.5.2.1: IRRIGATION LAND-USE

CATCHMENT				TOTAL IRRIGATED AREA (km^2)	ESTIMATED HARVESTED AREAS OF CROP TYPES (km^2) [(1)]							
SECONDARY		TERTIARY / QUATERNARY			Deciduous Fruit	Grapes (Wine, Table, Raisins)	Citrus	Lucerne and Pasture	Potatoes	Other Vegetables	Other Crops	TOTAL
No.	Description	No.	Description									
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	301,3	13,2	184,8	0	101,9	0	0	1,4	301,3
		G10G to G10M	Berg River downstream of Voëlvlei	92,9	3,9	2,8	0,1	85,4		0,7		92,9
Sub-total (Berg River)				**394,2**	**17,1**	**187,6**	**0,1**	**187,3**	**0**	**0,7**	**1,4**	**394,2**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	0	0	0	0	0	0	0	0	0
		G21C to G21F	Diep River	67,8	0,1	7,2	0	60,2	0	0,3	0	67,8
		G22E to G22K	Combined Kuils /Eerste/Lourens/ Sir Lowry Rivers	87,1	4,0	83,0	0	0,1	0	0	0	87,1
		G22A to G22D	Combined Cape Peninsula Rivers	13,9	0	2,3	0	2,5	0	9,1	0	13,9
Sub-total (Diep River and West Coast belt)				**168,8**	**4,1**	**92,5**	**0**	**62,8**	**0**	**9,4**	**0**	**168,8**
G4	Steenbras River	G40A	Steenbras River	0	0	0	0	0	0	0	0	0
TOTAL IN BERG WMA				**563,0**	**21,2**	**280,1**	**0,1**	**250,1**	**0**	**10,1**	**1,4**	**563,0**

1. Areas of crop types are based on information provided by the Western Cape Department of Agriculture modified in accordance with information provided by officials of the DWAF Western Cape Regional Office. The total irrigated areas are thought to be reasonably accurate, but the distribution of crop types is at a low level of confidence.

TABLE 3.5.2.2: ASSURANCE OF IRRIGATION WATER FOR CROP TYPES

CATEGORY	CROP EXAMPLES
Low	Lucerne and pasture for small stock
Medium	Vegetables, potatoes, lucerne and pasture for dairying
High	Citrus, deciduous fruit, grapes and speciality vegetables

Berg River upstream of Voëlvlei Dam (G10A - G10F)
The Berg River rises in the mountains formed of geological strata of the Table Mountain Group, along the south-east boundary of the WMA (G10A and G10B) and flows north by-passing Voëlvlei Dam (off-stream storage dam). This portion of the Berg River catchment is intensively cultivated with an estimated 30 130 ha under irrigation. The greater portion of this irrigated land is under vines (18 480 ha) and lucerne and pasture (10 190 ha).

During winter, water abstracted from the Berg River is transferred into Theewaterskloof Dam. In summer, releases from Theewaterskloof back into the Berg River are used for irrigation in the Berg and Eerste River catchments.

Berg River downstream of Voëlvlei Dam (G10G - G10M)
Downstream of Voëlvlei Dam, the climate gradually becomes more dry. Fewer vineyards are found, whilst lucerne and pasture become the more predominant crops. Of the 9 300 ha of land under irrigation, 8 540 ha is under lucerne and pasture. Dryland grain farming, with wheat predominating in the Swartland, occurs on a large scale.

Releases from Voëlvlei Dam supply water to irrigators along the middle and lower Berg River.

The West Coast (G21A and G21B)
This area falls within the lower rainfall regions of the WMA and within the sandy soils of the West coast. Consequently there is no irrigation on a significant scale because there is insufficient water.

Diep River (G21C - G21F)
The mean annual precipitation across this catchment varies between 400 mm and 600 mm. Approximately 6 800 ha of land are under irrigation, of which 720 ha are under grapes and 6 000 ha are under lucerne and pasture. The remainder includes small areas of deciduous fruit and vegetables.

Kuils / Eerste / Lourens and Sir Lowry Rivers (G22E - G22K)
The mean annual precipitation increases from 600 mm in the west to 1 500 mm in the east. Deciduous fruit (400 ha) and grapes (8 300 ha) are the predominant crops of the total 8 700 ha under irrigation. During summer, releases from Theewaterskloof Dam into the Eerste River, via the Kleinplaas balancing dam, provide water for irrigation along the Eerste River.

Peninsula rivers (G22A - G22D)
Approximately 1 400 ha of cultivated land are under irrigation. The predominant crops are vegetables (900 ha), grapes (250 ha) and lucerne and pasture (250 ha). The Cape Flats Aquifer provides water for irrigation.

3.5.3 Dryland Farming

Mainly grain crops, with wheat predominating are grown under dryland conditions in the Lower Berg River catchments, the catchments of the West Coast rivers and the Diep River catchment. Grapes for wine are also grown in the Lower Berg River catchments, as well as in the upper Berg River area, the Cape Peninsula and the catchments of the Kuils, Eerste, Lourens and Sir Lowry Rivers. There is also some dryland cultivation of fruit orchards in these catchments. Information obtained from land use maps derived from satellite images (CSIR, 1999), provided an indication of dryland cultivation areas. A total area under dryland cultivation of 156 000 ha was estimated. Because of the small scale of images, this area probably includes roads and other uncultivated areas between fields. As a result the actual area under crops is likely to be about half of the area shown. The distribution of the dryland farming areas within the Berg WMA is shown in Table 3.5.1.1. As mentioned earlier, no dryland sugar cane is commercially grown.

3.5.4 Livestock and Game Farming

The distribution of the main types of livestock found in the WMA is shown in Table 3.5.4.1, which also shows the Equivalent Large Stock Units (ELSU). ELSU are used to measure the water requirements of livestock. Each ELSU is equivalent to 0,85 head of cattle, 1 horse, 6,5 sheep, or 4 pigs. A detailed table for use in converting mature livestock and game populations to ELSU is included in Appendix D.

The numbers of livestock shown in Table 3.5.4.1 are approximate only because the information was obtained from the 1994 livestock census (Department of Agriculture, 1994), which gives information in terms of magisterial districts and not hydrological catchments. The data was converted to hydrological catchments by assuming the distribution of livestock to be proportional to the land area.

The estimated total number of livestock in the Berg WMA is approximately 297 000. Of this, 67% consist of sheep, 14% of cattle, 14% of pigs and the remaining 5% of horses and goats.

The distribution of livestock per key area, is shown diagrammatically on Figure 3.5.4.1.

No information on numbers of game or numbers of ostriches were obtained. The numbers are thought to be small.

TABLE 3.5.4.1: LIVESTOCK AND GAME

CATCHMENT					NUMBERS OF LIVESTOCK AND GAME [1]						NO. OF ELSU
SECONDARY		TERTIARY / QUATERNARY			Cattle	Sheep	Goats	Horses	Donkeys / Mules	Pigs	
No.	Description	No.	Description	Area (km^2)							
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	2 247	6 797	34 927	2 483	665	45	9 176	14 587
		G10G to G10M	Berg River downstream of Voëlvlei	6 665	17 260	106 116	1 047	814	98	8 626	34 257
Sub-total (Berg River)				**8 912**	**24 057**	**141 043**	**3 530**	**1 479**	**143**	**17 802**	**48 844**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	827	3 167	17 727	131	346	18	2 176	6 352
		G21C to G21F	Diep River	1 501	8 578	29 192	491	1 198	29	5 317	14 427
		G22E to G22K	Combined Kuils /Eerste/Lourens/ Sir Lowry Rivers	878	3 750	8 916	204	918	43	11 905	8 536
		G22A to G22D	Combined Cape Peninsula Rivers	847	2 773	2 354	221	1 893	11	5 979	6 157
Sub-total (Diep River and West Coast belt)				**4 053**	**18 268**	**58 189**	**1 047**	**4 355**	**101**	**25 377**	**35 472**
G4	Steenbras River	G40A	Steenbras catchment	72	487	356	36	146	9	333	713
TOTAL IN BERG WMA				**13 037**	**42 812**	**199 588**	**4 613**	**5 980**	**253**	**43 512**	**85 029**

- No information on numbers of game or ostriches was obtained, but the numbers are thought to be small.

3.5.5 Afforestation

No significant areas of indigenous forest are found within the Berg WMA, but there are small areas on the mountain ranges.

Approximately 120 km^2 of commercial afforestation occurs within the WMA (see Figure 3.5.1.1.). The predominant areas in which afforestation is found are:

- The Upper Berg River catchments (G10A and G10E)
- The Lourens and Steenbras River Catchments (G22J and G40A)

The distribution of afforestation is shown in Table 3.5.5.1 where it can be seen that pine is the main species grown. The total area of afforestation occupies less than 1% of the land area of the WMA.

TABLE 3.5.5.1: AREAS OF AFFORESTATION

CATCHMENT				AREAS OF AFFORESTATION			
SECONDARY		TERTIARY / QUATERNARY					
No.	Description	No.	Description	EUCALYPTUS (km^2)	PINE (km^2)	WATTLE (km^2)	TOTAL (km^2)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	2,5	73,0	0	75,5
		G10G to G10M	Berg River downstream of Voëlvlei	0	1,6	0	1,6
Sub-total (Berg River)				**2,5**	**74,6**	**0**	**77,1**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	0	0	0	0
		G21C to G21F	Diep River	0	2,5	0	2,5
		G22E to G22K	Combined Kuils/Eerste/ Lourens/Sir Lowry Rivers	0	20,4	0	20,4
		G22A to G22D	Combined Cape Peninsula Rivers	0,1	11,1	0	11,2
Sub-total (Diep River and West Coast belt)				**0,1**	**34,0**	**0**	**34,1**
G4	Steenbras River	G40A	Steenbras catchment	0	8,6	0	8,6
Sub-total (Steenbras River)				**0**	**8,6**	**0**	**8,6**
TOTAL IN BERG WMA				**2,6**	**117,2**	**0**	**119,8**

3.5.6 Alien Vegetation

The impacts of the widespread infestations by alien plants in South Africa are increasingly recognised. The total incremental water use of invading alien plants was estimated at 3 300 million m³/a by Le Maitre *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 Maitre *et al* (1999) estimate that the impact will increase significantly in the next 5 to 10 years, resulting in the loss of much, or possibly even all, of the available water in certain catchment areas. Again, this is a debatable point requiring more research to verify these statements.

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

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

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

Areas invaded by alien vegetation were mapped as independent polygons with each polygon accompanied by attribute data regarding species and density. All polygons and attribute data were captured in a GIS (Arc/Info).

The following shortcomings and limitations of the CSIR database 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.

Estimated areas of alien vegetation per key area are shown in Table 3.5.6.1. The values are for condensed areas, which are the equivalent areas that the alien vegetation would occupy if it were condensed to provide completely closed canopy cover.

TABLE 3.5.6.1: INFESTATION BY ALIEN VEGETATION

CATCHMENT				
SECONDARY		**TERTIARY / QUATERNARY**		
No.	**Description**	**No.**	**Description**	**Area (km^2)**
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	88,6
		G10G to G10M	Berg River downstream of Voëlvlei	930,3
Sub-total (Berg River)				**1018,9**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	202,7
		G21C to G21F	Diep River	94,1
		G22E to G22K	Combined Kuils /Eerste/Lourens/ Sir Lowry Rivers	18,6
		G22A to G22D	Combined Cape Peninsula Rivers	40,9
Sub-total (Diep River and West Coast belt)				**356,3**
G4	Steenbras River	G40A	Steenbras catchment	0,2
TOTAL IN BERG WMA				**1375,4**

As illustrated, alien infestation is found, in varying degrees, throughout the WMA. The most severely affected regions are the Lower Berg and the West Coast catchments.

It is of interest to note that the total condensed area of alien vegetation is more than 10 times greater than the area of afforestation.

In the year 2000 a total of 13 alien vegetation eradication projects were underway in the WMA as part of the Working for Water Programme. The budget for these projects was R13 million.

3.5.7 Urban Areas

Urban areas obtained from the CSIR land-use maps (CSIR, 1999) total 560 km^2, which is less than 5% of the total land area in the Berg WMA. Although the urban areas are small in relation to the whole WMA, the concentration is largely within the Cape Metropolitan Area. Approximately 20% of the land area in this district is occupied by urban development.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

The manufacturing industry contributes 25% of the total economy in the Berg WMA, but it is made up of numerous relatively small industries situated in the urban areas. Iscor brought a large steel mill into operation at Saldanha Bay in 1997 and Armscor has a factory of significant size at Krantzkop, as shown on Figure 3.5.1.1.

The power stations found within the Berg WMA are listed in Table 3.6.1 and shown on Figure 3.5.1.1.

TABLE 3.6.1: POWER STATIONS IN THE BERG WMA

QUATERNARY CATCHMENT	NAME	TYPE	GENERATING CAPACITY (MW)	OWNER
G21B	Koeberg	Nuclear	1 930	ESKOM
G22D	Athlone	Coal	180	ESKOM
G22K	Steenbras	Pumped storage	180	City of Cape Town

Koeberg Nuclear powerstation draws cooling water from the Atlantic Ocean and is not dependent on an inland water source. Athlone serves as a supplier of peaking power and does not generate on a continuous basis. The Steenbras Pumped Storage Scheme is described in more detail in Section 4.5.

3.7 MINES

With the exception of quarrying operations for building materials, no mining activity is found in the Berg WMA.

3.8 WATER RELATED INFRASTRUCTURE

A background to the historical development of the water related infrastructure in the Berg WMA is given in Section 3.1.

Urban and rural water supplies were generally adequate in 1995 and infrastructure for irrigation, both private and State owned, is well developed. The water related infrastructure is described in detail in Chapter 4.

CHAPTER 4: WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The Berg Water Management Area serves the largest urban population in the Western Cape Province as it contains the Cape Metropolitan Area which had a population of 2,7 million people in 1995. It also contains the Winelands District Municipality area, a significant part of the West Coast District Municipality area and a small part of the Breede River District Municipality area. In the latter three areas, agriculture is the dominant land-use activity. The District Municipalities were called District Councils in 1995.

The main components of infrastructure for the water supply were owned either by the City of Cape Town or DWAF in 1995 with substantial infrastructure in the form of canals, pipelines and small dams owned by irrigation boards. Ownership of the infrastructure that belonged to the City of Cape Town has since passed to the metropolitan council for the area which is known as the City of Cape Town CMC - Administration. The main water supply schemes are :

- The Table Mountain and Southern Peninsula Schemes owned by the City of Cape Town.
- The Steenbras Water Supply Scheme owned by the City of Cape Town.
- The Wemmershoek Water Supply Scheme owned by the City of Cape Town.
- The Voëlvlei Government Water Supply Scheme owned by DWAF, but with some of the treatment works and distribution pipelines owned by the City of Cape Town.
- The Riviersonderend/Berg River Government Water Supply Scheme owned by DWAF.
- The Berg River Saldanha and Swartland Government Water Schemes owned by DWAF and operated by the West Coast District Municipality.

Municipalities which have their own sources (Stellenbosch, Paarl and Wellington, for example) are often augmented by the City of Cape Town supplies.

Most schemes utilise surface water. Groundwater supplies the town of Atlantis, while four boreholes are used to augment the supply to Somerset West.

Large quantities of water are imported from the Breede River WMA to augment supplies from sources within the Berg WMA. This is done by means of the Riviersonderend/Berg River Government Water Supply Scheme which acquires most of its water from the Theewaterskloof Dam in the Breede WMA through a system of tunnels. The scheme is further described in Section 4.2.

The Palmiet River Government Water Supply Scheme, which also transfers water from the Breede WMA to the Berg WMA, was not operational in 1995.

In addition, smaller quantities of water for agricultural use are imported from the Witte River near Wellington and the Breede River near Wolseley. Water for the town of Franschhoek is imported from the Du Toits River, which is also in the Breede WMA.

The combined capacities of individual town and regional water supply schemes in the Berg WMA totalled 336 million m^3/a in 1995 and provided water to an estimated 95% of the population, as shown in Table 4.1.1.

The cumulative capacity shown in Table 4.1.1 is based on the lesser of the yield of the raw water source or the capacity of treatment works in each of the town or regional water supply schemes shown on Table 4.1.2.

Reliable data on capacities of water supply schemes and the number of people supplied was not available for all the schemes. Therefore, the information shown in Table 4.1.1 should be regarded as indicative only of the true situation.

Table 4.1.1 shows the average availability of water to those supplied by town or regional schemes to have been 292 ℓ/c/d. A significant portion of this quantity was, in fact, used for industrial purposes. The value is, nevertheless, high enough to suggest that water supplies for human needs are generally adequate in terms of the Reconstruction and Development Programme minimum requirement of 25 ℓ/c/d. Notwithstanding this, the water distribution infrastructure in some urban areas was inadequate in 1995, with the result that some 260 000 people (8% of the population of the WMA) did not have access to 25 ℓ/c/d of potable water (DWAF, 2000d).

Table 4.1.1 shows a total scheme capacity of 336 million m^3/a, which is less than the urban and rural domestic water requirements of 362 million m^3/a shown in Table 5.1.1 in Chapter 5. The shortfall is in the formal allocations of raw water to urban use. In practice, however, the shortfall is made up by additional water that is made available from unused allocations to agriculture from Voëlvlei and Theewaterskloof Dams. The capacities of water treatment works listed in Table 4.2.2 total 1 714 Mℓ/d, which, assuming a peak factor of 1,6, can supply an average annual requirement of 390 million m^3. Therefore, treatment capacity was more than adequate in 1995.

Table 4.1.1 also shows statistics on potable water supply schemes on a district council basis, and the main features of the water-related infrastructure are shown on Figure 4.1.1.

TABLE 4.1.1: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES IN 1995 BY DISTRICT COUNCIL AREAS

PROVINCE	DISTRICT COUNCIL AREA	AREA (km^2)	POPULATION	TOWN AND REGIONAL WATER SUPPLY SCHEMES			
				Number of People Supplied	% of Population	CAPACITY (million m^3/a)	CAPACITY (ℓ/c/d)
Western Cape	Cape Metro	2 113	2 726 444	2 698 000	99	300	302
	Winelands	2 298	298 611	227 000	76	14	169
	West Coast	7 862	203 674	170 000	83	20	322
	Breede River	754	18 313	6 000	33	1	456
TOTAL FOR WMA		**13 037**	**3 247 042**	**3 101 000**	**95**	**335**	**292**

The portion of the population not supplied by the individual town or the regional water supply schemes is the rural population living mainly on farms that rely on their own private water supplies from local sources.

Agriculture accounts for some 33% of the total water requirements in the WMA. Water use in this sector is mainly for irrigation and infrastructure for this purpose is highly developed as described in Section 4.3.

TABLE 4.1.2: POTABLE WATER SUPPLY SCHEMES IN THE BERG WMA

SCHEME NAME	RAW WATER SOURCE	POPULATION [1] SUPPLIED	SCHEME CAPACITY	
			million m^3/a	Limiting factor
1. WESTERN CAPE WATER SUPPLY SYSTEM				
Table Mountain and Southern Peninsula WSS	Hely Hutchinson Dam De Villiers Dam Victoria Dam Alexandra Dam Woodhead Dam Albion Spring	Cape Metropolitan Area	5	Raw water yield
	Kleinplaas Dam Lewis Gay Dam	Simon's Town Simon's Town	1,8	Raw water yield
Steenbras WSS	Steenbras Upper Dam Steenbras Lower Dam	Strand, Newlands, Wynberg	40	Raw water yield
Wemmershoek WSS	Wemmershoek Dam	Cape Town Met. Area Paarl Wellington	54	Raw water yield
Voëlvlei GWSS	Voëlvlei Dam, receiving water from Klein Berg River, Leeu River, Twenty Four Rivers, own small catchment area	Cape Town Met. Area Armscor Factory at Krantzkop Swartland to Saldanha Regional Schemes	89	Raw water yield
RSE/Berg River GWSS	Theewaterskloof Dam	Stellenbosch Cape Metropolitan Area	124	Raw water yield
Atlantis	36 boreholes	Atlantis Mamre	6,0	Raw water yield
Paarl	Nantes Dam Bethel Dam Berg River Pumpstation	Paarl	2,8	Raw water yield
Somerset West	Land-en-Zeezicht Dam 4 boreholes	Somerset West	2,0	Raw water yield
Strand	Lourens River	Strand	0,8	Raw water yield
Stellenbosch	Eerste River at Jonkershoek	Stellenbosch	5,5	Raw water yield
Wellington	Antoniesvlei (supplementing supply from Wemmershoek)	Wellington	0,5	Raw water yield
2. OTHER SCHEMES [2]				
Piketberg	Voëlvlei Dam and local sources	7 750 people	1,0	Treatment capacity
Saron	Twenty-four Rivers Canal	Saron	0,34	Pipeline capacity
Porterville	Local sources	4 350 people	0,6	Raw water yield
Tulbagh	Local sources	4 700 people	0,6	Not known
Franschhoek	Local sources	4 500 people	0,6	Raw water yield
Pniel	Local sources	2 150 people	0,04	Storage
TOTAL SCHEME CAPACITY			**334,58**	

(1) Because of the complex distribution system within the Cape Metropolitan Area, population numbers and per capita supply have not been tabulated. These are provided at District Council level in Table 4.1.1.
(2) This list may not be comprehensive.

4.2 REGIONAL WATER SUPPLY SCHEMES

Water supplies in the Cape Metropolitan Area (see Figure 3.4.8.1) and adjacent areas are provided by a number of regional schemes which, in some cases augment supplies from smaller local schemes that have become inadequate as water demands have grown. The combination of these schemes is referred to in this report as the Western Cape Water Supply System.

The main provider of bulk supplies of treated water within this system was the City of Cape Town in 1995, and has been the City of Cape Town CMC-Administration since the re-organisation of local government structures that occurred early in 2001.

The following municipalities (now called "administrations") within the Cape Metropolitan Area are supplied by the City of Cape Town : Blaauwberg (except Atlantis), Cape Town, Southern Peninsula, Tygerberg, Oostenberg, and Helderberg (approximately 50%). The City of Cape Town also supplies water to the towns of Paarl (85%) and Wellington (80%).

The following towns have their own local water supply schemes : Atlantis (part of the Blaauwberg Administration), Somerset West (part of the Helderberg Administration), Strand and Somerset West (part of the Helderberg Administration), Simon's Town (part of South Peninsula Administration), Paarl, Stellenbosch and Wellington. Supplies to Somerset West, Strand and Simon's Town are obtained from the City of Cape Town when the supplies from local sources cannot meet the demand.

The Vredenburg/Saldanha (G10M) area and several of the smaller towns to the north (G10J, K, L) of the Cape Metropolitan Area are supplied by regional schemes that rely for their raw water supplies on Voëlvlei Dam, which is also one of the main sources of water of the City of Cape Town CMC-Administration. Therefore, these schemes, namely the Berg River Government Water Scheme (the Berg River/Saldanha Scheme) and the Berg River/Swartland Government Water Scheme, are also part of the Western Cape Water Supply System. The two schemes supply the following towns : Saldanha, Langebaan, Paternoster, Laaiplek, Velddrift and Hopefield by the Berg River/Saldanha Scheme and Malmesbury, Darling, Moorreesburg, Yzerfontein, Riebeeck-Wes, Riebeeck-Kasteel, Koringberg, Hermon and Gouda via the Berg River/Swartland Scheme. They also supply water for livestock and domestic requirements to numerous farms in the area. After 1995, the Berg River/Saldanha Scheme also supplied the new Saldanha Steel steel mill.

A total of 20 dams, both large and small, provide raw water for the Western Cape Water Supply System. Nineteen of these are within the Berg WMA and information on their storage capacities and yields is given in Table 4.2.1. The only one of the 20 dams that is not in the Berg WMA is Theewaterskloof in the Breede WMA. Its yield characteristics are given in the description of the Berg River/Riviersonderend Government Water Scheme given later in this section.

Information on the water treatment works supplied by the dams is summarised in Table 4.2.2, and brief descriptions of the individual schemes follow :

The Table Mountain and Southern Peninsula Schemes rely for raw water on six dams (Hely Hutchinson, De Villiers, Victoria, Alexandra, Woodhead and Silvermine), owned by the City of Cape Town and two (Kleinplaas and Lewis Gay) near Simon's Town, which are owned by the South Peninsula Administration, and the Albion Spring owned by the City of Cape Town.

Five of the six dams owned by the City of Cape Town are used for urban supply with a combined capacity of 2,376 million m^3 while the sixth (Silvermine) with a capacity of 0,082 million m^3 is mainly used for irrigation. Water for urban supply is also obtained from the Albion Spring. The combined yield of the five dams and the spring is estimated to be 5 million m^3/a at 99% assurance of supply (DWAF, 1992).

Two of the five dams (Hely Hutchinson and Woodhead) supply water to a treatment plant at Kloof Nek while the three others supply a treatment plant at Constantia Nek. The two treatment plants have a combined capacity of 20 Mℓ/day.

TABLE 4.2.1: MAIN DAMS IN THE BERG WMA

QUATERNARY	NAME	LIVE STORAGE (million m³)	NATURAL MAR (million m³/a)	YIELD (million m³/a) (1)				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
G10B	Wemmershoek	58,8	72	54,0	0	0	54,0	City of Cape Town	1:50 year yield. No compensation flows. These are made from the Theewaterskloof Tunnel System	Western Cape System Analysis Report No. P G 000/00/4493.
G10C	Nantes	0,77	-	0,5	0	0	0,5	Paarl	1:20 year yield	Ninham Shand Report No. CT 103, Oct 1970.
G10C	Bethel	0,54	-					Paarl		
G10H	Voëlvlei Dam	164,1	Off Channel	89	32	0	121	DWAF	Direct runoff under 1:50 year condition is about 3,4 million m³/a. Dam is fed by three diversions, giving runoff of about 214 million m³/a (1:50 year) 1:50 year yield is 121 million m³/a made up of 105 million m³/a from the dam and 16 million m³/a supplied from the canals.	Western Cape System Analysis. Report No. PG 000/00/4493.
G10J	Misverstand	6,1	762 (2)	5	0	0	5	DWAF	Used mainly for abstraction of releases from Voëlvlei.	Western Cape System Analysis. Report No. PG 000/00/4493.
G22A	Lewis Gay	0,18	?	1,8	0	0	18	South Peninsula Mun.	1:20 year yield	Ninham Shand Report No. CT34 of 1969.
G22A	Kleinplaas	1,37	?					South Peninsula Mun.		
G22B	Alexandra	0,13	?	5	0	0	5	City of Cape Town	1:100 year yield, but includes 1,64 million m³/a from Albion Spring.	Western Cape System Analysis. Report No. PG 000/00/1490.
G22B	Woodhead	0,95	?					City of Cape Town		
G22B	De Villiers	0,24	?					City of Cape Town		
G22B	Victoria	0,13	?					City of Cape Town		
G22B	Hely Hutchinson	0,92	?					City of Cape Town		
G22D	Silvermine	0,08	?	?	?	?	?	City of Cape Town	Yield not known. Used mainly for irrigation.	Western Cape System Analysis. Report No. PG 000/00/1490
G22F	Kleinplaas	0,36	9	18,5	1,5	0	20	DWAF	Receives water from the Franschhoek/Jonkershoek Tunnel and supplies the Stellenboschberg Tunnel and irrigation along the Eerste River. The yield of 20 million m³/a is from its own catchment.	Western Cape System Analysis. Report No. PG 000/00/4093.
G22G	Idas Valley 2	1,54	?	?	?	?	?	Stellenbosch	Act as balancing dams for water from the Eerste River at Jonkershoek.	Western Cape System Analysis. Report No. PG 000/00/1490.
G22G	Idas Valley 1	0,50	?	?	?	?	?	Stellenbosch		
G22J	Land-en-Zeezicht	0,45	Off channel	?	0	0	?	Somerset West	Water pumped from the Lourens River.	Western Cape System Analysis. Report No. PG 000/00/1490.
G40A	Steenbras Upper	26,3	20,3	40	0	0	40	City of Cape Town	1:50 year yield. Transfers from the Palmiet River are possible and would increase the yield by 22,5 million m³/a.	Western Cape System Analysis. Report No. PG 000/00/4393.
G40A	Steenbras Lower	33,7	50,7					City of Cape Town		

(1) 1:50 year yield unless otherwise stated.
(2) Between proposed Skuifraam Dam site, where the natural MAR is 115 million m³/a, and Misverstand.

TABLE 4.2.2: REGIONAL WATER SUPPLY SCHEMES : WATER TREATMENT WORKS IN THE WESTERN CAPE WATER SUPPLY SYSTEM

TREATMENT WORKS			RAW WATER SOURCE					
NAME	**CAPACITY (Mℓ/day)**	**OWNER/OPERATOR**	**NAME**	**YIELD (million m^3/a)**	**ASSURANCE OF SUPPLY**	**ADDITIONAL YIELI ALLOCATED TO OTHER USERS (million m^3/a)**	**OWNER**	**OPERATOR**
Albion Spring	4,5	Cape Town	Albion Spring			None	Cape Town	Cape Town
Kloof Nek	17	Cape Town	Hely Hutchinson Dam Woodhead Dam	5	1:100 year	None	Cape Town	Cape Town
Constantia Nek	3	Cape Town	Victoria Dam, Alexandra Dam, De Villiers Dam			None	Cape Town	Cape Town
Steenbras	150	Cape Town	Upper Steenbras Dam Lower Steenbras Dam	40	1:50 year	None	Cape Town	Cape Town
Wemmershoek	270	Cape Town	Wemmershoek	54	1:100 year	None	Cape Town	Cape Town
Wemmershoek Pre-treatment	140	Cape Town	RSE/Berg River Transfer	N/A	N/A	None	DWAF	DWAF
Voëlvlei	273	Cape Town	Voëlvlei Dam	70	1:50 year	51	DWAF	DWAF
Blackheath	400	Cape Town	RSE/Berg River Transfer	90	1:50 year	134	DWAF	DWAF
Brooklands	5,4	Simon's Town	Kleinplaas Dam Lewis Gay Dam	1,8	1:20 year	None	Simon's Town	Simon's Town
Faure	500	Cape Town	RSE/Berg River Transfer	not operating in 1995	N/A	None	DWAF	DWAF
Land-en-Zeezicht	14	Somerset West	Land-en-Zeezicht Dam	0,5	Unknown	None	Somerset West	Somerset West
Idas Valley	11,5	Stellenbosch	Jonkershoek Stream Idas Valley Dams	5,5	Approximate	None	Stellenbosch	Stellenbosch
Paradyskloof	10	Stellenbosch	RSE/Berg River Transfer	3,0	100%	221	DWAF	DWAF
Paarlberg	-	Paarl	Berg River Nantes Dam Bethel Dam	2,3 } 0,5	Unknown 1:20 year	None	Paarl Paarl	Paarl Paarl Paarl
Antoniesvlei	-	Wellington	Antoniesvlei	0,5	Unknown	None	Wellington	Wellington
Swartland	22,7	West Coast District Council	Voëlvlei Scheme	3,3	1:50 year	117,7	DWAF	DWAF
Withoogte	32,4	West Coast District Council	Misverstand/Voëlvlei	8,0	1:50 year	113	DWAF	DWAF

Simon's Town's two dams have a combined capacity of 1,55 million m^3. They supply water to the Brooklands treatment plant which has a capacity of 5,4 Mℓ/day. The yield of the dams has been estimated to be 1,8 million m^3/a at 1:20 year assurance.

The Steenbras Water Supply Scheme is owned by the City of Cape Town and comprises the two dams on the Steenbras River in the Hottentots Holland Mountains, a treatment plant and three treated water pipelines. The Steenbras Upper Dam and the Steenbras Lower Dam have storage capacities of 31,8 million m^3 and 33,7 million m^3 respectively. The upper dam also acts as the upper reservoir for the Steenbras Hydro-Electric Pumped Storage Scheme. The 1:50 year yield of the two dams combined and including the small yield from the lower reservoir of the pumped storage scheme is 40 million m^3/a (Ninham Shand, 2001).

All water from the scheme is treated at the Steenbras Treatment Plant which has a capacity of 150 Mℓ/day. Three pipelines with respective capacities of 22,7 Mℓ/day, 69 Mℓ/day and 91 Mℓ/day deliver water from the treatment plant to consumers in the Strand, and the Newlands and Wynberg areas of Cape Town.

The Wemmershoek Water Supply Scheme comprises the Wemmershoek Dam (near Franschhoek), a treatment plant and a pre-stressed concrete pipeline supplying treated water to bulk, clear water service reservoirs at Tygerberg. Branch pipelines supply water to Paarl and Wellington. Additional water is supplied to the treatment plant via a pipeline from the Riviersonderend/Berg River Government Water Scheme. The Wemmershoek Dam has a capacity of 58,86 million m^3 and a yield of 54 million m^3/a at 1:50 year assurance of supply (Ninham Shand, 2001). The treatment plant has a theoretical capacity of 318 Mℓ/day but the practical maximum output is approximately 270 Mℓ/day. This constraint is attributed to the delivery pipeline to the treatment works, which can convey a maximum of approximately 270 Mℓ/day.

The Wemmershoek to Tygerberg pipeline consists of two sections with different diameters. The first 26,5 km has a pipe diameter of 1 525 mm and a design capacity of 318 Mℓ/day. It also carries the supply for Paarl and Wellington to the branch where the 102 Mℓ/day capacity Paarl/Wellington pipeline is situated (5 km downstream of the treatment plant). The branch to Paarl/Wellington was constructed in 1978. The remaining 23,2 km pipeline is 1 220 mm in diameter. It is designed to deliver a peak flow of 227 Mℓ/day to Tygerberg.

The Voëlvlei Government Water Supply Scheme includes Voëlvlei Dam which has a full supply capacity of 172 million m^3 and live storage of 164,1 million m^3. Its natural catchment area is only 31 km^2, contributing little runoff. The dam is fed via concrete lined canals from nearby rivers.

The scheme consists of a diversion weir in the Klein Berg River, one in the Leeu River and one in the Twenty-four Rivers, and a canal system carrying water from these weirs to the Voëlvlei Dam. The Dam supplies water to the City of Cape Town and local authorities and other consumers in the area from Malmesbury to St Helena Bay.

The Dam has an estimated yield (Ninham Shand, 2001) of 105 million m^3/a (at 1:50 year assurance). In addition, water for irrigation is supplied from the Twenty-four Rivers canal. The normal requirement is 20 million m^3/a, but it is estimated that only 16 million m^3/a can be supplied at 1:50 year assurance. Thus, the 1:50 year yield of the dam and the canal combined is 121 million m^3/a. Allocations of water from the dam and canal in 1995 totalled 128 million m^3/a, made up as follows :

City of Cape Town (treated at Voëlvlei WTW)	66,4 million m^3/a
Armscor factory at Krantzkop (treated at Voëlvlei WTW)	4,0 million m^3/a
Swartland and Saldanha Regional Schemes (Berg River Government Water Schemes treated at Withoogte and Swartland WTW)	11,3 million m^3/a
Berg River irrigation	21 million m^3/a (untreated)
Twenty-four Rivers irrigation	20 million m^3/a (untreated)
Other consumers	5,4 million m^3/a (untreated)

The assurances at which the water is allocated are not specified, and allocations to the Swartland and Saldanha Regional schemes have been increased to 21,64 million m^3/a since 1995.

The water treatment plant has a maximum output capacity of 273 Mℓ/day. The treated water is fed into a 9,1 Mℓ capacity clear water reservoir and, from there, it enters the primary distribution system.

From the clear water reservoir, water is conveyed to the Plattekloof reservoir via a 1 525 mm diameter pipeline, 80 km long, with a maximum capacity of 273 Mℓ/day. From the Plattekloof reservoir, water is distributed to the Cape Town municipal reticulation system and to Milnerton, Goodwood and Parow.

The untreated allocation to the Swartland Regional Scheme is abstracted from the canal downstream of Voëlvlei Dam. The Withoogte (Saldanha Scheme) allocation is released from Voëlvlei Dam into Misverstand Dam and abstracted from there.

The Riviersonderend/Berg River Government Water Supply Scheme is an inter-basin transfer scheme from the Riviersonderend in the Breede WMA to the Berg and Eerste Rivers in the Berg WMA. It consists of :

- The Theewaterskloof Dam on the Riviersonderend
- A tunnel through the Franschhoek Mountain Range to the Upper Berg River
- A siphon under the Berg River leading to another tunnel under the Klein Drakenstein Mountains to a balancing dam at Kleinplaas on the Jonkershoek tributary of the Eerste River.
- A third tunnel from the balancing dam to an outlet near Stellenbosch.
- Diversion works on the Banhoek and Wolwekloof Rivers (G10A) that allow surplus winter runoff to be diverted and conveyed through the tunnel system into Theewaterskloof Dam, where it is stored.

During summer, stored water in Theewaterskloof Dam can be released back through the tunnel and pipe system to outlets on the Berg and Eerste Rivers, as well as to the City of Cape Town.

Theewaterskloof Dam is the main raw water source and has a capacity of 480,4 million m^3. Kleinplaas Dam, which also serves as a balancing dam to the tunnel system, has a capacity of 0,376 million m^3. The 1:50 year yield of the system is estimated to be 224 million m^3/a (DWAF, 1994d). It is estimated that about 20 million m^3/a of this yield is abstracted from Kleinplaas Dam from runoff in the Berg WMA. Allocations in 1995 totalled 245 million m^3/a, made up as follows :

- 77 million m^3/a to Berg Irrigation
- 24 million m^3/a to Eerste Irrigation
- 90 million m^3/a to Cape Town
- 3 million m^3/a to Stellenbosch
- 49 million m^3/a to consumers in the Breede WMA
- 2 million m^3/a to other consumers in the Berg WMA

These allocations are no longer strictly adhered to and water is allocated on the basis of the quantity of water in storage at the end of winter.

The addition of a major dam at Skuifraam, on the Berg River, would increase the yield in the Berg WMA by 56 million m^3/a (DWAF, 1999).

Raw water is conveyed to the Wemmershoek Treatment Plant from the Franschhoekberg outlet through a pipeline with a design capacity of 140 Mℓ/day. Raw water is conveyed to the Blackheath Treatment Plant from the Stellenboschberg tunnel outlet by means of a pipeline with a design capacity of 400 Mℓ/day. The new treatment plant at Faure has a capacity of 500 Mℓ/day but was not operational in 1995.

Treated water from Blackheath flows to the Blackheath Service Reservoir, from where it is distributed to the Cape Town reticulation system. In addition, water is reticulated to the municipal areas of Bellville, Brackenfell, Kraaifontein and Durbanville via a link pipeline from the Blackheath reservoir to the Glen Garry Reservoir.

The Palmiet River Government Water Scheme supplements the Steenbras Scheme, described above, by means of a dual purpose water transfer and hydro-electric pumped storage scheme from the Palmiet River. The transfer of water was not in operation in 1995, but the scheme has a maximum capacity of 50 million m^3/a and can supply 22,5 million m^3/a at 1:50 year assurance (Ninham Shand, 2001).

Berg River Government Water Schemes

The Berg River/Saldanha Scheme abstracts water from the Berg River at Misverstand Weir some 70 km from the mouth for the supply of Saldanha, Langebaan, Paternoster, Laaiplek, Velddrift and Hopefield, and to supply numerous farms for livestock and human domestic requirements. This water is treated and pumped to the reservoir at Vergeleë before it is distributed to these towns. In summer, most of the water used originates from releases of water from Voëlvlei Dam into the Berg River upstream of the Misverstand Weir. The scheme supplied 9,8 million m^3 of water in 1995.

The Berg River/Swartland Scheme abstracts water from the Voëlvlei Dam and treats it at the Swartland Works. It supplies water to Malmesbury, Darling, Morreesburg, Yzerfontein, Riebeeck-Wes, Riebeeck-Kasteel, Koringberg, Hermon and Gouda and many farms. (Malmesbury also obtains 0,25 million m^3/a from the Perdeberg Dam). The scheme supplied 3,7 million m^3 of water in 1995.

Some local authorities obtain a portion of their water requirements from schemes that they operate themselves. Authorities operating their own schemes are : Atlantis, Paarl, Simon's Town, Somerset West, Stellenbosch, Wellington, Strand, Malmesbury and Saldanha.

Simon's Town

Both of Simon's Town's dams, Kleinplaas and Lewis Gay, are situated on the Woel River. Their combined storage capacity is 1,55 million m^3. Water is pumped into Kleinplaas Dam from the small Rawson Reservoir in the adjacent Klawer catchment. The estimated (Ninham Shand, 1969) system yield is 1,85 million m^3/a (1:25 year assurance). The dams supply water to the Brooklands Water Treatment Plant.

Atlantis

Atlantis and Mamre are supplied from 36 boreholes with an estimated yield of 7 million m^3/a (Baron and Seward, 2000). These wellfields are at Silverstroom and Witsands.

Paarl

Apart from the water supply from the Wemmershoek Scheme, Paarl supplements its water from the Nantes Dam (0,815 million m^3 storage capacity) and the Bethel Dam (0,543 million m^3 storage capacity) on Paarl Mountain. Water is pumped from the Berg River into these dams during winter, only when the water quality is high. The two dams have a combined yield from their catchments that has been estimated to be 0,5 million m^3/a at 1:20 year assurance (Ninham Shand, 1970). The water pumped from the Berg River into the dams is estimated (Ninham Shand, 2001) to provide an additional 0,7 million m^3/a. Paarl has rights to 2,8 million m^3/a, but these are not fully utilised because the quality of the water during the summer months is poor.

Somerset West

Somerset West obtains an estimated 2 million m^3/a of water from the Lourens River and four boreholes. Water is pumped from the river into the off-channel Land-en-Zeezicht Dam. The assured yield of the scheme is not known.

Strand

Strand obtained about 90% of its water requirements in 1995 from the Steenbras Scheme. The remaining portion of the town's water requirement was obtained from the Lourens River. Water is gravitated from the river to a water treatment works of approximately 2,4 Mℓ/day capacity. The yield obtainable from the Lourens River is about 0,8 million m^3/a, but the assurance is not known.

Stellenbosch

Stellenbosch obtains most of its water from its own abstraction works from the Eerste River in Jonkershoek. Water from this source is supplied directly to the town service reservoirs and water in excess of winter demand is stored in two dams in Idas Valley, for use during summer. The water is first passed through the Swartberg Treatment Plant before being distributed or stored. The treatment plant has a capacity of 24 Mℓ/day and the two Idas Valley dams have a combined capacity of 2,04 million m^3.

During dry summers, the Stellenbosch supply is supplemented from the Riviersonderend Scheme. The Stellenboschberg Tunnel outlet feeds a 450 mm dia. pipeline, which delivers water to the Paradyskloof Treatment Plant. A 10 Mℓ reservoir stores treated water before distribution.

Wellington

Wellington gets most of its water (80%) from the Wemmershoek Scheme. A portion of the town's requirements is obtained from Antoniesvlei, a stream draining the Bain's Kloof area. Excess winter water from this source is stored in two small dams, namely Withoogte (40,9 Mℓ capacity) and Welvanpas (45,4 Mℓ capacity), whence it is chlorinated and supplied to municipal service reservoirs. The assured yield of this scheme is not known, but historically it has not provided less than 0,5 million m^3/a (DWAF, 1992).

Because of the complex distribution system within the Cape Metropolitan Area, information on the populations supplied by the individual schemes described above is not readily available. The total population supplied by the Western Cape Water Supply System in 1995 is estimated to have been 3,07 million people. The supply areas of the individual schemes are shown in Table 4.1.2. There are a number of towns in the Berg WMA that do not receive any water from regional schemes at all. These are discussed in the following section.

4.3 INDIVIDUAL TOWN WATER SUPPLIES

In the Berg River catchment downstream of Voëlvlei Dam, the small town of Saron obtained approximately 0,34 million m^3 of water from the Twenty-four Rivers canal in 1995, Piketberg obtains water from its own pump station on the Berg River, but obtained a supply from Misverstand Weir as well, after 1995, and Porterville obtained its requirements of 0,6 million m^3/a from a mountain spring. Tulbagh in catchment G10E also obtains water from local surface water sources, but details were not obtained.

In the Upper Berg River Catchment, Franschhoek obtains its water from boreholes and the Du Toits River in the Mount Rochelle Nature Reserve, which is in the Breede WMA. Water from the Du Toits River is diverted into six reservoirs with a combined capacity of 3,5 Mℓ. The inflow to the reservoirs from the river is estimated by the town engineer to be approximately 2 Mℓ/d, or 0,7 million m^3/a. No records of water consumption were kept before 2001. Water requirements in 2001 are estimated to be 0,6 million m^3/a. A supplementary supply of water from Wemmershoek Dam was commissioned in 2001.

The villages of Pniel and Kylemore (G10C), also in the upper Berg River Catchment, obtain water from mountain streams which is diverted into a reservoir with a capacity of 0,75 Mℓ. The yield of the streams is not known, but a supplementary supply of treated water provided by Stellenbosch Municipality has been used in recent years to make up any seasonal shortfalls from the mountain streams in meeting the requirements of approximately 0,04 million m^3/a.

Wolseley lies partly in the Breede WMA and partly in the Berg WMA, but obtains its water from the Breede River.

4.4 IRRIGATION INFRASTRUCTURE IN THE BERG RIVER

Infrastructure for providing water for irrigated agriculture is well developed in the WMA, particularly in the catchments of the Berg, Eerste and Lourens Rivers. Because most of the rainfall, and hence most of the flow in the rivers, occurs between the winter months of May and October each year, the infrastructure has been developed to store some of the runoff that occurs during the winter months and to distribute it to irrigated lands during the remainder of the year. Two of the Government Water Supply Schemes described in Section 4.2, namely the Berg River/Riviersonderend Government Water Scheme and the Voëlvlei Government Water Scheme provide large volumes of water for irrigation as well as for urban supplies.

In addition, a large number of privately owned farm dams have been constructed. Most of these are located on the tributaries of the larger rivers to store runoff from their own catchments as well as water diverted into them from large rivers, either by diversion weirs and systems of furrows on gravity pipelines, or by pumping.

In 1995, some 267 farm dams with a combined capacity of 88 million m^3 were registered in the WMA. The distribution of these within the WMA is shown in Table 4.4.1. There are, in addition, a large number of dams that are too small to require registration, but that have been estimated (DWAF, 1992a) to have a combined capacity equal to about 20% of that of the registered dams. On the basis of this assumption, the total capacity of the farm dams is 104 million m^3.

The area of economically irrigable land in the Berg WMA exceeds the quantity of water that is available for irrigation (DWAF 1994d), with the result that it is necessary for the State to control allocations of water. Under the Water Act of 1956 this was done by declaring those areas in which the requirements of users exceeded the supply to be Government Water Control Areas in which the State allocated water to users. The Water Act of 1956 also provided for the promotion of the interests of local communities through the establishment of irrigation districts. This could be done upon the request of a local community, or on the recommendation of the Minister of Water Affairs on his own initiative. After an irrigation district had been proclaimed by the State President, board members were elected by those landowners who had an interest in the irrigation of land within the district. An irrigation board administered its district by means of a schedule of rateable areas which recorded the quantity of public water to which each owner of land in the district was entitled. Where the district incorporated land that lay within a Government Water Control Area and in respect of which the Minister of Water Affairs had determined water rights, the irrigation board had to include the Minister's determinations in its schedule of rateable areas.

With the introduction of the National Water Act (Act No 36 of 1998), irrigation boards were required to apply for registration as water user associations and, as explained in Section 3.4, the previous concept of riparian rights and private ownership of water was done away with. The nation's water resources became common property, belonging to the nation as a whole, and all water use for irrigation on a commercial scale is now subject to control by the Minister of Water Affairs.

TABLE 4.4.1: FARM DAMS IN THE BERG WMA

CATCHMENT				REGISTERED FARM DAMS [1]		ESTIMATED CAPACITY OF UNREGISTERED FARM DAMS [2] (million m^3)	TOTAL CAPACITY OF FARM DAMS (million m^3)
SECONDARY		QUATERNARY		NO.	CAPACITY (million m^3)		
No.	Description	No.	Description				
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	116	50	10	60
		G10G to G10M	Berg River downstream of Voëlvlei	43	13	2	15
Sub-total (Berg River)				**156**	**63**	**12**	**75**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	0	0	0	0
		G21C to G21F	Diep River	30	4	0	4
		G22E to G22K	Combined Kuils /Eerste/Lourens/ Sir Lowry Rivers	70	20	4	24
		G22A to G22D	Combined Cape Peninsula Rivers	11	1	0	1
Sub-total (Diep River and West Coast belt)				**111**	**25**	**4**	**29**
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0
TOTAL IN BERG WMA				**267**	**88**	**16**	**104**

1. Data obtained from the register of the Dam Safety Office.
2. Dams that are too small to require registration estimated (DWAF, 1992a) to equal approximately 20% of the capacity of registered farm dams.

However, this report deals with the situation as it was in 1995 when the Water Act of 1956 was still in force. At that time there were 20 proclaimed irrigation districts in the Berg WMA. Of these, 16 were in the catchment of the Berg River itself, and the remaining 4 in the catchment of the Eerste River. The irrigation districts, together with some statistics on them, are listed in Table 4.4.2. It should be noted that, in some instances, the boundaries of irrigation districts overlap, with the result that a particular area of land might be entitled to allocations of water from two or more irrigation boards, as well as to what was "private" water prior to 1998.

The system of allocating water in 1995 was a complex one as a single piece of land might have been entitled to water from a Government Water Scheme, from riparian rights, from allocations to one or more irrigation districts, from allocations made by a Water Court, and from "private" water. Water allocations within the Berg WMA are referred to in the brief descriptions of the infrastructure in the individual irrigation districts that follow, and are discussed further in Section 5.13.

The Upper Berg Irrigation District

The Upper Berg Irrigation District extends along the Berg River from the Franschhoekberg Tunnel outlet (G10A) to Zonquasdrift (G10F) which is just upstream of the point on the Berg River at which water from Voëlvlei Dam is released for use further downstream. The Upper Berg Irrigation Board administers the supply of water from Theewaterskloof Dam to many of the other irrigation districts listed in Table 4.4.2 and to individuals with allocations from Theewaterskloof. The water is released from the tunnel outlet and diverted by means of weirs or by pumping into the distribution systems of the various irrigation districts.

An area of 14 985 ha of land was scheduled under the Upper Berg Irrigation District in 1995, but much of this land was also scheduled under the smaller irrigation districts described below.

The Berg River Irrigation District

The Berg River Irrigation District is located on the banks of the Berg River near Paarl in catchment G10C. It has an allocation of natural runoff in the Berg River of 18,5 million m^3/a, based on an originally scheduled area of 8 388 ha with an allocation of 2 205 m^3/ha/a. The scheduled area in 1995 was 11 262 ha, but water from Theewaterskloof Dam is also available.

Details of the infrastructure developed to use the water were not readily available.

The Banhoek Irrigation District

The Banhoek Irrigation District is situated in the headwaters of the Berg River in the catchment of its Banhoek/Dwars River tributary. The scheduled area of land is 450 ha with a quota of 4 000 m^3/ha/a, giving an allocation of 1,8 million m^3/a. Water from Theewaterskloof Dam is released on request into the river channel from the Banhoek Diversion intake at the end of the Franschhoekberg Tunnel. The water is abstracted from the river channel at various points for irrigation of the scheduled lands.

TABLE 4.4.2: IRRIGATION DISTRICTS IN THE BERG WMA IN 1995

KEY AREA				IRRIGATION DISTRICTS						
SECONDARY		QUATERNARY		NAME	CATCHMENT	SCHEDULED AREA (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)	SOURCE OF WATER	REMARKS
No.	Description	No.	Description							
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	Upper Berg	G10A G10C G10D G10F	14 985	Varies	75,4	Theewaterskloof Dam via Franschhoek Tunnel	25% river losses. Uses about 38% of allocation
				Banhoek	G10A	450	4 000	1,8	Theewaterskloof Dam via Banhoek Diversion intake	Full allocation used
				Berg River *	G10C	11 242	5 000	56,2	Natural runoff in the Berg River and Theewaterskloof Dam	
				Daljosaphat	G10C	215	Not known	Not known	Dal River	
				Palmiet	G10C	313	3 300	1,0	Hugo's River	Summer flow rights and allowance for conveyance losses (10%) increase allocation to 1,42 million m^3/a
				Simonsberg *	G10C	125	4 000	0,5	Summer flow in Berg River	Abstract water in December, January, February
				Noord-Agter-Paarl *	G10C	1 079	5 000	5,40	Natural winter runoff in the Berg river and water from Theewaterskloof Dam	2,0 million m^3/a can be abstracted from 1 May to 31 October from surplus water. Balance from Theewaterskloof in summer
				Suid-Agter-Paarl *	G10C	876	4 000	3,50	Natural winter runoff in the Berg River and water from Theewaterskloof Dam	2,1 million m^3/a can be abstracted from 1 May to 31 October from surplus water. Balance from Theewaterskloof Dam in summer.
				La Motte	G10C	230	Not known	Not known	Berg River	
				Kromme River	G10D	646	Not known	Not known	Kromme River and transfer from Wit River	5 million m^3/a imported from the Wit River
				Perdeberg *	G10D	1 487	6 000	8,92	Natural runoff in the Berg River and Theewaterskloof Dam	

* Indicates irrigation districts forming part of the Upper Berg Irrigation District.

TABLE 4.4.2: IRRIGATION DISTRICTS IN THE BERG WMA IN 1995 (Continued)

KEY AREA				IRRIGATION DISTRICTS						
SECONDARY		QUATERNARY		NAME	CATCHMENT	SCHEDULED AREA (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)	SOURCE OF WATER	REMARKS
No.	Description	No.	Description							
				Klein Berg	G10E	1 465	Not known	Not known	Klein Berg River	
				Dwars River	G10E	1 458	Not known	Not known	Breede River	4 million m^3/a imported from the Breede River
				Riebeek Kasteel *	G10F	150 (winter) 177 (summer)	5 000	0,88	Natural runoff in the Berg River and Theewaters-kloof Dam	Scheme designed for 50% evaporation and conveyance losses
				Riebeeck West	G10F	697	--	4,06	Natural winter flow in Berg River	4,06 million m^3/a is maximum that may be abstracted from 1 May to 31 October
				Twenty-four Rivers	G10J	2 144	8 500	20,0	Twenty-four Rivers	
		G10G to G10M	Berg River downstream of Voëlvlei	Lower Berg River	G10F, G10J, G10K	3 644 (summer) 1 051 (winter)	7 000 (summer)	10,0 11,2 <u>4,3</u> <u>25,5</u>	Voëlvlei Dam Theewaterskloof Dam Summer flow and winter flow stored in farm dams	Water from Voëlvlei and Theewaterskloof Dams supplied on request. Only about 70% of allocation used.
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast Rivers	No irrigation districts	--	---	--	--	--	--
		G21C to G21F	Diep River	No irrigation districts	--	---	--	--	--	--
		G22E to G22K	Kuils/Eerste/Lourens/Sir Lowry Rivers	Helderberg	G22H	1 192	340	0,406	Theewaterskloof Dam via pipeline from Stellen-boschberg Tunnel outlet to Faure Water Treatment Works	Scheduled area increased to 2 447 ha after 1995 and allocation to 9,8 million m^3/a
				Lower Eerste River	G22H	514	--	1,6	Theewaterskloof Dam via Stellenboschberg Tunnel outlet	Also receives 1,5 million m^3/a compensation water
				Stellenbosch	G22F	1 703	4 000	6,8	Theewaterskloof Dam via Stellenboschberg Tunnel outlet	Scheduled area increased to 2 938 ha by 1998 and allocation to 11,75 million m^3/a
G4	Steenbras River	G40A	Steenbras	No irrigation districts	--	--	--	--	--	--

* Indicates irrigation districts forming part of the Upper Berg Irrigation District.

The Daljosaphat Irrigation District

The Daljosaphat Irrigation District (G10C) is situated in the catchment of the Dal River tributary of the Berg River on the north-east side of Paarl. Water is diverted from the Dal River by means of diversion box into a pipeline which delivers it to farm dams for storage. An area of 215,8 ha of land was scheduled in the district in 1995. No information on quotas or allocations was found.

The Palmiet River Irrigation District

The Palmiet River Irrigation District is situated in the catchment of the Hugos River tributary of the Berg River between Paarl and Wellington in catchment G10C. An area of 313 ha of land was scheduled in the district in 1995. Water is diverted from the Hugos River (formerly called the Palmiet River) by means of a 350 mm diameter pipeline into a 1,17 million m^3 capacity dam on a tributary stream. The water is distributed from the dam in summer through a network of 41,7 km of pipeline ranging in diameter from 450 mm to 250 mm to irrigate crops on seven farms. The crops consist of wine grapes (70%), table grapes (12%), peaches (11%) and small areas of guavas, citrus, apricots and olives. The allocation from excess winter water was 1 million m^3/a at a quota of 3 300 m^3/ha/a. The district was also entitled to use normal summer flow in the Hugo's River, bringing the total quantity of water available to about 1,45 million m^3/a (Government White Paper N-73).

The Simonsberg Irrigation District

The Simonsberg Irrigation District is situated on the west side of the Berg River valley well upstream of Paarl. The district is not riparian to the Berg River and its allocation of 0,5 million m^3/a has to be pumped from the river through a 2,5 km long, 250 mm diameter rising main into a network of 200 mm and 110 mm diameter pipelines for storage in farm dams. In terms of a Water Court Order, the allocation had to be abstracted from the Berg River during the months November to February inclusive, and it is usually obtained during December, January and February. The scheduled area is 125 ha on six farms with a quota of 4 000 m^3/ha/a. the crops irrigated are mainly peaches, plums and wine grapes. The Berg River water is supplemented with water from boreholes and surface water runoff originating on the farms.

Noord-Agter Paarl Irrigation District

The Noord-Agter Paarl Irrigation District is situated adjacent to the northern edge of Paarl in catchment G10C. An area of 814 ha of land, mainly under table grapes, is scheduled in the district. The quota is 5 000 m^3/ha/a and the water allocation, which is from the Berg River, is 4,07 million m^3/a. A maximum quantity of 2,0 million m^3 of water may be abstracted from surplus flow in the river between 1 May and 31 October each year. The rest of the allocation is obtained from water transferred from Theewaterskloof Dam during the summer months. The water is pumped through a 2,4 km long, 450 mm diameter rising main into an off-channel storage dam with a capacity 1,9 million m^3. It is distributed from there to 69 farms by means of three pump stations through a network of pipelines ranging in diameter from 350 mm to 50 mm (Government White Paper 0-67).

The Suid-Agter Paarl Irrigation District

The Suid-Agter Paarl Irrigation District is situated immediately to the west of Paarl in catchment G10C. An area of 876 ha of land with a quota of 3 500 m^3/ha/a is scheduled, to give an allocation of 3,06 million m^3/a. Some 16 landowners use the water to irrigate about 1 000 ha of predominantly (95%) wine grapes. In terms of a Water Court Order a maximum of 2,1 million m^3 of surplus winter water may be abstracted from the Berg River each year between 1 May and 31 October. This water is pumped through a network of 16 km of pipelines ranging in diameter from 450 mm to 50 mm to storage in farm dams. The rest of the allocation is obtained in summer from water transferred from Theewaterskloof Dam and released into the Berg River.

The La Motte Irrigation District

This irrigation district, which has a scheduled area of 230 ha, is situated in catchment G10C and obtains water from the Berg River. Information on quotas, allocations and infrastructure was not found.

The Kromme River Irrigation District

The Kromme River Irrigation District is situated in the upper reaches of the catchment of the Krom River tributary of the Berg River in catchment G10D. The scheduled area is 646 ha and a quantity of 5 million m^3/a is imported from the Wit River in the Breede WMA for purposes of irrigating this land. Details of the infrastructure were not found.

The Perdeberg Irrigation District

The Perdeberg Irrigation District is situated in catchment G10D to the west of the Berg River opposite Wellington. The scheduled area of land is 1 433 ha with a quota of 3 500 m^3/ha, giving an allocation of 5,0 million m^3/a. In terms of a Water Court allocation, a maximum of 8,255 million m^3/a of surplus winter water may be abstracted from the Berg River between 1 May and 31 October each year. The water is distributed to storage on some 60 farms through a network of 60 km of pipelines ranging in diameter from 700 mm to 50 mm. The crops grown are mainly wine grapes (80%) table grapes (7%) deciduous fruit (5%) and vegetables, tobacco and pasture (8%) (Government White Paper J-80).

The Klein Berg Irrigation District

The Klein Berg Irrigation District is situated in the upper reaches (G10E) of the catchment of the Klein Berg River tributary of the Berg River. It has a scheduled area of 1 465 ha of land and obtains water from the Klein Berg River. Details of quotas and infrastructure were not found.

The Dwars River Irrigation District

The Dwars River Irrigation District is also in catchment G10E, being the upper reaches of the Klein Berg River. It has a scheduled area of land of 1 458 ha which is irrigated by means of 4 million m^3/a of water imported from the Breede WMA by means of a canal leading from the Breede River itself at Witbrug near Michell's Pass (H10F).

The Riebeeck Kasteel Irrigation District

The Riebeeck Kasteel Irrigation District is situated adjacent to the town of Riebeeck Kasteel in catchment G10F. The scheduled area is 150 ha which is under vineyards, apricots and peaches. The quota is 4 200 $m^3/ha/a$, giving an allocation of 0,6 million m^3/a. Surplus winter water is pumped from the Berg River during the period from 1 May to 31 October each year through a 12 km long pipeline varying in diameter from 250 mm to 100 mm. The water is stored in farm dams. A scheduled area of 176,6 ha also has an allocation of water from Theewaterskloof Dam, which is supplied on request during the summer months. The size of this allocation is not known.

The Riebeeck West Irrigation District

The Riebeeck West Irrigation District is also situated in catchment G10F and has a scheduled area of land of 662 ha which is under mainly wine grapes and tobacco. A Water Court allocation allows a maximum of 4,06 million m^3 of surplus winter water to be pumped from the Berg River between 1 May and 31 October each year. This water is stored in farm dams for use during the summer months. An additional quantity of water of about 0,7 million m^3/a is obtained from boreholes and surface water runoff originating on the farms.

The Lower Berg River Irrigation District

The Lower Berg River Irrigation District extends along the Berg River from Zonquasdrift opposite Voëlvlei Dam in catchment G10F downstream to the confluence of the Berg and Sout Rivers at the outlet of catchment G10K. An area of 3 644 ha of land is scheduled for summer water rights and 1 051 for winter. The allocation, based on a quota of 7 000 m^3/ha/a for the summer water rights, is 25,5 million m^3/a. The allocation is made up of 10,0 million m^3/a supplied from Voëlvlei Dam, 11,2 million m^3/a supplied from Theewaterskloof Dam, and 4,3 million m^3/a that can be pumped from summer and winter flow in the Berg River. Water from Voëlvlei and Theewaterskloof Dams is supplied on request by releases into the Berg River. The water is abstracted at various points further downstream along the river and is stored in farm dams.

The Twenty-four Rivers Irrigation District

The Twenty-four Rivers Irrigation District is situated in the catchment of the Twenty-four Rivers tributary of the Berg River (G10J) and extends from the outlet of catchment G10G to the banks of the Berg River. An area of 2 144 ha of land, mainly under grapes and deciduous fruit, is scheduled in the district. Water is obtained from the weir that was constructed to divert water from the Twenty-four Rivers to Voëlvlei Dam. The irrigation board's infrastructure consists of two concrete lined canals. One, on the right bank of the Twenty-four Rivers, has a capacity of 0,5 m^3/s, and extends for approximately 20 km from the weir to close to the Berg River. The other, on the left bank, abstracts water from the Voëlvlei Canal some 3,5 km from the diversion weir and is 8 km long with a capacity of 0,3 m^3/s. Water for irrigation is abstracted at numerous points along the canals (Government White Paper O-66 and K-68). The quota is 9 000 m^3/ha, giving an allocation of 19,2 million m^3/a. Up to 12,7 million m^3/a of this may be abstracted from the Voëlvlei Canal.

The Helderberg Irrigation District

The Helderberg Irrigation District is situated in the catchment of the Eerste River (G22H) and had a scheduled area of 1 192 ha of land with a quota of 4 000 m^3/ha/a and an allocation of water from Theewaterskloof Dam of 0,46 million m^3/a in 1995. The water is supplied on request from the City of Cape Town's pipeline from the Stellenboschberg Tunnel outlet to the Faure Water Treatment Works. By 1999 the scheduled area in the district had increased to 2 446,6 ha, and the allocation to 9,786 million m^3/a.

The Lower Eerste River Irrigation District

The Lower Eerste River Irrigation District is situated along the Eerste River downstream of Stellenbosch (G22F). An area of 514 ha of land is scheduled with an allocation of 1,65 million m^3/a of water from Theewaterskloof Dam. It also has rights to 1,5 million m^3/a of water from Kleinplaas Dam. This water is also provided from Theewaterskloof. Details of infrastructure for use of the water were not found.

The Stellenbosch Irrigation District

The Stellenbosch Irrigation District is situated in the catchment of the Eerste River upstream of Stellenbosch (G22F) and had a scheduled area of 1 703 ha in 1995, with a quota of 4 000 m^3/ha/a and an allocation of 6,8 million m^3/a. By 1999 the scheduled area had increased to 2 938 ha and the allocation to 11,75 million m^3/a. The water is supplied on request from Theewaterskloof Dam. Information on the infrastructure that has been developed to use the water was not found.

4.5 HYDROPOWER AND PUMPED STORAGE

The only hydro-powerstation in the WMA is the Steenbras Pumped Storage Scheme which is owned by the City of Cape Town CMC Administration. Its position is shown on Figure 4.1.1.

The Steenbras Upper Dam (G40A) in the Hottentots Holland Mountains acts as the main storage reservoir for the scheme and water is released from it through the turbines to an open reservoir (G22K) at the foot of the mountains. The water from the reservoir is either pumped back to the Steenbras Dam during periods of low electric power demand, or it is pumped to the Faure Water Treatment works if required there.

The station is used to provide peaking power and operates at annual load factors of between 12% and 16%. Some of the principal statistics are given in Table 4.5.1.

TABLE 4.5.1: STEENBRAS PUMPED STORAGE SCHEME

Locality	Latitude Longitude	34° 09'S 18° 54'E
Rated capacity		180 MW
Peak capacity (generator limitation)		185 MW
Load factor		12% - 16%

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

Water requirements in the WMA totalled an estimated 960 million m³/a in 1995, distributed amongst user groups as shown in Table 5.1.1. Consumptive water requirements (i.e. excluding the ecological flow requirements) totalled 839 million m³/a. The major users are the agricultural and domestic user sectors which, at 350 million m³/a and 362 million m³/a respectively, account for 85% of total consumptive water requirements. The next biggest water requirement, although not a consumptive use, is the riverine ecosystem, which requires an estimated 121 million m³/a to sustain it. Hydropower generation is by means of a pumped storage scheme which has negligible evaporation and seepage losses and is therefore not considered to be a user of water.

Significant areas of alien vegetation are found and the reduction in runoff that they cause constitutes approximately 10% of the total estimated average annual consumptive water requirement.

The values shown in Table 5.1.1 include conveyance and distribution losses, where applicable, and have not had return flows that are re-used further downstream deducted from them. Therefore, they represent estimates of gross water use.

It should be noted that, because of the limited availability of reliable data, the level of confidence in the estimates is not high. Values are given to one decimal place in Table 5.1.1 for ease of correlation with other more detailed tables appearing later in this chapter, but these should not be interpreted as being accurate to one decimal place.

The agricultural water use shown in Table 5.1.1 represents both irrigation and livestock watering requirements, but livestock accounts for only 4,9 million m³/a.

The requirements at 1:50 year assurance for the domestic, bulk water use and agricultural user groups, are equivalent requirements. They are presented in this way to bring quantities of water that are required at different assurances of supply by consumers to a common base for purposes of comparing water requirements with the available yield. For example, a portion of the yield of a dam might be allocated to industrial use at 1:200 year assurance, a portion to irrigation of orchards at 1:20 year assurance, and a portion to annual crops at 1:5 year assurance. The yield/assurance curve for a dam defines the quantity of water that can be supplied at any particular assurance : the lower the assurance, the greater the quantity of water that can be provided. Thus, for the hypothetical dam of the above example, the quantity of water supplied at 1:200 year assurance could be converted to a theoretical equivalent greater quantity of water at 1:50 year assurance by using the yield/assurance curve. Similarly, the quantities of water supplied at 1:20 year assurance and 1:5 year assurance could be converted to equivalent theoretical smaller quantities at 1:50 year assurance. Adding together the three equivalent quantities at 1:50 year assurance would give the total equivalent requirement at 1:50 year assurance. This value could be compared with the yield of the dam at 1:50 year assurance to determine the balance between yield and allocations of water.

Domestic water requirements and the drinking water requirements of livestock have been assumed to be supplied at 1:50 year assurance under normal conditions. The assurances at which water for irrigation is required have been assumed to vary with the commercial value of the crops irrigated. This accounts for the smaller requirement at 1:50 year assurance for agriculture in Table 5.1.1.

The estimated water requirement for the ecological Reserve shown in Table 5.1.1 is the average volume of water that needs to be allowed to flow into the sea from the WMA. The requirement at 1:50 year assurance is the impact of the ecological Reserve requirement on the 1:50 year yield of the water resources as developed in 1995.

Similarly, the estimated requirements for afforestation and alien vegetation are the reductions that they cause in mean annual runoff, while the requirements at 1:50 year assurance are their impacts on the developed yield in 1995.

The distribution of total equivalent water requirements at 1:50 year assurance is shown on Figure 5.1.1. Where water is transferred from one quaternary catchment to another, the quantity exported is shown as a water requirement in the source catchment and the demand that the transfer satisfies is shown as a requirement in the receiving catchment.

Water requirements per user group are shown on Figure 5.1.2.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT (million m^3/a)	REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)
Ecological Reserve	121,0	19,5 (5)
Domestic (1)	362,2	362,2
Bulk water use (4)	4,4	4,4
Neighbouring States	0	0
Agriculture (2)	349,8	305,3
Afforestation	26,0	0,2
Alien vegetation	86,7	0,1
Water transfers (3)	0	0
River losses	10	10
Hydropower	0	0
TOTALS (6)	960,1	704,7

(1) Includes urban and rural domestic requirements and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, dry land sugar cane, livestock and game.
(3) No net transfers out of the WMA.
(4) Includes thermal power stations and major industries.
(5) The Reserve, afforestation and alien vegetation requirements shown at 1:50 year assurance represent the impacts on the system yield as developed in 1995 of these requirements. These impacts will increase as the water resources are developed.

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 Münster, 1999) to provide a low-confidence estimate of the quantity of water required for the ecological component of the Reserve, which is suitable for use in this water resources situation assessment.

The method involves the extrapolation of high confidence results of previous instream flow requirement (IFR) workshops, the use of a reference time series of monthly runoff at the outlet of the quaternary catchment and a number of hydrological indices or parameters that have been defined for 21 desktop Reserve parameter regions in South Africa. These desktop Reserve parameter regions are described and shown in Figure 5.2.1.1. The Berg WMA falls within the Western Cape (wet), the Western Cape (dry), and the Western Karoo regions. The instream flow requirements that were determined previously were mostly based on the use of the Building Block Method (King and Louw, 1998). The monthly time series of natural flow that has been used is described in Section 6.3. The following are the two main hydrological parameters :

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

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

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

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

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

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

- The method assumes that the monthly time series of natural flows are representative of real natural flow regimes and many of the algorithms rely upon the flow characteristics being accurately represented. Should the data indicate more extended base flows than actually occur, the hydrological index of flow variability would be under-estimated and the water requirements for the ecological component of the Reserve would be over-estimated.

5.2.2 Quantifying the Water Requirements

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

The simulation model provides annual maintenance and drought low flows and maintenance high flows (expressed as a proportion of the mean annual runoff). The model also provides for the seasonal distribution and assurances associated with the monthly flows on the basis of a set of default parameters that has been developed for each of the 21 desktop Reserve parameter regions of South Africa referred to in Section 5.2.1. The quaternary catchments in the Berg Water Management Area include portions of the Western Cape (wet), the Western Cape (dry) and the Western Karoo regions (see Figure 5.2.1.1).

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

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

The effects on the yield of the river system of the water required for the ecological component of the Reserve have been based on an analysis of the monthly time series of these water requirements for the same 70-year period as for the natural time series of flows, that is described in Section 6.3. This has been estimated by establishing the average annual quantity of water required for the ecological component of the Reserve during the most severe or so-called critical drought that has determined the yield of the river system at a recurrence interval of 50 years. The duration of the critical drought can be approximated by the (inverse of) marginal rate of increase of the yield of the river system per unit increase in storage capacity, i.e. the slope of the storage-yield curve at the storage capacity under consideration. The periods of high and low flows in the monthly time series of water requirements for the ecological component of the Reserve also mimic the periods of high and low flows in the monthly time series of natural flows used to establish the yield of the river system. Therefore, the portion of the yield of the system that is required for the ecological component of the Reserve can be estimated by finding the lowest average flow for all periods in the monthly time series of water requirements for the ecological component of the Reserve that are as long as the critical drought period.

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

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

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

- Similarly, the regional parameters for the assurance rule curves have been based on the duration curve characteristics of the natural flow regimes represented by the monthly time series of flow described in Section 6.3 and some experience of setting assurance rules used at past IFR workshops. Regionalising was done by investigating a representative sample of quaternary catchments and it is therefore possible that some have been assigned to the wrong regions.

- The estimates of water required for the ecological component of the Reserve are the best estimates that can be given at this stage, but must be regarded as low confidence estimates. As more detailed estimates are made for a wider range of rivers, the estimates will be improved through modifications made to the delineation of the regions and the regional parameters that have been assigned. It is also anticipated that a better way of accounting for regional or site-specific ecological considerations will be added in due course.

5.2.3 Comments on the Results

The members of the specialist team that carried out the classification of the rivers expressed their opinions on the strengths and weaknesses of the processes. These opinions are summarised below :

- Accuracy of assessments was facilitated by the diverse number of specialists involved in the process. However, some considered the fact that, in most cases, only one specialist in each field was present made it difficult to verify the results obtained.

- The upgrading of rivers to a higher class is decided by possible improvements through flow modification. This leaves uncertainty as to how other factors should be addressed. It was felt, for instance, that in some instances catchment management options such as removing invasive alien vegetation and reducing bulldozing of river beds would improve conditions, yet these options were not addressed. Very few rivers have the potential to be upgraded over a short period and the majority require upgrading over ten years or more.

- Groupings of various catchments are rather big, leading to very broad based assessments which could result in inaccuracies. A number of quaternaries were linked together, but only the main stem river was taken into account. The tributaries could be ecologically more important than the main stem, in which case the class determined for the main stem might not be accurate for the quaternary overall.

- Confidence levels need to be attached to all the classes determined.

- Ideally, rivers should be grouped according to ecotones rather than quaternary catchments, as the latter are ecologically inappropriate, but it is acknowledged that this would not meet the resolution requirements of the water balance component of the study.

5.2.4 Presentation of Results

The results of the assessment are shown in Table 5.2.4.1 where the requirements of the ecological component of the Reserve are shown in terms of percentage of MAR, long term average annual flow volume and impact on 1:50 year yield, for key points. The key points are all located at the outlets of catchments and are points of particular interest from the water resources point of view. They are described in more detail in Section 2.1.

The long term average total ecological flow requirement for the whole WMA is 217 million m^3/year, or 15% of the total naturalised MAR. However, it can be seen from Table 5.2.4.1 that the percentage of the MAR required for ecological flows varies considerably from key point to key point in the WMA. The highest requirement in terms of percentage of MAR is in the Steenbras River where 23,8% is required. This is because of the high conservation value of the Steenbras River, for the reasons given in Section 2.6.3.

TABLE 5.2.4.1: WATER REQUIREMENTS FOR THE ECOLOGICAL COMPONENT OF THE RESERVE

KEY POINT	PRESENT [(1)] ECOLOGICAL STATUS CLASS (PESC)	RIVERINE ECOLOGICAL WATER REQUIREMENTS FOR PESC		
		% VIRGIN MAR	LONG-TERM AVERAGE REQUIREMENT (million m^3/a)	IMPACT ON 1:50 YEAR YIELD (million m^3/a)
Berg River upstream of Voëlvlei (G10A-F)	D	14,3	(95,7) [(2)]	(11,7) [(2)]
Berg River downstream of Voëlvlei (G10G-M)	C	16,5	45,2	10,0
Combined West Coast rivers (G21A & B)	C, D	14,1	3,7	0 [(3)]
Diep River (G21C-F)	C	13,7	12,1	0 [(3)]
Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers (G22E-K)	C, D	15,1	31,1	5,4
Combined Cape Peninsula rivers (G22A-D)	C, E	15,2	19,6	0 [(3)]
Steenbras River (G40A)	C	23,8	9,3	6,0
TOTAL FOR BERG WMA	---	---	121,0	21,4

1. The class allocation in the table denotes that of the river at the key point (i.e. outlet of the catchment). In "combined outlet" catchments, (West Coast rivers, for example), more than one class is applicable as a common outlet does not physically occur.
2. Upper Berg requirement assumed to be available in the Lower Berg.
3. There is no impact on 1:50 year yield because it is assumed that there is no utilisable 1:50 year yield in 1995.

5.2.5 Discussion and Conclusions

Apart from Voëlvlei Dam, which is off-channel and is filled by flow diverted from nearby rivers during the winter months, Wemmershoek is the only major dam in the Berg River catchment. The impact of the ecological Reserve on the 1:50 year yield of Wemmershoek was estimated to be 6,6 million m^3/a. The impact of the ecological Reserve on the run-of-river yield in the catchment of the dam was estimated to be 0,9 million m^3/a. Thus, the only part of ecological releases from Wemmershoek Dam that is likely to contribute to ecological flows that impact on run-of-river yields of downstream catchments is 0,9 million m^3/a. Hence the impact on the system yield of ecological releases from Wemmershoek Dam was assumed to be 5,7 million m^3/a (6,6 million m^3/a - 0,9 million m^3/a) in addition to any run-of-river yield impacts further downstream. The impact on run-of-river yield at the outlet of catchment G10F was estimated to be 6,0 million m^3/a. Thus the total impact of the ecological Reserve on the Berg River upstream of Voëlvlei was assumed to be 11,7 million m^3/a (5,7 million m^3/a + 6,0 million m^3/a). The impact on the run-of-river yield of Catchment G10M upstream of the estuary is estimated to be 10 million m^3/a. As the Berg River upstream of Voëlvlei provides more than this, the excess was assumed to contribute to river losses or run-of-river yield, and the impact of the ecological Reserve on the 1:50 year yield of the whole Berg River catchment is estimated to be 10 million m^3/a. The maximum impacts on the run-of-river yields of the Eerste (2,8 million m^3/a), Lourens (1,9 million m^3/a) and Sir Lowry (0,7 million m^3/a) Rivers occur immediately upstream of their mouths and total 5,4 million m^3/a. The impacts on the yields of the other rivers is negligible because they have very little or no flow during the summer months.

The Steenbras dams are close to the river mouth and no run-of-river yield has been developed downstream of the dams. Therefore, the impact of the ecological Reserve is a 6,0 million m^3/a reduction in the 1:50 year yield of the dams.

It is emphasised that the estimates of the ecological Reserve originating from the procedure used in this study should be used only for broad, very general planning purposes. The confidence levels in the classes determined for individual quaternary catchments are highly variable, as they depend on the levels of knowledge of the individuals of the specialist team. This, as well as the comments regarding each quaternary catchment that are presented in Appendix F, should be borne in mind when using the data. In all cases where information requirements go beyond the general planning level, the procedures developed for the determination of the ecological Reserve at the Rapid, Intermediate, or Comprehensive levels should be applied.

5.3 URBAN AND RURAL

5.3.1 Introduction

The distribution of urban water requirements and rural domestic water requirements is shown on Figure 5.3.1.1 and in Table 5.3.1.1. As previously stated, the requirements shown include distribution and conveyance losses.

The total combined requirement at 1995 levels of development was estimated to be 362 million m^3/a, of which approximately 353 million m^3/a was required by the towns and 9 million m^3/a by consumers in the rural areas. Most of the water requirements in these categories occur in the densely populated south-western part of the WMA. It was assumed that the full requirement was at 1:50 year assurance.

TABLE 5.3.1.1: URBAN AND RURAL DOMESTIC WATER REQUIREMENTS

CATCHMENT				URBAN REQUIREMENTS (million m^3/a)	RURAL DOMESTIC WATER REQUIREMENTS (million m^3/a)	COMBINED URBAN AND RURAL DOMESTIC REQUIREMENTS (million m^3/a)	REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)	HUMAN RESERVE (million m^3/a)
SECONDARY		QUATERNARY						
No.	Description	No.	Description					
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	18,7	1,7	20,4	20,4	2,0
		G10G to G10M	Berg River downstream of Voëlvlei	19,0	4,4	23,4	23,4	1,4
	Sub-Total (Berg River)			**37,7**	**6,1**	**43,8**	**43,8**	**3,4**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0,1	0,7	0,8	0,8	0,1
		G21C to G21F	Diep River	4,4	1,5	5,9	5,9	0,6
		G22E to G22K	Combined Kuils/Eerste/ Lourens/Sir Lowry Rivers	10,5	0,8	11,3	11,3	0,9
		G22A to G22D	Combined Cape Peninsula rivers	300,0	0,4	300,4	300,4	24,6
	Sub-total (Diep River and West Coast belt)			**315,0**	**3,4**	**318,4**	**318,4**	**26,2**
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0	0
	TOTAL IN BERG WMA			**352,7**	**9,5**	**362,2**	**362,2**	**29,6**

(1) Conveyance and Distribution losses are included.

Table 5.3.1.1 also shows the Human Reserve requirement, calculated on the basis of 25*l* /person/day for the total population, and totalling 29,6 million m³/a for the WMA. This requirement is included in those requirements shown in the other columns of Table 5.3.1.1

5.3.2 Urban

Introduction

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

Methodology

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

Direct water use

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

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

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

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

The study then proceeded to derive per capita water use for each of these categories using information from the South African Local Government Handbook (Gaffney Group, 1998), and the data collected as part of the Water Resources Situation Assessments from local authorities at the time. Where detailed data was not available, an estimation procedure was followed. The categories defined were associated with default unit water uses to generate overall water use estimates where hard data was not available. These categories and default unit water uses are listed in Table 5.3.2.1.

TABLE 5.3.2.1: DIRECT WATER USE: CATEGORIES AND ESTIMATED UNIT WATER USE

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

Indirect water use

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

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

TABLE 5.3.2.2: CLASSIFICATION OF URBAN CENTRES RELATED TO INDIRECT WATER USE

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

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

URBAN CENTER CLASSIFICATION	COMMERCIAL	INDUSTRIAL	INSTITUTIONAL	MUNICIPAL
Metropolitan	0.2	0.3	0.15	0.08
Cities				
Towns Industrial				
Towns Isolated				
Towns Special	0.30	0.15	0.08	0.03
Towns Country	0.10	0.15	0.03	0.10
New Centres	0.15	0.08	0.08	0.08

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

The distribution of urban water requirements determined on this basis is shown in Table 5.3.2.4, where bulk conveyance losses and distribution losses have been added to the estimated direct and indirect water requirements to derive total water requirements.

Information on water use by different categories of housing and on the ratios of indirect to direct water use was not available for the towns in the Berg WMA. Therefore, the appropriate ratios of those shown in the above tables were used to estimate the split between direct and indirect water use.

It can be seen from Table 5.3.2.4 that most (89%) of the total urban water requirements of 353 million m^3/a in 1995 occurred in the Cape Peninsula environs (294 million m^3/a).

The water requirement is shown as occurring in catchments G22A to G22D, but it is, in fact, the estimated requirement of all the urban areas within the Cape Metropolitan Area, excluding Atlantis, which extend beyond catchments G22A to G22D into all the other sub-areas shown in Table 5.3.2.4 for the "Diep River and West Coast belt". The requirements of the Cape Metropolitan Area, excluding Atlantis, which has its own supply, were shown as concentrated in catchments G22A to G22D because information on the distribution of water requirements within the Cape Metropolitan Area was not readily available when the estimate was made. The separate urban requirements shown for Catchments G22E to G22K are those of Stellenbosch, which is not within the Cape Metropolitan Area, those shown for catchments G21C to G21F are for Malmesbury, and those shown in catchments G21A and G21B are for Atlantis and Mamre.

TABLE 5.3.2.4: URBAN WATER REQUIREMENTS IN 1995

CATCHMENT				URBAN WATER REQUIRMENTS (million m^3/a)							URBAN TOTAL AT 1:50 YEAR ASSURANCE	RETURN FLOWS			
SECONDARY		QUATERNARY		DIRECT	INDIRECT	BULK CONVEYANCE LOSSES		DISTRIBUTION LOSSES		TOTAL		EFFLUENT	IMPERVIOUS URBAN AREA	TOTAL RETURN FLOW	RETURN FLOW AT 1:50 YEAR ASSURANCE
No.	Description	No.	Description	(million m^3/a)	(million m^3/a)	(million m^3/a)	%	(million m^3/a)	%	(million m^3/a)	(million m^3/a)	(million m3 /a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	8,7	5,5	0,9	5	3,6	19	18,7	18,7	9,4	1,4	10,8	10,8
		G10G to G10M	Berg River down-stream of Voëlvlei	10,8	3,8	0,9	5	3,5	18	19,0	19,0	4,6	1,1	5,7	5,7
Sub-total (Berg River)				19,5	**9,3**	**1,8**	5	**7,1**	19	**37,7**	**37,7**	**14,0**	**2,5**	**16,5**	**16,5**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	3,1	2,9	0	0	0	0	6,0	6,0	3,0	0,6	3,6	3,6
		G21C to G21F	Diep River	2,0	1,3	0,2	5	0,9	20	4,4	4,4	0,9	1,1	2,0	2,0
		G22E to G22K	Combined Kuils/ Eerste/Lourens/Sir Lowry Rivers	4,9	3,0	0,5	5	2,1	20	10,5	10,5	5,2	0	5,2	5,2
		G22A to G22D	Combined Cape Peninsula rivers	133,0	74,3	28,5	10	58,3	19	294,1	294,1	139,2	0	139,2	139,2
Sub-total (Diep River and West Coast belt)				143,0	**81,5**	**29,2**	10	**61,3**	19	**315,0**	**315,0**	**148,3**	**1,7**	**150,0**	**150,0**
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL IN BERG WMA				162,5	**90,8**	**31,0**	9	**68,4**	19	**352,7**	**352,7**	**162,3**	**4,2**	**166,5**	**166,5**

The estimate of 294 million m^3/a for the total water use in the Cape Metropolitan Area in the 1995 calendar year may be slightly high as, in the period July 1994 to June 1995 the former Cape Town City Council supplied 293,7 million m^3 to its own consumers (City of Cape Town, 1996) and various other municipalities that now fall within the Cape Town Metropolitan Area. This amount included approximately 18,7 million m^3 supplied to Paarl, Wellington and riparian owners downstream of Wemmershoek Dam. It did not include supplies to Atlantis, which used about 6 million m^3/a at that time. Thus the quantity supplied to consumers in the present Cape Metropolitan Area was 275 million m^3, including bulk conveyance losses. In addition, the local sources of the other municipalities would have provided about 5 million m^3, bringing the total consumption, excluding that of Atlantis, to 280 million m^3, compared to the estimate used in this report of 294 million m^3/a.

The full requirements of the seven categories of direct water use shown in Table 5.3.2.1 and the four categories of indirect water use shown in Table 5.3.2.3 are supplied at different assurances, some at more than 1:50 year assurance and some at less than 1:50 year assurance. However, as neither the quantities of water required in the various user categories, nor the assurances at which they are supplied are accurately known for all urban areas, it was assumed that the average assurance of supply is 1:50 year.

In 1995, the water requirements of Robben Island, amounted to about 0,15 million m^3, and were obtained from the Cape Town municipal supply and transported by ship to the island. This quantity is included in the indirect requirements in Table 5.3.2.4. In 1998, a seawater desalination plant with a capacity of 0,18 million m^3/a was commissioned on Robben Island and it, together with some groundwater, provides the requirements of the island.

It can be deduced from the figures shown in the table that the allowances for conveyance and distribution losses account for approximately 28% of the estimated total urban requirements in the WMA. The reasons for this are discussed in the following section.

Water Losses

Water losses occur in the conveyance of water from the raw water source to the water treatment works and from the treatment works to bulk treated water storage reservoirs. These are referred to in this report as bulk conveyance losses. They occur as a result of spillage, leakage and evaporation from canals, leakage from pipelines and storage reservoirs, and backwashing of filters at water treatment works.

Further losses occur between the bulk treated water storage reservoirs and consumers, mainly as a result of leaking or broken pipes and fittings. These are known as distribution losses.

Little information on losses in the various town supplies could be obtained. Therefore it was necessary to make assumptions based on the type of raw water supply, the distance over which water is conveyed, and the nature of the distribution system. The assumed values are shown in Table 5.3.2.4.

In the context of the overall water resources of the WMA, some of the water used by urban consumers is returned to the rivers as treated effluent, and can contribute to ecological flow requirements or be abstracted and re-used further downstream. However, most of the urban use is in coastal areas where the treated effluent is discharged to the sea.

Return Flows

Reliable information on return flows was available for the towns in the Cape Metropolitan Area. This area houses the majority of the urban water users. For smaller towns lying outside of this area, return flows of 50% of the direct and indirect water requirements were assumed. The return flows are shown in Table 5.3.2.4.

Where there are large urban areas, increased runoff from paved areas can significantly increase the runoff to rivers. This runoff can be considered to be a component of urban return flows. In the Berg WMA most of the additional runoff generated in this way is discharged to small watercourses that flow into the sea and that are not economically utilisable as sources of water supply. Therefore the contribution to yield of increased runoff from urban areas has been assumed to be zero.

5.3.3 Rural

Rural water users include the inhabitants of farms, small rural settlements not classified as towns, and coastal resorts that are not classified as towns. No detailed information on rural water use was found. The rural population in the Berg WMA constitutes only 5,2% of the total and consequently, the rural water use is small when compared to the urban water use.

In order to obtain an estimate of the total water requirements, consumers were considered to fall into three economic categories, with associated unit water requirements. These categories are "Rural", being people living far from towns and not part of the communities of large commercial farms, "Developing Urban" being people of the lower income group living close to towns and typically on smallholdings, and "Commercial farming" being the owners of large commercial farms and their workers.

The assumed unit water requirements are shown in Table 5.3.3.1. For want of better information, losses were assumed to be 20% of total water requirements, including losses.

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

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct Use (ℓ/c/d)	Distribution losses		Total (ℓ/c/d)
		(ℓ/c/d)	(%)	
Rural	75	19	20	94
Developing urban	150	38	20	188
Commercial farming	175	44	20	219

Rural water requirements were calculated from the estimated number of people in each user category in each quaternary catchment. Detailed estimates are given in Appendix F and the results are summarised in Table 5.3.3.2.

TABLE 5.3.3.2: RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						RURAL WATER REQUIRMENTS							RETURN FLOWS	
PRIMARY		SECONDARY		QUATERNARY		DOMESTIC (1) (million m^3/a)	SMALL SCALE IRRIGATION (2) (million m^3/a)	LIVESTOCK AND GAME	LOSSES		TOTAL	TOTAL AT 1:50 YR ASSURANCE	NORMAL	TOTAL AT 1:50 YR ASSURANCE
No.	Description	No.	Description	No.	Description			(million m^3/a)	(million m^3/a)	%	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
		G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	1,4	-	0,7	0,5	20	2,6	2,6	0	0
				G10G to G10M	Berg River downstream of Voëlvlei	3,5	-	1,8	1,2	20	6,5	6,5	0	0
		Sub-total (Berg River)				**4,9**	**-**	**2,5**	**1,8**	**20**	**9,2**	**9,2**	**0**	**0**
		G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0,6	-	0,3	0,2	20	1,1	1,1	0	0
				G21C to G21F	Diep River	1,2	-	0,6	0,4	20	2,2	2,2	0	0
				G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	0,7	-	0,3	0,2	20	1,2	1,2	0	0
				G22A to G22D	Combined Cape Peninsula Rivers	0,3	-	0,2	0,1	20	0,7	0,7	0	0
		Sub-total (Diep River and West Coast belt)				**2,8**	**-**	**1,4**	**1,0**	**20**	**5,2**	**5,2**	**0**	**0**
		G4	Steenbras River	G40A	Steenbras catchment	0	-	0	0	0	0	0	0	0
		TOTAL IN BERG WMA				**7,7**	**-**	**3,9**	**2,8**	**20**	**14,4**	**14,4**	**0**	**0**

1. Household use.
2. Use of "leiwater" for watering of gardens and smallholdings falls into this category. No information was obtained on the extent, if any, to which "leiwater" is used in the Berg WMA.

Drinking water for livestock is also considered to be part of rural water requirements and was calculated as 45ℓ/ELSU/day using the Equivalent Large Stock Units shown in Table 3.5.4.1.

The distribution of water requirements for livestock is shown in Table 5.3.3.2 where it can also be seen that all rural water requirements were estimated to total 14,4 million m^3/a in 1995, including distribution losses.

It was assumed that the total rural water requirement is at 1:50 year assurance.

Return flows from rural users are assumed to be negligible.

5.4 BULK WATER USE

This section deals with industries, mines and thermal powerstations having individual bulk water supplies or direct supplies from DWAF.

A total of 1,65 million m^3/a is allocated from Voëlvlei Dam to lime quarries in the Diep River catchment but only 0,4 million m^3 were used in 1995.

The only industrial supply in 1995 was to the Armscor factory at Krantzkop, which had an allocation of 4 million m^3/a from Voëlvlei Dam. In practice, the water was supplied by the City of Cape Town from its treatment works at Voëlvlei. However, as it is not in the Cape Metropolitan Area, it is shown in Table 5.1.1 as a bulk supply. The Saldanha Steel Mill was under construction in 1995 and did not require any water for operational purposes at that stage. However, production began in 1997, and from then onwards it required 4,38 million m^3/a. This water is supplied from Voëlvlei Dam by the Berg River/Saldanha Water Supply Scheme as part of the supply to the urban area of Vredenburg/Saldanha.

The Koeberg Nuclear Powerstation uses seawater for cooling, and the Maitland Power Station obtains its water from recycled wastewater.

No information on water losses associated with bulk supplies is available. Losses have been assumed to be 20% of the total quantity supplied. Return flows have been assumed to be negligible.

5.5 NEIGHBOURING STATES

No water is supplied to neighbouring states, nor are any water resources shared with them.

5.6 IRRIGATION

5.6.1 General

Comprehensive detailed observed data on water use for irrigation in the WMA is not available. Therefore, irrigation water requirements were estimated from available information on irrigated areas, typical quotas and assurances of supply.

The information on irrigated areas was that shown in Table 3.5.2.1., which was obtained from the sources described in Section 3.5.2. Water requirements were calculated by applying typical values of water use per hectare, provided by officials of the DWAF Western Cape Regional Office, to the irrigated areas shown in Table 3.5.2.1.

5.6.2 Water Use Patterns

Estimated average water requirements for irrigation in 1995 and equivalent requirements at 1:50 year assurance are shown for key areas in Table 5.6.2.1. The table also shows estimated conveyance losses, and estimated return flows. Insufficient information is available for a distinction to be made between conveyance losses to farms and "on-farm" conveyance losses.

The typical annual irrigation requirements per hectare, on which the calculation of the field edge water requirements shown in Table 5.6.2.1 was based, are shown in Table 5.6.2.2.

In the vegetable growing area of the Cape Flats (G22D), irrigation is almost exclusively from groundwater. Large quantities of groundwater are also used in the Diep River catchment (G21E, F), in the Kuils River catchment (G22E) and in parts of the Berg River catchment (G10E, G10F, G10J). Use of groundwater for irrigation elsewhere in the WMA is on a small scale only, the main source of water being surface runoff that is stored during the wet winter months and used for irrigation during the dry summer months.

Total irrigation water use in 1995 is estimated to have been 345 million m^3/a, including conveyance losses. About 58% of this was used in the Upper Berg River catchments (G10A - G10F). These areas comprise only 17% of the surface area of the WMA. The distribution of irrigation water requirements is shown diagrammatically on Figure 5.6.2.1.

TABLE 5.6.2.1: IRRIGATION WATER REQUIREMENTS

CATCHMENT				WATER REQUIREMENTS					RETURN FLOWS				
SECONDARY		QUATERNARY		FIELD EDGE WATER REQUIREMENT (million m³/a)	CONVEYANCE LOSSES (1)		TOTAL WATER REQUIREMENT	TOTAL WATER REQUIREMENT AT 1:50 YR (2) ASSURANCE	LEACHING BEYOND THE ROOT ZONE	ADDITIONAL RETURN FLOW FROM LANDS	FROM CONVEYANCE LOSSES	TOTAL RETURN FLOW (million m³/a)	
												NORMAL	AT 1:50 YR ASSURANCE
No.	Description	No.	Description		(million m³/a)	%	(million m³/a)	(million m³/a)	(million m³/a)	(million m³/a)	(million m³/a)	(million m³/a)	(million m³/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	165,7	33,2	17	198,9	176,0	0	8,0	0	8,0	7,7
		G10G to G10M	Berg River downstream of Voëlvlei	62,2	8,7	12	70,9	59,9	0	4,7	0	4,7	3,5
Sub-total (Berg River)				**227,9**	**41,9**	**16**	**269,8**	**235,9**	**0**	**12,7**	**0**	**12,7**	**11,2**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0	0	0	0	0	0	0	0	0	0
		G21C to G21F	Diep River	20,3	2,0	9	22,3	19,4	0	0	0	0	0
		G22E to G22K	Combined Kuils/Eerste/ Lourens/Sir Lowry Rivers	39,2	2,0	5	41,2	35,1	0	0	0	0	0
		G22A to G22D	Combined Cape Peninsula Rivers	11,0	0,6	5	11,6	10,1	0	0	0	0	0
Sub-total (Diep River and West Coast belt)				**70,5**	**4,6**	**6**	**75,2**	**64,6**	**0**	**0**	**0**	**0**	**0**
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0	0	0	0	0	0	0
TOTAL IN BERG WMA				**298,4**	**46,5**	**13**	**344,9**	**300,5**	**0**	**12,7**	**0**	**12,7**	**11,2**

(1) Includes river losses and "On Farm" conveyance losses as a percentage of the total water requirement.
(2) Water requirement at 1:50 year assurance is the equivalent quantity that could be provided at 1:50 year assurance.

TABLE 5.6.2.2: TYPICAL ANNUAL FIELD EDGE IRRIGATION REQUIREMENTS

AREA	QUATERNARY CATCHMENTS	PREDOMINANT CROP	FIELD EDGE WATER REQUIREMENT (m^3/ha/a)	
			TYPICAL (m^3/ha/a)	ASSUMED AVERAGE (m^3/ha/a)
Upper Berg	G10A - G10C G10D G10E G10F	Grapes Pastures Grapes, stone fruit Pastures and grapes	4 000 5 500 7 500 7 000	5 500
Lower Berg	G10H, J, K G10M	Pastures and grapes Pastures	7 000 3 000	6 700
Diep River	G21C, D, F G21E	Pastures Pastures	3 000 5 000	3 000
Kuils/Eerste/Lourens/ Sir Lowry's River	G22E to G22K	Grapes, stone fruit, vegetables	4 500	4 500
Cape Peninsula	G22A to G22D	Grapes, vegetables	8 000	8 000

5.6.3 Water Losses

Irrigation water losses are considered in two categories, namely :

- Canal and river losses incurred in conveying water from the dam in which it is stored to the farms where it is used for irrigation, and

- On-farm conveyance losses, which occur in conveying the water from the point at which it is abstracted from a canal, river or farm dam to field edge.

The main river conveyance losses occur in the Berg River through channel losses and evaporation.

As reliable information on farm conveyance losses is not available, estimates of combined canal, river, and on-farm conveyance losses were provided by officials of the DWAF Western Cape Regional Office. These are reported as combined conveyance losses in Table 5.6.2.1 where they are shown as percentages of total water use.

5.6.4 Return Flows

Irrigation return flows are generated from water lost during conveyance to irrigated lands, by surface runoff and seepage of irrigation water applied to lands, and by excess water applied to leach unwanted salts from the soils of irrigated lands.

Leaching of soils is not widely practised in the Berg WMA, and most of the irrigation return flows arise from conveyance losses and normal irrigation of lands.

No reliable observed data on the quantity of irrigation return flows were found. Therefore estimates, provided by officials of the DWAF Western Cape Regional Office, of the percentages of field edge applications that become return flows were used to obtain an indication of the volume of return flows generated. The assumed percentages are shown in Table 5.6.4.1.

Return flows are low because much of the irrigation occurs in areas in which there is little or no flowing surface water during the summer months.

TABLE 5.6.4.1: ESTIMATED IRRIGATION RETURN FLOWS AS PERCENTAGES OF FIELD EDGE IRRIGATION REQUIREMENTS

AREA	CATCHMENTS	RETURN FLOWS (% OF FIELD EDGE IRRIGATION REQUIREMENTS)
Berg River upstream of Voëlvlei	G10A - G10F	5%
Berg River downstream of Voëlvlei	G10G - G10J G10K - G10M	5% 2%
Kuils/Eerste/Lourens/Sir Lowry Rivers	G22E - G22K	0%
Cape Peninsula rivers	G22A - G22D	0%

5.7 DRYLAND SUGARCANE

No sugarcane is grown commercially in the Berg WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

Along the lower reaches of the Berg River the evaporation losses from the water surface during the summer months exceed the inflow from the surrounding catchment area. The flow that does occur in the area during summer is the result of inflow from the wetter upper catchments, and the flow volume decreases downstream as a result of the evaporation losses and evapotranspiration by riparian vegetation. The volume of these losses has not been accurately measured because it has been hidden in records obtained from streamflow gauging stations by the effects of abstractions of water and releases of water into the river channel from Theewaterskloof and Voëlvlei Dam. For the purposes of this assessment the volume of river losses has been very roughly calculated from evaporation data and the surface area of flow in the river channel to be 10 million m^3/a on average.

Approximately 32 million m^3/a of water is estimated to evaporate from dams. Voëlvlei Dam is estimated to account for 17 million m^3/a of this quantity, and Steenbras Upper Dam and Steenbras Lower Dam for 1,7 million m^3/a. The remainder of some 13 million m^3/a is from farm dams and small municipal dams.

These are rough estimates only, and are probably indicative of the upper limits of evaporation losses, which vary widely from year to year, depending on climatic conditions and the storage volumes in the dams.

The distribution of evaporation losses from dams is shown in Table 5.8.1.

TABLE 5.8.1: EVAPORATION LOSSES FROM DAMS

CATCHMENT				EVAPORATION LOSSES FROM DAMS (million m³/a)
SECONDARY		QUATERNARY		
No.	Description	No.	Description	
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	25,0
		G10G to G10M	Berg River downstream of Voëlvlei	2,0
		Sub-total (Berg River)		**27,0**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0
		G21C to G21F	Diep River	0,4
		G22E to G22K	Combined Kuils/Eerste/Lourens/Sir Lowry Rivers	2,3
		G22A to G22D	Combined Cape Peninsula rivers	0,6
		Sub-total (Diep River and West Coast belt)		**3,3**
G4	Steenbras River	G40A	Steenbras catchment	1,7
		TOTAL IN BERG WMA		**32,0**

5.9 AFFORESTATION

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) (DWAF, 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) 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.

An area of 120 km^2 of commercial timber plantations is found in the Berg WMA. The plantations are found in the high rainfall catchments. The reduction in runoff due to afforestation is estimated to be 26 million m^3/a. The corresponding reduction in the system 1:50 year yield (estimated by the WSAM development team) is 0,2 million m^3/a as shown in Table 5.9.1.

The impact on yield is so low because very little of the afforestation is in catchments regulated by major dams. The estimate is at a low level of confidence and requires verification.

TABLE 5.9.1: WATER USE BY AFFORESTATION IN 1995

CATCHMENT				AVERAGE WATER USE		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
SECONDARY		QUATERNARY					
No.	Description	No.	Description	(million m^3/a)	(mm/a) [1]	(million m^3/a)	(mm/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	15,7	7	0,2	--
		G10G to G10M	Berg River downstream of Voëlvlei	0,1	0	0	
	Sub-Total (Berg River)			**15,9**	**1,8**	**0,2**	**--**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0	0	0	
		G21C to G21F	Diep River	0,1	0,1	0	
		G22E to G22K	Combined Kuils/ Eerste/ Lourens/Sir Lowry Rivers	6,0	6,8	0	
		G22A to G22D	Combined Cape Peninsula rivers	2,4	2,9	0	
	Sub-total (Diep River and West Coast belt)			**8,5**	**2,1**	**0**	
G4	Steenbras River	G40A	Steenbras catchment	1,7	24,3	0	
	TOTAL IN BERG WMA			**26,1**	**2,0**	**0,2**	--

(1) Based on catchment area, not area of afforestation.
(2) This estimate is at a low level of confidence and requires verification.

5.10 HYDRO POWER AND PUMPED STORAGE

The single hydropower installation in the Berg WMA is a pumped storage scheme that uses water stored for urban use in the Steenbras Upper Dam. The evaporation losses attributable to the pumped storage scheme are those occurring from the lower pond, which are negligible.

5.11 ALIEN VEGETATION

Quaternary catchment information for condensed areas of infestation by alien vegetation and stream flow reductions was obtained from the CSIR (Environmentek) (Versfeld, *et al*, 1997).

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

The distribution of alien vegetation in the Berg WMA is described in Section 3.5.6. Corresponding estimates of average reduction in runoff and reduction in the system 1:50 year yield are shown in Table 5.11.1 and on Figure 5.11.1.

It can be seen from the table that most of the reduction in runoff caused by alien vegetation occurs in the catchments of the Berg River downstream of Voëlvlei Dam. Considerable infestation by alien vegetation is also found in the catchments of the West Coast rivers (G22A and G22B). The total reduction in runoff for the Berg WMA, due to alien vegetation is estimated at 87 million m^3/a. The reduction in the 1:50 year yield is estimated as 0,1 million m^3/a.

It should be noted that the reliability of these estimates is uncertain, as neither the true extent of infestation by alien vegetation, nor its effect on runoff is accurately known.

TABLE 5.11.1: WATER USE BY ALIEN VEGETATION IN 1995

CATCHMENT				AVERAGE WATER USE		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
SECONDARY		QUATERNARY					
No.	Description	No.	Description	(million m^3/a)	(mm/a)[(1)]	(million m^3/a)	(mm/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	15,1	6,7	0,1	---
		G10G to G10M	Berg River downstream of Voëlvlei	40,8	6,1	0	
		Sub-total (Berg River)		**55,9**	**6,3**	**0,1**	**---**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	14,4	17,4	0	
		G21C to G21F	Diep River	6,5	4,3	0	
		G22E to G22K	Combined Kuils/Eerste/ Lourens/Sir Lowry Rivers	3,0	3,5	0	
		G22A to G22D	Combined Cape Peninsula rivers	6,8	8,1	0	
		Sub-total (Diep River and West Coast belt)		**30,7**	**7,6**	**0**	
G4	Steenbras River	G40A	Steenbras catchment	0,1	0,8	0	
		TOTAL IN BERG WMA		**86,7** [(2)]	**6,7**	**0,1** [(2)]	**---**

(1) Based on catchment area, not area of alien vegetation.
(2) These estimates are at a low level of confidence and require verification.

5.12 WATER CONSERVATION AND DEMAND MANAGEMENT

5.12.1 Introduction

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

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

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

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

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

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

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

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

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

5.12.2 Background

Water resources and supply

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

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

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

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

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

Irrigation
Irrigation accounts for an estimated 41% of total consumptive water requirements (i.e. excluding ecological flow requirements) in the Berg Water Management Area. Irrigation losses (conveyance losses and poor efficiency) are often quite significant and it is estimated that often no more than 85% 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 3% of total water use in the Berg Water Management Area. Issues such as site selection and preparation, species selection, rotation periods and plantation management all affect the efficient use of water.

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

5.12.3 Legal and Regulatory Framework

General

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

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

Water Services Act

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

National Water Act

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

Codes of Practice

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

5.12.4 The Role of Water Conservation and Demand Management

Security of supply

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

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

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

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

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

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

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

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

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

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

5.12.5 Planning Considerations

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

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

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

5.12.6 Water Conservation and Demand Management Measures

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

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

5.12.7 Objectives of the National Water Conservation and Demand Management Strategy

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

- Create a culture of water conservation and demand management within all water management and water service institutions in South Africa.
- Support water management and water services institutions to implement water demand management and water conservation.
- Create a culture of water conservation and demand management for all consumers and users in South Africa.
- Promote international co-operation and participate with other Southern African countries, particularly co-watercourse states, to develop joint water conservation and demand management strategies.
- Enable water management and water resources institutions to adopt integrated resource planning.
- Promote social development and equity in South Africa.
- Contribute to the protection of the environment, ecology and water resources.
- Contribute to the parameters of water economics to development planning processes.

5.12.8 Water Conservation in South Africa

History

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

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

The Working for Water programme

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

Water restrictions

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

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

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

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

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

- The overall reduction in water use depends on a number of factors. However, when water use is reduced beyond 30% it can be detrimental to the user from a financial and motivational perspective.

- Voluntary reduction in water use fails to achieve the savings possible with mandatory steps.

- The most effective methods of reducing water use are higher tariffs, restriction of garden watering times, the banning of domestic hose pipe usage and allotting quotas to industry, bulk consumers and irrigators.

- The most effective motivations are pamphlets/newsletters, higher tariffs and punitive measures.

- The major interventions required to reduce both physical and non-physical losses from pipe networks are leak detection/monitoring, replacing old plumbing and the repair/ monitoring of meters.

- The most effective methods of saving water used by commerce and industry are technical adjustments, recycle/re-use and promotion campaigns.

- The ratio of return flow to water use is not materially changed by changes in water use.

The measures implemented during the drought in the mid- 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 in the Berg 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. In depth investigations of the potential for water conservation in the Western Cape Water Supply System have shown that :

- because of the use of sophisticated irrigation equipment (mainly microjet and drip) and management, and the tendency to under-irrigate, further water conservation and demand management measures would at best result in savings in on-farm water use of 5% by 2006 and 10% by 2011, and at worst, result in no further savings.

- urban demands could be reduced over a three year period by between 8% and 15% of what they would be if no action were taken.

The greatest scope for water conservation in the Berg WMA appears to be in reducing the conveyance and distribution losses that occur in the provision of water to the urban sector.

Existing measures taken include :

- Limited municipal leak detection and repair progammes
- Re-use of limited volumes of sewage effluent for irrigation and cooling water
- Stepped tariffs for urban users.

The effectiveness of these measures is not known because their impact has been masked by the implementation of limited water restrictions at the same time.

5.13 WATER ALLOCATIONS

5.13.1 Introduction

As explained in Section 3.4, numerous allocations of water have been made in the past under the provisions of the Water Act of 1956 and earlier legislation. Under the National Water Act (Act No. 36 of 1998) these allocations will be replaced by general authorisations or by licensing of specific water uses. The previous allocations were, however, still valid in 1995, and are summarised in this section of the report for comparison with estimated water availability in 1995.

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

(a) Article 63 : Irrigation scheduling and quotas from Government Water Schemes.
(b) Article 56(3) : Allocations to other users from Government Water Schemes.
(c) Article 62 : Scheduling and quotas from Government Water Control Areas.
(d) Articles 32A and 32B : Scheduling and quotas from Government Subterranean Water Control Areas.
(e) Industrial, mining and effluent permits (including Articles 12, 12B and 21).
(f) Other allocations (including Section 9B permits, Water Court orders and older legislation).

Under (c) and (d) above, reference is made to Government Water Control Areas and Government Subterranean Water Control Areas. The first mentioned were a feature of the Water Act of 1956 which was applied to areas in which it was necessary in the public interest for the allocation of rights to the use of public water to be based on considerations other than only the extent of irrigable riparian land. The Water Act of 1956 provided for such cases to be dealt with by empowering the State President to declare the relevant area a Government Water Control Area in which the Minister of Water Affairs was entitled to allocate water. In all other areas water could be allocated only by a Water Court, primarily in proportion to the extent of irrigable riparian land.

Government Subterranean Water Control Areas provided for a similar situation in areas where over-exploitation of groundwater aquifers occurred.

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

In the Berg WMA, most of the Berg River valley and the valleys of some of its tributaries as well as the Eerste River valley were Government Water Control Areas. The Yzerfontein area (G21A, G10L, G10M) in the vicinity of Saldanha was a Government Subterranean Water Control Area.

5.13.2 Permits and Other Allocations in the Berg WMA

The information on water allocations given in this section cannot be compared directly with the allocations in irrigation districts shown in Table 4.4.2 of Section 4.4 because the latter include Article 62 allocations (scheduling and quotas from Government Water Control Areas) which are not included in this Section because a comprehensive list of such allocations could not be obtain in this study. Article 62 allocations covered run-of-river flow which was not necessarily included in Article 63 allocations (scheduling and quotas from Government Water Schemes).

In the Berg WMA, the main allocations of water were made from the Riviersonderend-Berg River Government Water Scheme (Theewaterskloof Dam) and the Voëlvlei Water Scheme. Article 63 allocations to irrigation districts were made to a total annual volume of water in 1995 of 105,3 million m^3 and allocations to irrigation districts under Article 56(3) totalled 36,7 million m^3/a, bringing the total allocation to irrigation districts to 142,0 million m^3/a for a total scheduled area of 25 672 ha. The combined allocations to irrigation districts under both Article 63 and Article 56(3) are summarised in Table 5.13.2.1.

TABLE 5.13.2.1: ARTICLE 63 AND ARTICLE 56(3) SCHEDULING AND QUOTAS FROM GOVERNMENT WATER SCHEMES FOR IRRIGATION DISTRICTS IN THE BERG WMA

SCHEME	QUATERNARY CATCHMENTS	SCHEDULING (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)
Riviersonderend-Berg River	G10A, C, D, F, J, K G22F, H	20 820	4 000 5 000 6 000	101,0
Voëlvlei	G10F, J, K	4 852,4	7 000 8 500	41,0 [(1)]
TOTALS	---	**25 672,4**	---	**142,0**

(1) Includes 20 million m^3/a supplied to Twenty-four Rivers Irrigation District from the Twenty-four Rivers canal to Voëlvlei Dam.

Allocations from Voëlvlei Dam under Article 56(3) are shown in Table 5.13.2.2. The total under "irrigation" includes 20,0 million m^3/a for the Twenty-four Rivers Irrigation District which is included in Table 5.13.2.1 as well. The remaining 16,7 million m^3/a of the total of 36,7 million m^3/a of Article 56(3) allocations to irrigation districts referred to above were from Theewaterskloof Dam. Allocations from Theewaterskloof Dam to other water users in the Berg WMA are also shown in Table 5.13.2.2. There were, in addition, Article 56(3) allocations from Theewaterskloof Dam to consumers in the Breede WMA totalling 28,54 million m^3/a. The total allocation to irrigation of 38,82 million m^3/a shown in Table 5.13.2.2 comprises 36,7 million m^3/a to irrigation districts and 2,12 million m^3/a to private landowners not in irrigation districts. Details of the Article 56(3) allocations to municipalities are shown in Table 5.13.2.3.

TABLE 5.13.2.2: ARTICLE 56(3) ALLOCATIONS FROM GOVERNMENT WATER SCHEMES TO CONSUMERS IN THE BERG WMA

SCHEME	QUATERNARY CATCHMENTS	ALLOCATION (million m^3/a)					
		HOUSEHOLD & STOCK WATERING	MUNICIPALITIES	BULK INDUSTRIAL	BULK MINING	IRRIGATION	TOTAL
Voëlvlei	G10F, G, H, J, L, M	0,99	15,05	1,69	0	21,93	39,66
Riviersonderend-Berg River	G10A, C, D G22F, G, H, J	0	88,42	0	0	16,89	105,31
TOTALS	**---**	**0,99**	**103,47 (1)**	**1,69 (2)**	**0**	**38,82**	**144,97**

1. See Table 5.13.2.3 for details of allocations to municipalities.
2. Only 0,4 million m^3/a used (see Table 5.13.2.5).

TABLE 5.13.2.3: ARTICLE 56 (3) ALLOCATIONS FROM GOVERNMENT WATER SCHEMES TO MUNICIPALITIES (1)

SCHEME	MUNICIPALITY	ALLOCATION (million m^3/a)	REMARKS
Voëlvlei	Piketberg Vredenburg-Saldanha Langebaan Moorreesburg West Coast District Council Other	2,895 0,165 0,008 0,584 11,300 0,096	All allocations except Piketberg supplied through the West Coast District Council via the Withoogte and Swartland Treatment Works
Sub-total from Voëlvlei		**15,048**	
Riviersonderend-Berg River	Cape Town Paarl Stellenbosch Other	83,000 2,109 3,00 0,31	
Sub-total from Riviersonderend-Berg River		**88,419**	
TOTAL FOR BOTH SCHEMES		**103,467**	

1. This Table provides details of the allocations to municipalities shown in Table 15.3.2.2.

In addition to the allocations shown in Table 5.13.2.3, Cape Town had an allocation of 66,36 million m^3/a from Voëlvlei Dam and Armscor an allocation of 4 million m^3/a, but these do not appear to have been Article 56(3) allocations

Most of the allocations to "household and stockwatering", "municipalities", and "bulk and industrial" shown in Table 5.13.2.2 were supplied as treated water by the West Coast District Council

Numerous allocations of water have been made under Water Court orders, other sections of the Water Act of 1956, and earlier legislation. Those that have been identified from readily available sources are listed in Table 5.13.2.4, but the list is not necessarily comprehensive.

TABLE 5.13.2.4: MISCELLANEOUS ALLOCATIONS

WATER USER	QUATERNARY CATCHMENT	ALLOCATION (million m^3/a)	LEGISLATION	REFERENCE
Noord Agter Paarl Irrigation District	G10C	2,0	Water Court Order	White Paper 0-67
Suid Agter Paarl Irrigation District	G10C	2,1	Water Court Order 24 September 1974	White Paper H-79
Riebeek Kasteel Irrigation District	G10F	0,6	Water Court Order	White Paper P-68
Perdeberg Irrigation District	G10D	8,255	Water Court Order 24 September 1974	White Paper J-80
Palmiet River Irrigation District	G10C	1,42	Water Court Order	White Paper N-73
Riebeek West Irrigation District	G10F	4,06	Water Court Order	DWAF files
Lower Berg Irrigation District	G10F to G10K	4,3	Article 62	DWAF letter to Irrigation Board dated 13-09-93
Paarl Municipality	G10C	8,30	Act 6 of 1952. From Wemmershoek pipeline	White Paper 0-73
Paarl Municipality	G10C	2,70	Not known but from Berg River	White Paper 0-73
Individual properties	G10C	1,337	Water Court Order 28 March 1973	White Paper Q-77
Wellington Municipality	G10D	3,30	Not known, but from Wemmershoek pipeline	White Paper 0-73
Wellington Municipality	G10D	0,42	Not known, but from Antoniesvlei	White Paper 0-73
TOTAL FOR BERG RIVER		**38,792**		
Stellenbosch Municipality	G22F, G	4,6	Water Court Order 17 November 1924	White Paper 0-73
Eerste River riparian land upstream of Stellenbosch	G22F, G	3,58	Water Court Order 17 November 1924	White Paper 0-73
TOTAL FOR EERSTE RIVER		**8,18**		

A summary of water allocations in 1995 from Voëlvlei and Theewaterskloof Dams, which is derived from information provided by the DWAF Western Cape Regional Office, is shown in Table 5.13.2.5.

The allocations to Cape Town shown in Table 5.13.2.5 total 160,36 million m^3/a and, in addition to the allocations referred to above of 66,36 million m^3/a from Voëlvlei and 83 million m^3/a from Theewaterskloof, they include the 4 million m^3/a allocation to Armscor and an additional 7 million m^3/a from Theewaterskloof. The Armscor allocation is included under Cape Town because it is supplied by Cape Town as treated water from the Voëlvlei Water Treatment Works. The additional 7 million m^3/a from Theewaterskloof was ceded by Paarl in exchange for an equivalent quantity of water provided to Paarl by Cape Town from its Wemmershoek Dam. In practice, additional water was made temporarily available to Cape Town because irrigation water requirements grew less than anticipated when the scheme was planned.

With regard to the Yzerfontein Subterranean Water Control Area it appears that, even though land was scheduled, no allocations of water were made.

TABLE 5.13.2.5: SUMMARY OF WATER ALLOCATIONS AND WATER USE FROM GOVERNMENT WATER SCHEMES IN 1995

SCHEME	WATER USERS	IRRIGATION		ALLOCATION (1) (million m^3/a)	WATER USED JUNE '95 to JULY '96 (1)	
		SCHEDULED AREA (ha)	QUOTA (m^3/ha/a)		URBAN/RURAL DOMESTIC (million m^3/a)	IRRIGATION (million m^3/a)
Berg River (Voëlvlei/Misverstand Dams)	1, City of Cape Town		--	70,360	51,575	--
	2. Pretoria Portland Cement	--	--	0,850	0,388	--
	3. Piketberg Municipality	--	--	0,704	0,444	--
	4. West Coast District Council (Swartland Treatment Works)	--	--	3,300	3,711	--
	5. Private landowners	--	--	0,036	0,005	--
	6. Lime Sales	--	--	0,001	0,001	--
	7. Lower Berg Irrigation Board	3 497,4	varies	21,000	--	16,648
	8. Twenty-four rivers Irrigation Board	1 355,0	varies	20,000	--	19,987
	9. Saron	--	--	0,305	--	0,504
	10. Yacht Club, Angling Club	--	--	0,001	0,001	--
	11. ICS Farm	--	--	3,570	--	0,053
	12. Voorberg Prison	--	--	--	--	--
	13. West Coast District Council (Withoogte Treatment Works)	--	--	8,000	10,786	--
	Sub-totals for Berg River Scheme	4 852,4	--	128,127	66,911	37,192
Riviersonderend-Berg/River (Theewaterskloof Dam)	***(a) In Breede WMA***	7 183,4	varies	48,680	2,578	30,641
	(b) In Berg WMA					
	1. City of Cape Town	--	--	90,000	121,521	--
	2. Stellenbosch Municipality	--	--	3,000	1,876	--
	3. Private landowners (Dewdale and La Roche)	--	--	--	0,019	--
	4. Dewdale Trout Farm	--	--	2,000	--	0,745
	5. Barnett Harris Farms	--	--	0,180	--	0,194
	6. Eerste River Trout Farm	--	--	0,310	--	0,133
	7. Upper Berg River Irrigation Board	14 985,1	varies	75,411	--	19,178
	8. Banhoek Irrigation Board	450,0	4 000	1,800	--	1,415
	9. Eerste River Irrigation Board	516,3	4 000	2,065	--	1,675
	10. Stellenbosch Irrigation Board	2 938,3	4 000	11,753	--	3,441
	11. Helderberg Irrigation Board	2 446,6	4 000	9,786	--	6,608
	Sub-totals for Riviersonderend/Berg River Schemes	28 519,7	--	244,985	125,994	64,030
TOTALS FOR BOTH SCHEMES		33 372,1	--	373,112	192,905	101,222
TOTALS FOR BERG WMA ONLY		**26 188,7**	--	324,432	190,327	70,581

(1) Values are rounded to three decimal places.

5.13.3 Allocations in Relation to Water Requirements and Availability

The total allocation from Voëlvlei Dam was 128 million m^3/a (Table 5.13.2.5) which compares with an estimated (DWAF, 1999b) 1:50 year yield from the system of 121 million m^3/a (105 million m^3/a from Voëlvlei Dam and 16 million m^3/a from the Twenty-four Rivers Canal to irrigators). The equivalent 1:20 year yield is about 128 million m^3/a (112 million m^3/a from the dam and 16 million m^3/a from the canal) (DWAF, 1994b).

The total allocation from the Riviersonderend-Berg River Scheme was 245 million m^3/a (Table 5.13.2.5), including allocations to the Breede WMA, which compares with a 1:50 year yield of 224 million m^3/a (DWAF, 2000c).

Table 5.13.2.5 also shows the quantities of water used from the two schemes between the end of June 1995 and the beginning of July 1996. The total water use from the Riviersonderend-Berg River Scheme was, at 190 million m^3/a, only 77% of the allocation and less than the 1:50 year yield.

The low water use in 1995 relative to allocations may be ascribed partially to farmers not having developed land for which they had acquired irrigation allocations and partially to good rains that fell at the end of winter and in mid-summer and resulted in the requirement for irrigation water being about 20 million m^3 less than it would normally have been.

It can be seen that water supplied to Cape Town from the Riviersonderend-Berg River scheme exceeded the allocation by 31 million m^3/a, thereby utilising some of the unused allocation to irrigation.

In Table 5.13.3.1, water requirements in 1995 and the allocations discussed above are compared. Some of the allocations to irrigation districts shown in Table 4.4.2 are not covered by the allocations identified in this section. These have been added to the allocations shown in Table 5.13.3.1. Some of the Water Court allocations to irrigation districts that are listed in Table 5.13.2.4 are provided through allocations from Theewaterskloof Dam. Therefore, the total allocation of 364,7 million m^3/a shown in Table 5.13.3.1 is less than the sum of the allocations shown in Tables 5.13.2.4 and 5.13.2.5.

It can be seen from Table 5.13.3.1 that the estimated water requirements in 1995 were considerably higher than the allocations that have been identified.

In the case of the allocations to irrigation, conveyance losses need to be added to the allocations to make them comparable to the estimates of requirements. Even with this adjustment, the estimated requirements would be considerably higher than the allocations. This suggests that either the estimates of requirements are too high, or that a considerable amount of what was classified as "private" water in the Water Act of 1956 is used. This aspect is discussed further in Chapter 7 where the balance between water requirements and availability is considered.

In the case of urban water requirements, the City of Cape Town obtains about 105 million m^3/a from sources other than Theewaterskloof and Voëlvlei Dams. Information on permits for these sources was not found during this study. Cape Town also has access to water from Theewaterskloof Dam that is additional to its allocation.

TABLE 5.13.3.1: COMPARISON OF IDENTIFIED ALLOCATIONS AND ESTIMATED WATER REQUIREMENTS

CATCHMENT				URBAN AND RURAL DOMESTIC WATER		IRRIGATION WATER		TOTALS	
SECONDARY		QUATERNARY		REQUIREMENT (million m^3/a)	ALLOCATIONS (million m^3/a)	REQUIREMENT (million m^3/a)	ALLOCATIONS (million m^3/a)	REQUIREMENT (million m^3/a)	ALLOCATIONS (million m^3/a)
No.	**Description**	**No.**	**Description**						
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	22,4	21,7	198,9	85,7	221,.3	107,4
		G10G to G10M	Berg River downstream of Voëlvlei	26,6	12,8	70,9	49,1	97,5	61,9
Sub-total (Berg River)				49,0	34,5	269,8	134,8	318,8	169,3
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	1,2	0	0	0	1,2	0
		G21C to G21F	Diep River	6,8	0	22,3	0	29,1	0
		G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	12,2	7,6	41,2	27,5	53,4	35,1
		G22A to G22D	Combined Cape Peninsula Rivers	315,0	160,3	11,6	0	326,6	160,3
Sub-total (Diep River and West Coast belt)				335,2	167,9	75,1	27,5	410,3	195,4
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0	0	0
TOTAL IN BERG WMA				384,2	202,4	344,9	162,3	729,1	364,7

5.14 EXISTING WATER TRANSFERS

A transfer of approximately 186 million m^3/a (1:50 year assurance) takes place from Theewaterskloof Dam in the Breede WMA into the Berg WMA. This transfer is used for urban water supply in the Berg WMA as well as for irrigation in the Berg/Eerste River catchments. A portion of this water, amounting to 25 million m^3/a on average, is obtained from the Berg River itself, during winter, from where it is transferred to Theewaterskloof for storage. Thus, the net import from Theewaterskloof Dam is 161 million m^3/a. A further 9 million m^3/a is transferred from the Breede to the Berg WMA outside of the RSE Scheme. A canal from Michell's Pass transfers approximately 4 million m^3/a from the Breede River to the Dwars Irrigation District near Wolseley. A further 5 million m^3/a transfer occurs between the Upper Wit River (Breede WMA) and the Kromme River catchment (G10D) in the Berg WMA and 0,6 million m^3/a is imported from the Du Toit's River (H60B) to the town of Franschhoek (G10A).

Information on these transfers is summarised in Table 5.14.1, and they are shown diagrammatically on Figure 5.14.1.

TABLE 5.14.1: AVERAGE INTER-WATER MANAGEMENT AREA TRANSFERS UNDER 1995 DEVELOPMENT CONDITIONS

DESCRIPTION OF TRANSFER	SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY RECEIVER WMA (million m^3/a)	TRANSFER QUANTITY SOURCE WMA (million m^3/a)		
				TRANSFER	LOSSES [1]	TOTAL
TRANSFERS OUT OF WMA :						
Wolwekloof and Banhoek Diversion to Theewaterskloof Dam	Berg	Breede	25	25	0	25
TRANSFERS INTO WMA :						
Theewaterskloof Dam to Berg and Eerste Rivers and Cape Town	Breede	Berg	186	186	0	186
Upper Wit River to Kromme River	Breede	Berg	5	5	0	5
Witbrug to Dwars Irrigation District	Breede	Berg	4	4	0	4
Du Toits River to Franschhoek	Breede	Berg	0,6	0,6	0	0,6
TOTAL WATER EXPORTS IN 1995 : 25 million m^3						
TOTAL WATER IMPORTS IN 1995 : 195,6 million m^3						

1. Losses are not known and have therefore been assumed to be zero.

5.15 SUMMARY OF WATER LOSSES AND RETURN FLOWS

A summary of water requirements, losses and return flows is presented in Table 5.15.1. About 47% of the consumptive water requirements in the WMA are for urban use. Losses in bulk distribution and reticulation systems were roughly estimated to account for 28% of the total urban requirement. The urban losses are made up of 19% of the total urban requirement in unaccounted for water and leakage in the reticulation system and an assumed 9% in the bulk supply system. The assumption of 9% may be too high, as the

Cape Town City Engineer estimated the bulk distribution system loss to be 3% in 1994/1995. The proportions of the categories of losses are shown on Diagram 5.15.1.

The return flows are re-usable as these are predominantly treated effluent from the various urban wastewater treatment plants. However, many of the treatment works are situated in close proximity to the coast and as a result, the effluent is primarily discharged to sea. The proportions of the categories of return flows are shown on Diagram 5.15.2.

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

CATEGORY		ON-SITE WATER REQUIREMENTS (million m^3/a)	LOSSES		RETURN FLOW (million m^3/a)
			(million m^3/a)	(%)	
Irrigation (1)		298,4	46,5	13	12,7
Urban		253,3	99,4	28	166,5
Rural		11,6	2,8	20	0
Bulk	a) Strategic	0	0	0	0
	b) Mining	0,3	0,1	20	0
	c) Other	3,2	0,8	20	0
Hydro-power (2)		0			0
Rivers, wetlands, dams		0	32	--	0
TOTAL		**566,8**	**181,6**	**23**	**179,2**

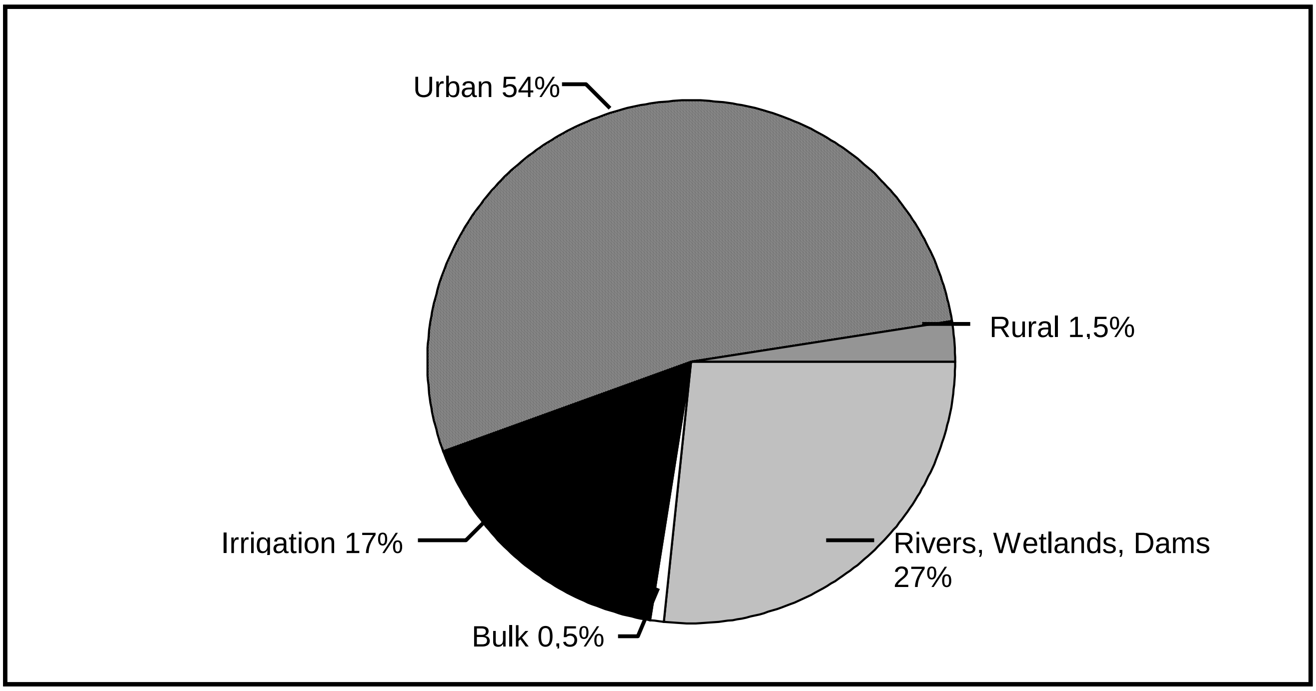

Diagram 5.15.1: Category loss as a proportion of the total losses in the WMA

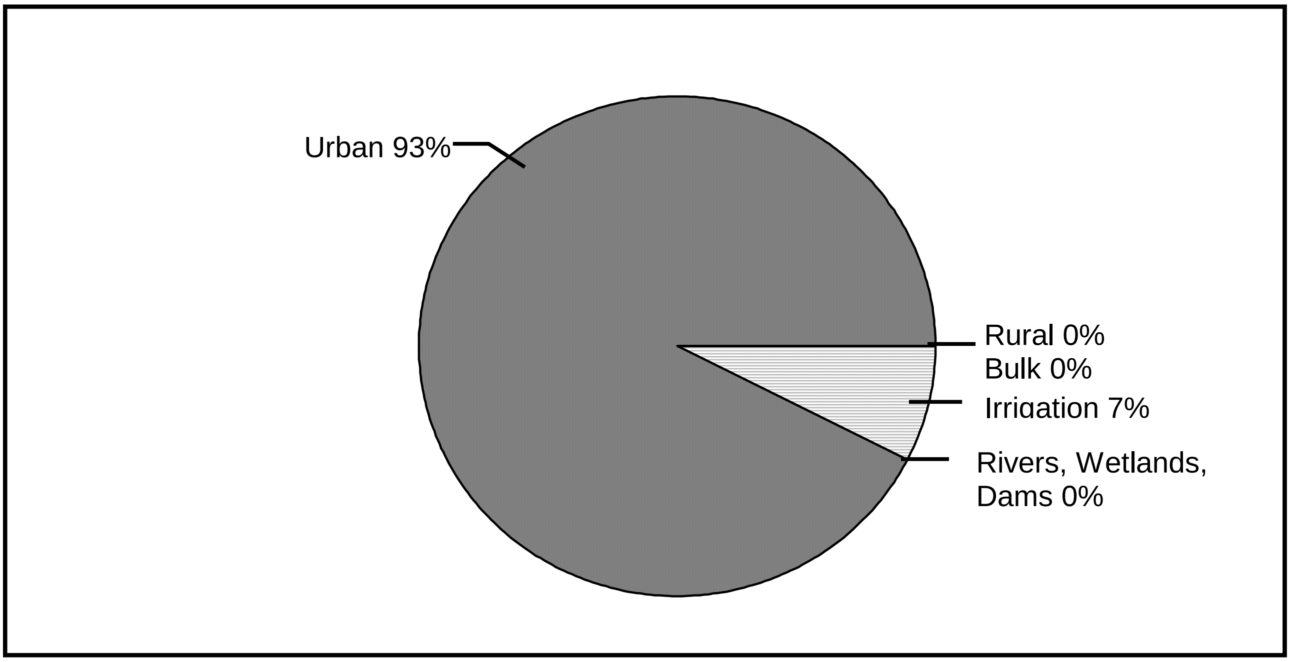

Diagram 5.15.2: Category return flow as a proportion of the total return flow in the WMA

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

It has been estimated from the Western Cape System Analysis (DWAF, 1994) and from data provided in the Water Research Commission publication, *The Surface Water Resources of South Africa, 1990* (Midgley *et al*, 1994) that, under virgin or natural conditions, the total MAR of the Berg WMA was 1 407 million m^3. Approximately 67% of this, or 942 million m^3, flowed out to sea through the mouth of the Berg River. A further 26%, or 384 million m^3 flowed out to sea from the Cape Peninsula rivers as well as the Kuils/Eerste/Lourens/Sir Lowry and Steenbras Rivers.

The remainder of the natural runoff, totalling 81 million m^3/a on average, came from the catchments comprising the coastal strips along the Cape West Coast (G21A and G21B) and the Diep River (G21C - G21F). The contribution of the northern coastal strip to this was only about 1 million m^3/a, because the area is relatively arid and sandy.

The natural runoff has been reduced by the construction of dams, the pumping of water from rivers and, to a lesser extent, by the effects of timber plantations and alien vegetation. As a result, the present day MARs at the river mouths are reduced. The present day MARs have been extracted from the Western Cape Systems Analysis (DWAF, 1994b) and are representative of catchment conditions in 1990.

The natural MAR in the Berg River estuary is estimated as 942 million m^3 and the reduced present day (1990) MAR, 682 million m^3 (DWAF, 1994b).

The yields shown in Table 6.1.1 are those available before the ecological Reserve has been provided for. As the National Water Act (No. 36 of 1998) provides for the Reserve to take preference over other water users in the allocation of water resources, the yield available for other user sectors is less than the totals shown in Table 6.1.1. However, it has been estimated, as described in Chapter 7, that the effect of making releases for the ecological Reserve, once the details of the releases have been determined and become a legal requirement, will be to reduce the 1:50 year yield available for other users by about 22 million m^3/a under present conditions of river regulation and water utilisation. Riverine ecologists believe that the Reserve requirements have been under-estimated, in which case the reduction in yield would be greater.

The base flow in rivers originates from seepage from groundwater. Therefore, where boreholes extract water from the same groundwater source, the surface water runoff is reduced by the quantity of water abstracted from the boreholes.

In an assessment of the extent to which the groundwater resources are additional to the surface water resources of the Berg WMA it was concluded for the reasons given in Section 6.2 that, as a rough approximation, groundwater resources and surface water resources should be assumed to be linked. It has, however, also been assumed that the surface water yields determined for development in 1995 made allowance for the effects on surface water runoff of groundwater use as it was in 1995. Therefore, in Table 6.1.1, the total water resource developed in 1995 is the sum of the developed surface water and groundwater yield. The total potential water resource includes, in addition to the surface and groundwater development in 1995, all potential additional

TABLE 6.1.1: WATER RESOURCES

CATCHMENT				SURFACE WATER RESOURCES (million m^3/a)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL (million m^3/a) [5]		TOTAL WATER RESOURCE (million m^3/a)	
SECONDARY		TERTIARY		CUMU-LATIVE NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995 [1]	1:50 YEAR TOTAL POTENTIAL YIELD [1]	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED IN 1995 [1]	1:50 YEAR TOTAL POTENTIAL [1]
No.	Description	No.	Description							
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	668	279	389 [2]	12	87	291	401
		G10G to G10M, G30A	Berg River downstream of Voëlvlei	274	52	52	11	97	63	122
		Sub-total (Berg River)		**942**	**331**	**441**	**23**	**184**	**354**	**523**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	26	0	0	7	20	7	20
		G21C to G21F	Diep River	55	3	3	7	22	10	25
		G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	205	29	56 [3]	8	26	37	64
		G22A to G22D	Combined Cape Peninsula rivers	128	6	6	12	41	18	47
		Sub-total (Diep River and West Coast belt)		**414**	**38**	**65**	**34**	**109**	**72**	**156**
G4	Steenbras River	G40A	Steenbras catchment	51	40	40	0	5	40	40
TOTAL IN BERG WMA				**1 407**	**409**	**546 [4]**	**57**	**298**	**466**	**719**

1. Includes "run of river" and minor/farm dam yields.
2. Includes Voëlvlei Augmentation (30 million m^3/a), Skuifraam (56 million m^3/a), Skuifraam Supplement (24 million m^3/a)
3. Includes the possible Lourens (19 million m^3/a) and Eerste River (8 million m^3/a) diversions.
4. A further potential source of water is the treated effluent produced by the wastewater treatment works in the Berg WMA (approximately 135 million m^3/a is not re-used and is discharged to sea).
5. Groundwater exploitation potential is assumed to be linked to surface water potential. Therefore, undeveloped groundwater potential has been added to the total potential water resource only in those areas not suitable for significant further development of surface water resources.

NOTE : Imports from outside the Berg WMA are excluded from the above figures.

surface water resource developments that comprehensive separate detailed studies have shown to be economically viable. However, the development of the full groundwater potential that was not developed in 1995 has been added only in those areas not suitable for significant further surface water development. It has been simplistically assumed that in other areas, any further development of groundwater yield would result in an equal reduction in surface water yield. The areas in which further development of groundwater has been added to the total potential water resource are described in Section 6.2.

The total developed water resource (excluding imports from other WMAs) in 1995 was estimated to have a yield, at 1:50 year assurance, of 466 million m^3/a (409 million m^3/a from surface water and 57 million m^3/a from groundwater). The total potential yield at 1:50 year assurance is estimated to be 719 million m^3/a. The distribution of the yield in 1995 is shown diagrammatically on Figure 6.1.1 and Figure 6.1.2 shows the total potential yield.

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 reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential, i.e. 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 utilisable 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

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

CATCHMENT				GROUNDWATER EXPLOITATION POTENTIAL (million m^3/a)	GROUNDWATER USE IN 1995 (million m^3/a)	UNUSED GROUNDWATER EXPLOITATION POTENTIAL IN 1995 (million m^3/a)	GROUNDWATER CONTRIBUTION TO SURFACE BASE FLOW (million m^3/a))	PORTION OF GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE BASE FLOW (million m^3/a)
SECONDARY		QUATERNARY						
No.	Description	No.	Description					
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	87	12	75	29	58
		G10G to G10M, G30A	Berg River downstream of Voëlvlei	97	11	86	5	92
		Sub-total (Berg River)		**184**	**23**	**161**	**34**	**150**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	20	7	13	0	20
		G21C to G21F	Diep River	22	7	15	2	20
		G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	26	8	18	13	13
		G22A to G22D	Combined Cape Peninsula rivers	41	12	29	3	38
		Sub-total (Diep River and West Coast belt)		**109**	**34**	**75**	**18**	91
G4	Steenbras River	G40A	Steenbras catchment	5	0	5	3	2
TOTAL IN BERG WMA				**298**	**57**	**241**	**55**	**243**

from groundwater abstraction. The estimates of utilisable surface water given in Section 6.3 have been derived on the basis of no increased groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilisable groundwater not contributing to the base flow of the surface water that can be added to the utilisable surface water to estimate the total utilisable resources has therefore been ignored, except in those areas where there was little utilisation of surface water in 1995 and there is little potential for future surface water development.

The existing groundwater use was determined by Baron and Seward (2000). Estimates of groundwater use were also made at a workshop held in the Berg WMA by the water resources situation assessment team. This provided local input to the estimates of groundwater use provided by Baron and Seward which were then adjusted accordingly (see Table 6.2.1 and Figure 6.2.4).

The groundwater balance compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilised (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-utilised, 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 utilised, if the total use was more than 66% of the Exploitation Potential the groundwater in the catchment was considered to be moderately utilised, and if the total use was less than 66% of the Exploitation Potential, the groundwater in the catchment was considered to be under-utilised.

In the Berg WMA, groundwater in catchments G10J, G21E and G22E is heavily utilised. In catchments G10F, G21B and G22D it is moderately utilised, and it is under-utilised in all the other catchments.

Total groundwater use in 1995 was estimated to be 57 million m^3/a, of which about 8 million m^3/a was for municipal use, 2 million m^3/a for livestock, and 47 million m^3/a for irrigation. Municipal use was mainly in Atlantis (6 million m^3/a) and Cape Town (1 million m^3/a), with several smaller towns accounting for the balance. About 18 million m^3/a of the agricultural use is in catchments G22D and G22E, and most of the remainder is in the catchment of the Klein Berg River (G10E) where about 10 million m^3/a is used, catchment G10J, in the Berg River valley, and in the Diep River catchment (G21E, F).

In estimating the total potential water resource, it has been assumed that the total groundwater exploitation potential in catchments G10K, G10L and G10M, and part of G30A, amounting to some 70 million m^3/a, will contribute as there is little potential for the development of surface water in this area. Similarly, the total groundwater exploitation potential of the Diep and Modder River catchments G21A to G21F, amounting to 42 million m^3/a, and of the Cape Peninsula catchments (G22A to G22D), amounting to 41 million m^3/a has been assumed to contribute to the total potential water resource. It has also been assumed that the groundwater potential developed in 1995 in the other catchments (12 million m^3/a in G10A to G10F and 8 million m^3/a in G22E to G22K) will continue to contribute to the total resources. Thus, the assumed total contribution of groundwater to the total potential water resource shown in Table 6.1.1 is 173 million m^3/a. Current perceptions about these potential yields are that they are very optimistic.

The City of Cape Town is currently investigating the possibility of extracting water from deep boreholes in aquifers of the Table Mountain Group of geological strata. Two possible sites have been identified in the Berg WMA. One is immediately downstream of Wemmershoek Dam (G10B) and the other is close to the town of Franschhoek (G10A). At this stage, it is envisaged that water would be pumped from boreholes about 500 m deep at these sites directly into the City of Cape Town's water supply system from the Wemmershoek site, and to storage in the proposed Skuifraam Dam from the Franschhoek site. The estimated yields of the wellfields are 15 million m^3/a from Wemmershoek and 40 million m^3/a from the one near Franschhoek.

It is not known what the effects of these wellfields, if developed, would be on surface water yield. As significant further development of the surface water resources of the Upper Berg River has been allowed for in estimating the total potential resource shown in Table 6.1.1, the potential of these deep aquifers has not been included.

Similarly, because the economic feasibility of exploiting these deep aquifers is still being verified, their yield is not included in the figures and tables in this chapter and in Appendix G. However, if the potential yield of deep aquifers were taken into account together with conjunctive operation of the other existing and potential groundwater and surface water sources, then the potential groundwater yield may be as high as 173 million m^3/a.

6.3 SURFACE WATER RESOURCES

The basis for the analysis of surface water resources was the synthesised streamflow data at quaternary catchment level developed for the Water Research Commission funded study of the water resources of South Africa (Midgley *et al*, 1994) which is commonly referred to as WR90. Certain adjustments, as described below were made to these flow sequences. Comparison of the WR90 natural flows with those derived in the Western Cape System Analysis highlight certain discrepancies. The WR90 natural flow at the Diep River mouth (G21F) is reported as 88 million m^3/a. The corresponding figure from the Western Cape System Analysis is 55 million m^3/a. In the Steenbras River catchment the Western Cape System Analysis natural flow at the river mouth is 50 million m^3/a whilst the WR90 figure is reported as 38 million m^3/a. In both cases, the Western Cape System Analysis figures are assumed to be more accurate and have been adopted.

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

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

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

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

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

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

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

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

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

Based on the three steps described above, the WR90 naturalised flow series were then adjusted for all the afforested quaternary catchments in the country. If the runoff reduction due to afforestation estimated by means of the CSIR curves was lower than the runoff reduction estimated by means of the Van der Zel curves, the virgin runoff of WR90 would have been reduced and vice versa. The difference between the adjusted MARs and the original WR90 values ranges between a reduction of 18% and an increase of 28%. For most of the catchments the difference varies between zero and an increase of 7%. In the Berg WMA the increase was between 1% and 2%.

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

The most important limitations of the method described above are :

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

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

The perfect solution is to re-calibrate all affected catchments. However, as was explained above, at this stage it was considered inappropriate. It is recommended that a sensitivity analysis should be done in order to determine whether these limitations have a significant effect on the results.

Several detailed studies of the hydrology of portions of the Berg WMA have been carried out in the past. Brief descriptions of them follow.

- The Western Cape System Analysis (DWAF, 1994b), carried out by Ninham Shand and BKS, investigated the Berg, Diep, Eerste, Lourens, Sir Lowry's Pass and Steenbras River Basins. The same study also investigated the Berg River Estuary.

- The Voëlvlei Augmentation Scheme Feasibility Study (DWAF, 2001), carried out by Arcus Gibb, investigated the pumping of Berg River winter water into Voëlvlei Dam.

- The Feasibility Study of the Skuifraam Supplement Scheme (DWAF, 1999), carried out by Ninham Shand, investigated the potential yield of this scheme in conjunction with Skuifraam Dam.

- The Integrated Water Resource Planning Study (City of Cape Town, 2001), investigated the Lourens and Eerste River Diversions, the Cape Flats Aquifer and re-use of treated wastewater effluent (Ninham Shand, Arcus Gibb).

The results of the Western Cape System Analysis were used to derive the 1995 and total potential yields shown in Table 6.3.1.

The developed surface water yield in 1995 shown in Table 6.3.1 is derived as follows :

- Berg River upstream of Voëlvlei (G10A - G20F)
  - the yield of Wemmershoek Dam of 54 million m^3/a.
  - the yield of Voëlvlei Dam of 105 million m^3/a.
  - farm dams and run-of-river yield of 120 million m^3/a to give a total of 279 million m^3/a.

- Berg River downstream of Voëlvlei (G10G - G10M)
  - the yield of Misverstand Weir of 5 million m^3/a.
  - farm dams and run-of-river yield of 47 million m^3/a to give a total of 52 million m^3/a.

- Combined West Coast Rivers (G21A, G21B)
  - no surface water yield.

- Diep River (G21C to G21F)
  - yield of farm dams in the Diep River catchment of 3 million m^3/a.

- Combined Kuils, Eerste, Lourens and Sir Lowry Rivers (G22E to K)
  - estimated yield of Kleinplaas Dam of 20 million m^3/a.
  - farm dams and run-of-river yield of 9 million m^3/a giving a total of 29 million m^3/a.

- Cape Peninsula rivers (G22A to G22D)
  - the yield of the municipal dams of 6 million m^3/a.

- Steenbras catchment (G40A)
  - the yield of the Steenbras Dams of 40 million m^3/a.

The combined run-of-river yields and yields of farm dams were estimated in consultation with officials of the DWAF Western Cape Regional Office on the following basis. It was assumed that, because of the high investment cost of developing the vineyards and orchards that are the predominant crops grown under irrigation in the WMA, the development of irrigated land has been balanced against the availability of water. In this regard, the availability of water from what was private water and from riparian rights is seen as particularly important because it costs less than water supplied from government water schemes. As the yield from "private" sources is not well documented, it was assumed that the portion of estimated irrigation requirements that is not provided for from government water schemes is provided from farm dams and run-of-river yield.

This led to an estimated yield from these sources in the Berg River upstream of Voëlvlei Dam of 120 million m^3/a. From subsequent consideration of the estimated capacity of farm dams in the catchment based on the results of the Western Cape System Analysis (DWAF, 1994c) and the Voëlvlei Feasibility Study (DWAF, 2001) and the WR90 Deficient flow-Duration-Frequency curves for 1:50 year drought conditions (Midgley *et al*, 1994), it appears that the estimate of 120 million m^3/a may be too high. The combined capacity of the farm dams is estimated to be 60 million m^3, and as these are filled by natural runoff, diversion furrows, and pumping from rivers during the winter months, and used for irrigation during the summer months, they can be expected to give a yield of about 55 million m^3/a. From consideration of the WR90 curves, it appears that a run-of-river yield of about 20 million m^3/a could be obtained under 1:50 year drought conditions. On this basis the yield from farm dams and run-of-river yield would be 75 million m^3/a.

Similar considerations apply to the Berg River downstream of Voëlvlei Dam, but the original estimates for the other areas of the WMA appear to be reasonable. For the purposes of this situation assessment the original higher estimates have been retained as historically there have not been sustained shortages of water for irrigation. Nevertheless, it should be noted that the quantity of water obtained from local sources needs to be reliably established.

The potential maximum yield of the Berg River system could be developed in a number of different ways. These include :

- Construction of a pumping station on the Berg River near Voëlvlei Dam (G10F) and abstraction of Berg River winter flows into Voëlvlei Dam (or for direct usage by Cape Town if water quality concerns preclude storing it in the dam).

- Construction of the Skuifraam Dam (DWAF, 1999) in the upper reach of the Berg River (G10A).

- Construction of the Skuifraam Supplement Scheme (G10C) downstream of the Berg/Dwars River confluence and abstracting winter water to be pumped up to Skuifraam Dam (DWAF, 2000c).

- Construction of diversion weirs on the Lourens (G22J) and Eerste Rivers (G22H) to augment supply to Faure Treatment Works.

- Utilisation of groundwater potential in the Cape Flats (G22D) and the West Coast catchments (G10M, G21A).

- Re-use of treated wastewater effluent generated by the various wastewater treatment works in the Berg WMA.

- Possible groundwater exploitation with deep wells.

The total potential yield from surface water resources shown in Table 6.3.1 is based on the following assumptions :

- Berg River upstream of Voëlvlei (G10A - G10F)
  - The estimated yield of Wemmershoek Dam of 54 million m^3/a.
  - An estimated farm dam and run-of-river yield of 120 million m^3/a.
  - The yield of Voëlvlei Dam of 105 million m^3/a.
  - Voëlvlei Augmentation Scheme (additional yield of 30 million m^3/a) involving winter pumping from the Berg River into Voëlvlei Dam.
  - Construction of Skuifraam Dam (additional yield of 56 million m^3/a) in the Upper Berg River.
  - Construction of Skuifraam Supplement Scheme and winter pumping into Skuifraam Dam (additional yield of 24 million m^3/a)
    to give a total of 389 million m^3/a.

- Berg River downstream of Voëlvlei (G10G - G10M)
  - no additional development of surface water yield assumed.

- Combined West Coast rivers (G21A and G21B)
  - no additional surface water yield assumed.

- Diep River (G21C - G21F)
  - no additional surface water yield assumed.

- Kuils/Eerste/Lourens/Sir Lowry Rivers (G22E to G22K)
  - Estimated incremental yield from Kleinplaas Dam of 20 million m^3/a.
  - Farm dam and run-of-river yield of 9 million m^3/a.
  - Possible Lourens River diversion (additional yield of 19 million m^3/a).
  - Possible Eerste River diversion (additional yield of 8 million m^3/a)
    to give a total of 56 million m^3/a.

TABLE 6.3.1: SURFACE WATER RESOURCES

CATCHMENT				CATCHMENT AREA (km²)	MEAN ANNUAL PRECIPITATION (mm/a) [1]	MEAN ANNUAL EVAPORATION (mm/a)	NATURAL MAR		YIELD [3] (1:50 YEAR)	
SECONDARY		QUATERNARY					INCREMENTAL (million m³/a)	CUMULATIVE (million m³/a)	DEVELOPED IN 1995 (million m³/a)	TOTAL POTENTIAL (million m³/a)
No.	Description	No.	Description							
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	2 247	765	1 579	668	668	279	389
		G10G to G10M	Berg River downstream of Voëlvlei	6 665	396	1 517	274	274	52	52
	Sub-total (Berg River)			**8 912**	**489**	**1 533**	**942**	**942**	**331**	**441**
G2	Diep River and West Coast belt	G21A to B21B	Combined West Coast Rivers	827	414	1 448	26	26	0	0
		G21C to G21F	Diep River	1 501	505	1 490	55 [2]	55	3	3
		G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	878	767	1 419	205	205	29	56
		G22A to G22D	Combined Cape Peninsula Rivers	847	707	1 400	128	128	6	6
	Sub-total (Diep River and West Coast belt)			**4 053**	**585**	**1 447**	**414**	**414**	**38**	**65**
G4	Steenbras River	G40A	Steenbras catchment	72	1 121	1 405	50 [2]	50	40	40
TOTAL IN BERG WMA				**13 037**	**522**	**1 505**	**---**	**1 406**	**409**	**546**

(1) MAPs are based on weighted averages using quaternary catchment MAPs from WR90.
(2) Naturalised MARs for these two catchments are based on the WCSA results and not WR90.

- Cape Peninsula rivers (G22A to G22D)
  - no further development of surface water resources assumed.

- Steenbras River (G40A)
  - no further development of surface water yield from local sources assumed.

The above potential yields exclude the following :

- Transfers into the Berg WMA from the Breede WMA
- Potential use of 135 million m^3/a treated wastewater effluent which currently discharges to sea.

6.4 WATER QUALITY

6.4.1 Mineralogical Surface Water Quality

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

The mineralogical water quality of the surface water bodies is 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 Berg River catchment is well monitored and there is a good distribution of monitoring points on the main stem river and on most of the major tributaries. There are fewer monitoring points in the lower Berg River catchment which is probably a reflection of reduced impacts on the main stem river. The Diep River catchment (G21C - G21F) is poorly monitored by the National Chemical Water Quality Monitoring Programme but the Western Cape Regional Office of DWAF has a few monitoring points in the lower reaches of the river. The distribution of DWAF monitoring points on the Eerste, Lourens and Kuils Rivers are adequate to assess their mineralogical status. There are no DWAF monitoring points on urban rivers in the Cape Metropolitan Area (G22A - G22D) that met the criteria spelled out below that could be used to characterise their mineralogical status. However, the City of Cape Town monitors these rivers on a regular basis as part of their urban catchment management initiatives.

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

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

The water quality is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements 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

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

TABLE 6.4.1.2: OVERALL CLASSIFICATION

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

The water quality of the Berg Water Management Area 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 BERG WATER MANAGEMENT AREA

SECONDARY CATCHMENT	NO OF QUATERNARY CATCHMENTS	NO OF QUATERNARY CATCHMENTS IN CLASS					
		BLUE	GREEN	YELLOW	RED	PURPLE	NO DATA
G10	12	5	4	0	0	3	0
G21	6	0	0	0	1	0	5
G22	10	3	1	0	1	0	5

The water quality of the Berg River catchment is influenced to a large degree by the geology of the basin (DWAF, 1993a & b). In the mountains and upland areas of the basin the geology comprises Table Mountain Sandstone (TMS). Downstream of Paarl, the remainder of the basin comprises Malmesbury Shale with a number of granite hills surrounded by clay soils derived from weathered granite. In this area the overlying TMS has been progressively eroded to expose bedrock of Malmesbury Shales. Malmesbury Shale remains the main underlying rock formation to the mouth of the river. This change in geology is reflected in the mineralogical water quality of the Berg River (Figure 6.4.1.1). Water quality in the catchments upstream of Paarl is classified as ideal, it changes to good in the middle reaches and to completely unacceptable in the lower reaches. The most downstream reaches are affected by the tidal effect and water quality is consequently characterised by higher salinities.

Salinity in the upper reaches of the Berg River, upstream of Paarl, is classified as ideal for domestic and agricultural water supply. The river and its tributaries (Franschhoek, Banhoek and Dwars Rivers) drain areas with Table Mountain Sandstone as the dominant geological formation (DWAF, 1993a, Nitsche *et al*., 2001). Water quality in the middle reaches is good. Tributaries on the eastern bank of this reach (Krom and Kompanjies River) drain areas with Table Mountain Sandstone while tributaries along the western bank (Doring River) drain areas with the saline Malmesbury Shales as dominant geological formation. Water quality in the lower reaches of the middle Berg River is classified as good because water is released from Voëlvlei Dam to supply downstream irrigation and domestic users with good quality water. In this section, only the Klein Berg River and Twenty Four Rivers drain Table Mountain Sandstone. Rivers on the western bank drain Malmesbury Shales and include the Vis, Sandspruit and Moorreesburgsruit. Water quality in the Matjies River, on the eastern bank of the lower middle reaches, is classified as unacceptable. It also drains areas with Malmesbury Shales as the dominant geological formation. In the lower Berg River, water is classified as unacceptable due to tidal effects and Malmesbury shales being the dominant geological formation of the lower catchment area.

Water quality in the lower reaches of the Diep River is classified as poor, largely as a result of Malmesbury Shale formations. An examination of City of Cape Town data indicated that urban rivers in the Cape Town Metropolitan Area (G22B to G22D) could be classified as poor in their lower reaches. This is probably due to urban impacts on water quality. The Eerste River (G22H) is classified as good water quality, the Lourens River (G22J) as poor (probably the result of urban impacts) and the Sir Lowry's Pass River as ideal.

6.4.2 Mineralogical Groundwater Quality

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

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

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

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

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

6.4.3 Microbiological Water Quality

Background

A method was developed and applied to assess the risk of microbial contamination of surface water and groundwater resources in South Africa. (Refer to Appendix G2 for details of the study). Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution. The maps provide a comparative rating of the risk of faecal contamination of the surface water and groundwater resources. The microbial information that has been provided is, however, intended for planning purposes only and is not suitable for detailed water quality assessments.

Mapping microbial contamination of surface water resources

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

As part of this study, the same screening method was applied to produce a potential surface faecal contamination map for the whole of South Africa using national databases for population density and degree of sanitation. The portion applicable to the Berg WMA is given in Figure 6.4.3.1 and it indicates that overall, there is a low risk of surface water contamination with faecal matter. The exception is Kuils River catchment (G22E) where there is a high risk, and the Cape Flats (G22D) where there is a medium risk of faecal contamination of surface waters due to the high population density and inadequate sanitation services in these areas.

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 sources

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 Berg WMA is given in Figure 6.4.3.2. This map shows the degree of potential faecal contamination of groundwater using a rating scale which ranges from low to medium to high. In the Berg WMA there are a number of areas where groundwater is vulnerable to faecal contamination. These are areas where primary and coastal aquifers occur and include Cape Flats aquifer (G22D and E), the Atlantis aquifer (G21B) and some of the west coast aquifers (G10L, M and G30A).

Conclusions and recommendations

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

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

6.4.4 Water Quality Issues

Berg River catchment

The key water quality concern in the Berg River is the increase in salinity in the lower and middle reaches which renders the water less fit for domestic and irrigation water supply. Other concerns that have been expressed about water quality in the Berg River include (Figure 6.4.4.1) :

- Nutrient enrichment – An increase in nutrient concentrations has been observed at all monitoring stations in the upper and middle main stem Berg River (Bath, 1989; Nitsche *et al*., 2001). This has been ascribed to the discharge of treated sewage effluent into the river and agricultural runoff. Previous studies have found algal concentrations resulting from the increased nutrients, were still within acceptable limits (DWAF, 1993a). However, the increasing trend in nutrients remains a cause for concern.

- Nuisance algal growth – Although nutrient concentrations in Voëlvlei Dam are not excessive, blooms of nuisance blue-green algae occur increasingly frequently during the summer months (Van Driel, pers. comm., 2001). This causes taste and odours in domestic water supplied to the City of Cape Town and the West Coast District Municipality water treatment works. The taste and odour problems are treated with activated carbon at a very high cost to consumers.

- Acidic and brown coloured water – The headwaters of stream and rivers draining Table Mountain Sandstone formations are acidic and coloured brown as a result of dissolved humic substances. These waters are generally also deficient in calcium. This occurs naturally but the water needs to be stabilised during water treatment to prevent damage to concrete, and corrosion damage to distribution infrastructure and household appliances (DWAF, 1993a).

- Agrochemicals – Recent studies by the University of Cape Town have found pesticide residues are washed off into surface waters in the Piketberg area (London *et al*., 2000). It was concluded that low levels of contamination are probably present in rural water sources in selected regions of the Western Cape, especially areas where agrochemicals are used intensively to control agricultural pests in vineyards and orchards.

Urban catchments

Rivers such as the Kuils, Eerste, Lotus, Salt and Black River, that flow through urban areas, have water quality problems that are generally associated with the impacts of urban areas on surface water bodies (Figure 6.4.4.1). These include :

- Nutrient enrichment – There are a number of wastewater treatment plants (WWTW) that discharge treated wastewater into urban rivers. These include Bellville, Scottsdene, Kraaifontein, 9SAI, Zandvliet, Stellenbosch and Macassar WWTW on the Kuils/Eerste River system, Borchards Quarry and Athlone WWTW on the Black River, Potsdam WWTW on the Diep River and Cape Flats WWTW on the Lotus River. These discharges are generally rich in nutrients and symptoms of eutrophication can be seen in the affected rivers (Ninham Shand and Chittenden Nicks, 1999).

- Bacteriological pollution – leaking sewers and contaminated stormwater runoff into urban rivers are the main cause of bacteriological contamination in urban rivers and the coastal waters (CMC, 2000).

- Litter – Litter is a serious problem in many of the urban rivers (Ninham Shand and Chittenden Nicks, 1999).

- Oil and toxic substances – oil spills and spills of other toxic substances are regarded as a problem in industrial areas and along major transport corridors (Ninham Shand and Chittenden Nicks, 1999).

- Nuisance aquatic plants – Water hyacinth is a problem in a number of urban rivers in the Cape Town metropolitan area and it is costly to control and remove the exotic plants.

6.5 SEDIMENTATION

The relationship between the flow in a river and the quantity of sediment that it carries is not constant but varies with the availability of sediment in the catchment of the river. This, in turn, varies with factors such as the condition of natural vegetation, the area of land cultivated and type of crops grown, and the extent of human settlements. Nevertheless, the analysis of measurements taken by DWAF, over many years, of silt accumulation in existing reservoirs countrywide, has made it possible to calculate average sediment yields for the catchments of these reservoirs. The results of analysis of data for reservoirs in the Berg WMA is shown in Table 6.5.1. Data is available for only Wemmershoek in the Berg WMA, but data for Clanwilliam Dam in the neighbouring Olifants/Doring WMA and Stettynskloof in the Breede WMA are also included, as the catchments of these dams are in similar geological formations. They should, therefore, have comparable sediment yields. However, it can be seen that the yield from the Wemmershoek catchment is considerably higher than the yields from the other catchments. This may be attributable to accelerated erosion caused by commercial forestry in the catchment. On the other hand, it might also be a consequence of differences in the accuracies of the basin surveys by means of which the sediment accumulation was measured.

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENTATION RATES FOR RESERVOIRS IN THE BERG AND ADJACENT WMAs

QUATERNARY CATCHMENT NO.	RIVER	DAM NAME	ECA (km^2)	PERIOD	V_T (million m^3)	V_{50} (million m^3)	SEDIMENT YIELD ($t/km^2.a$)
G10B	Wemmershoek	Wemmershoek	125	1957-1984	1,102	1,434	310
E10G	Olifants	Clanwilliam	2 033	1935-1980	9,715	10,117	134
H10K	Holsloot	Stettynskloof	55	1954-1984	0,088	0,109	54

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 fifty years at the same average yield.

Using the available data of this type on sediment accumulation in reservoirs and additional data on sediment loads in rivers, Rooseboom, *et al* in 1992 prepared a mean sediment yield map of South Africa. From this map and associated soil erodibility maps, an estimate of the average sediment yield from any desired area can be made. The Water

Research Commission publication, *Surface Water Resources of South Africa, 1990 (WR90)*, presents estimates of the mean sediment yield for quaternary sub-catchments calculated from the sediment yield and soil erodibility maps. Mean values of sediment yield in the Berg WMA, calculated from the WR90 estimates range from a low of 5 t/km^2.a in the south-eastern corner of the WMA to 34 t/km^2.a in the central interior in the catchment of the Diep River. Rooseboom also carried out statistical analyses of the recorded sediment yield data to obtain an indication of the confidence with which the sediment yield could be estimated for the various regions of South Africa. From these analyses he derived sets of curves which give multiples by which the estimated mean sediment yields should be multiplied to change the confidence level from the 50% confidence level of the mean yields. However, the data presented in this report is at the 50% confidence level.

Values of sediment yield in tonnes per year, and the 25 year sediment volume, expressed in million m^3 and adjusted to allow for consolidation of the sediment, are presented for each quaternary catchment in Appendix G. On Figure 6.5.1, the 25 year sediment volume is shown as a percentage of the naturalised incremental MAR for each quaternary catchment.

The information has been produced in this form for use in predicting the probable effects of sediment on the yields of dams in the WMA.

Research has shown that reservoirs with storage capacities in excess of 10% of the mean annual runoff will retain at least 70% of incoming sediments. It is only where reservoirs have storage capacities of very much less than 10% of mean annual runoff that it becomes possible to pass most of the incoming sediments through by designing the reservoirs so that high flow velocities are maintained through them during floods. Even so, a great deal of doubt exists regarding the accuracy with which the effective losses in the storage capacities of small reservoirs can be predicted. Only where adequate discharge facilities are provided and proper operational procedures are followed is it possible to ensure that a small reservoir will not lose virtually all its storage capacity, permanently or intermittently. Therefore, unless conditions for scouring are particularly favourable, it is not advisable to construct small storage dams on big rivers that carry high sediment loads. Where large dams are constructed, it is necessary to provide sufficient additional storage to accommodate the volume of sediment expected to accumulate during the economic life of the dam. Depending upon the characteristics of the dam site, it may be necessary either to construct the dam initially to provide the full volume of additional storage required to accommodate sediment, or to design the dam to be raised at a later stage if the accumulation of sediment begins to reduce the yield of the dam significantly.

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 organisations responsible for the various components of the data. This list also gives the reader a good indication of the type of data in the database.

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

7.1.2 Estimating the Water Balance

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

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

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

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modelling procedure. This is done relatively easily. The above impacts (ecological Reserve, etc.) were then determined 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 many areas of the country. However, in the case of the Berg WMA, WSAM did not appear to determine the run-of-river yield, and hence the water balance reliably. Therefore, these were determined external to the model, but making use of the database in the model.

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 abstracted from the WSAM into a spreadsheet and various worksheets set up, which reference this abstracted data. These worksheet were structured so a to present most of the information contained in the tables of this report. This is not only limited to water requirements but also lists land uses such as irrigated areas, afforested areas, etc.

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

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

Ecological Reserve

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

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

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

In the case of the Berg WMA, the smaller rivers draining to the sea are naturally dry during the summer months during droughts. Therefore, the ecological Reserve has an impact on the run-of-river yield of only the Berg (G10A - G10M), Upper Eerste (G22F), Lourens (G22J), Sir Lowry's (G22K) and Steenbras (G40A).

Water losses

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

Irrigation return flows

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

7.1.4 Estimating the Water Resources

The water resources were estimated using data from other more detailed studies as described in Section 6.2 for groundwater and in Section 6.3 for surface water.

7.2 OVERVIEW

For purposes of considering the water balance situation within the WMA, the outlets of the key areas defined in Table 2.1.1 in Section 2.1, and used in most of the tables in this report, were used, and referred to as key points. For key areas comprising two or more separate rivers flowing into the sea, the water balances at the river mouths were combined to obtain a composite value for a hypothetical key point for the key area. The key points are shown in Table 7.2.1.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION

LOCATION OF KEY POINT			DESCRIPTION
SECONDARY		QUATERNARY CATCHMENT	
NO.	DESCRIPTION		
G1	Berg River	G10F	Berg River below outlet from Voëlvlei Dam
		G10M	Berg River mouth
G2	Diep River and West Coast belt	G21A. G21B	Hypothetical point for small coastal catchments between the Berg and Diep River catchments.
		G21F	Diep River mouth
		G22E, G22H, G22J, G22K	Hypothetical point for catchments draining to the eastern half of False Bay
		G22A to G22D	Hypothetical point for Cape Peninsula catchments (including the Black River)
G4	Steenbras River	G40A	The Steenbras River mouth

In Table 7.2.2 the sums of the water requirements at the range of assurances at which they are normally provided for are shown for the key points.

It can be seen from Table 7.2.2 that the total water requirement in the WMA in 1995 is estimated to have been 960 million m^3/a. This value includes the provision of 121 million m^3/a for the ecological Reserve.

Within the Berg WMA, 46% of the water requirements are in the Berg River catchment and 50% are in the Diep River and West Coastal belt, including the Cape Peninsula, which consists largely of the Cape Metropolitan Area. The requirements within the Steenbras catchment are small.

As the water balance has been calculated on the basis of the 1:50 year yield of the water resources, it is necessary to consider the equivalent water requirements at 1:50 year assurance. These are shown in Table 7.2.3, where it can be seen that the conversion to total equivalent water requirements has reduced the quantity by 27% from 960 million m^3/a to 704 million m^3/a.

The main reduction relative to the requirements shown in Table 7.2.2 is in the ecological Reserve where the impact on the 1:50 year yield is shown in Table 7.2.3. For the reasons given in Section 5.2.4, the impact on yield is considerably less than the long term average flow requirement shown in Table 7.2.2.

Similarly, the water requirements of afforestation and alien vegetation are also shown in Table 7.2.3 as impacts on yield, which are negligible compared to the water use shown in Table 7.2.2.

Irrigation water requirements are also reduced significantly in Table 7.2.3 because parts of the total requirements are supplied at less than 1:50 year assurance.

The 1:50 year assurance water requirements in 1995 are compared in Table 7.2.4 with the 1:50 year developed yield in 1995. It can be seen that, for the WMA as a whole, the requirements exceed the yield plus imports and re-usable return flows by approximately 19 million m^3/a.

The main shortage of water occurs in the Berg River upstream of Voëlvlei Dam where the table indicates a shortfall of 19 million m^3/a. This is attributable to water use from the dams exceeding the 1:50 year yield of the major dams by about 7 million m^3/a, and the impact of the ecological Reserve of approximately 12 million m^3/a. The combined 1:50 year yield of Voëlvlei and Wemmershoek is 159 million m^3/a and the quantities supplied from the dams are :

Urban and bulk requirements in the Berg catchment	23 million m^3/a
Exports to Cape Town from Voëlvlei	67 million m^3/a
Exports to Cape Town from Wemmershoek	40 million m^3/a
Vredenburg/Saldanha and Swartland Schemes	14 million m^3/a
Voëlvlei to Lower Berg Irrigation District	16 million m^3/a
River losses	7 million m^3/a
TOTAL	167 million m^3/a

TABLE 7.2.2: TOTAL WATER REQUIREMENTS AT VARIOUS ASSURANCES OF SUPPLY IN 1995

CATCHMENT				STREAM FLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENTS						ECOLOGICAL RESERVE	TOTAL
SECONDARY		QUATERNARY		AFFORES-TATION	DRYLAND SUGAR CANE	ALIEN VEGETATION	RIVER LOSSES	BULK [1]	IRRIGA-TION [2]	RURAL [3]	URBAN [4]	HYDRO-POWER [5]	WATER TRANSFERS OUT OF WMA [6]		
No.	Description	No.	Description	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	15,7	0	15,2	5,0	4,0	198,9	2,7	18,7	0	0	95,7	355,9
		G10G to G10M	Berg River downstream of Voëlvlei	0	0	40,7	5,0	0,0	70,9	6,5	19,0	0	0	45,2	187,3
		Sub-total (Berg River)		**15,7**	**0**	**55,9**	**10,0**	**4,0**	**269,8**	**9,2**	**37,7**	**0**	**0**	**45,2**	**447,5**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0	0	14,4	0	0	0	1,1	6,0 [7]	0	0	3,7	25,2
		G21C to G21F	Diep River	0,1	0	6,5	0	0,4	22,3	2,2	4,4	0	0	12,1	48,0
		G22E to G22K	Combined Kuils/Eerste/Lourens/ Sir Lowry Rivers	6,0	0	3,0	0	0	41,2	1,2	10,5	0	0	31,1	93,0
		G22A to G22D	Combined Cape Peninsula Rivers	2,5	0	6,8	0	0	11,6	0,7	294,1 [8]	0	0	19,6	335,3
		Sub-total (Diep River and West Coast belt)		**8,6**	**0**	**30,7**	**0**	**0,4**	**75,1**	**5,2**	**315,0**	**0**	**0**	**66,5**	**501,5**
G4	Steenbras River	G40A	Steenbras catchment	1,7	0	0,1	0	0	0	0	0	0	0	9,3	11,1
TOTAL IN BERG WMA				**26,0**	**0**	**86,7**	**10,0**	**4,4**	**344,9**	**14,4**	**352,7**	**0**	**0**	**121,0**	**960,1**

(1) Requirements of wet industries, mines, thermal powerstations and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Hydropower is a secondary use and therefore is not included in totals.
(6) Water transfers out of the Berg River to Theewaterskloof Dam occur during winter months but are offset by re-releases from Theewaterskloof into the Berg/Eerste Rivers during the summer. This is therefore not reported as a net transfer out of the Berg WMA.
(7) Requirements of Atlantis and Mamre.
(8) Requirements of Cape Metropolitan Area except Atlantis and Mamre

TABLE 7.2.3: EQUIVALENT WATER REQUIREMENTS IN 1995 AT 1:50 YEAR ASSURANCE

CATCHMENT				STREAM FLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENTS						ECOLOGICAL RESERVE [7]	TOTAL
				AFFORES-TATION [10]	DRYLAND SUGAR CANE	ALIEN VEGETA-TION [10]	RIVER LOSSES	BULK [1]	IRRIGATION [2]	RURAL [3]	URBAN [4]	HYDRO-POWER [5]	WATER TRANSFERS OUT OF WMA [6]		
SECONDARY		TERTIARY / QUATERNARY													
No.	Description	No.	Description	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	0,2	0	0,1	5,0	4,0	176,0	2,7	18,7	0	0	11,7	218,4
		G10G to G10M	Berg River downstream of Voëlvlei	0	0	0	5,0	0,0	59,9	6,5	19,0	0	0	10,0	100,4
		Sub-total (Berg River)		**0,2**	**0**	**0,1**	**10,0**	**4,0**	**235,9**	**9,2**	**37,7**	**0**	**0**	**10,0** [8]	**307,1** [9]
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0	0	0	0	0	0	1,1	6,0	0	0	0	7,1
		G21C to G21F	Diep River	0	0	0	0	0,4	19,4	2,2	4,4	0	0	0	26,5
		G22E to G22K	Combined Kuils/Eerste/ Lourens/ Sir Lowry Rivers	0	0	0	0	0	35,1	1,2	10,5	0	0	5,4	52,2
		G22A to G22D	Combined Cape Peninsula Rivers	0	0	0	0	0	10,1	0,7	294,1	0	0	0	304,8
		Sub-total (Diep River and West Coast belt)		**0**	**0**	**0**	**0**	**0**	**64,5**	**5,2**	**315,0**	**0**	**0**	**5,4**	**390,6**
G4	Steenbras River	G40A	Steenbras catchment	0	0	0	0	0	0	0	0	0	0	6	6,0
		Sub-total (Steenbras River)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**6,0**
TOTAL IN BERG WMA				**0,2**	**0**	**0,1**	**10,0**	**0**	**300,5**	**14,4**	**352,7**	**0**	**0**	**21,4**	**703,7**

(1) Requirements of wet industries, mines, thermal powerstations and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Hydropower is a secondary use and therefore is not included in totals.
(6) Water transfers out of the Berg River to Theewaterskloof Dam occur during winter months but are offset by re-releases from Theewaterskloof into the Berg/Eerste Rivers during the summer. This is therefore not considered as a transfer out of the Berg WMA.
(7) The ecological Reserve shown in the table is the impact on the yield of the ecological reserve requirements.
(8) Net impact of the ecological Reserve.
(9) 218,4 + 100,4 = 318,8 - 11,7 for impact of ecological Reserve upstream of Voëlvlei not carried down = 307,1.
(10) The values shown in this table are the impact on the 1:50 year yield.

The other major shortfall is in the Diep River catchment where it appears that there is a shortfall of 16 million m^3/a in irrigation requirements. The reason for this is not clear, but may be a result of over-estimation of irrigation water requirements.

The table shows a small excess of 1,7 million m^3/a in the Cape Peninsula Area.

The export of 137 million m^3/a from the Berg River upstream of Voëlvlei that is shown in Table 7.2.4 is derived as follows :

From Wemmershoek to Cape Town	40 million m^3/a
From Voëlvlei to Cape Town	67 million m^3/a
From Voëlvlei to Saldanha and Swartland	14 million m^3/a
From Voëlvlei to Lower Berg Irrigation Districts	16 million m^3/a
TOTAL	137 million m^3/a

The remaining 14 million m^3/a of the yield of Wemmershoek is assumed to be used in the Berg catchment for supplies to Paarl and Wellington.

The import of 10 million m^3/a to the Eerste River catchment is the transfer for irrigation from Theewaterskloof Dam. The size of this import has increased since 1995 as more water rights have been exercised.

The import of 31,6 million m^3/a to the upper Berg catchment is an import of 5 million m^3/a from the Wit River to the Kromme River (Gawie se Water transfer), 4 million m^3/a from Witbrug to the Dwars River irrigation district Artois Canal transfer, 0,6 million m^3/a for Franschhoek, and an import of 47 million m^3/a from Theewaterskloof Dam from which 25 million m^3/a has been subtracted to compensate for water diverted from the Berg River via the Banhoek and Wolwekloof diversions, and stored in Theewaterskloof Dam. The import of 270 million m^3/a to the Cape Peninsula area is made up as follows :

From Theewaterskloof :		
161 million m^3/a - 22 million m^3/a to the Berg River		
- 10 million m^3/a to the Eerste River	=	129 million m^3/a
From Wemmerhsoek		40 million m^3/a
From Steenbras [(1)]		34 million m^3/a
From Voëlvlei		67 million m^3/a
TOTAL		270 million m^3/a

(1) Excludes the transfer of water from Palmiet which was not yet commissioned in 1995.

TABLE 7.2.4: WATER REQUIREMENTS AND AVAILABILITY IN 1995

CATCHMENT				AVAILABLE 1:50 YEAR YIELD IN 1995			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE [1] (million m^3/a)	YIELD BALANCE [3] AT 1:50 YEAR ASSURANCE (million m^3/a)
SECONDARY		QUATERNARY		SURFACE WATER (million m^3/a)	GROUNDWATER (million m^3/a)	TOTAL (million m^3/a)	IMPORTS (million m^3/a)	EXPORTS [2]) (million m^3/a)	RE-USABLE (million m^3/a)	TO SEA (million m^3/a)		
No.	Description	No.	Description									
G1	Berg River	G10A to G10F	Berg River upstream of Voëlvlei	279	12	291	31,6 [6]	-137 [7]	17,2	0	218,4	-15,6
		G10G to G10M	Berg River downstream of Voëlvlei	52	11	63	30,0 [4]	0	7,5	0	100,4	+0,1
	Sub-total (Berg River)			**331**	**23**	**354**	**61,6**	**-137**	**24,7**	**0**	**307,1 [5]**	**-3,8 [5]**
G2	Diep River and West Coast belt	G21A to G21B	Combined West Coast rivers	0	7	7	0	0	0	0	7,1	-0,1
		G21C to G21F	Diep River	3	7	10	0	0	0,1	0,9	26,5	-16,4
		G22E to G22K	Combined Kuils/Eerste/ Lourens/Sir Lowry Rivers	29	8	37	10,0	0	5,2	0	52,2	0
		G22A to G22D	Combined Cape Peninsula rivers	6	12	18	270,0	0	18,5	117,7	304,8	+1,7
	Sub-total (Diep River and West Coast belt)			**38**	**34**	**72**	**283**	**0**	**23,8**	**118,6**	**390,6**	**-14,8**
G4	Steenbras River	G40A	Steenbras catchment	40	0	40	0 [1]	-34	0	0	6,0	0
	Sub-total (Steenbras River)			**40**	**0**	**40**	**170,6**	**-34**	**0**	**0**	**6,0**	**0**
TOTAL IN BERG WMA				**409**	**57**	**466**	**344**	**0**	**48,5**	**118,6**	**703,7**	**-18,6**

(1) Imports to Steenbras from Palmiet average 23 million m^3/a. However, this scheme was not in place in 1995.
(2) Imports from the Breede WMA and allocations of developed yield within the Berg WMA are distributed approximately in the "IMPORT" and "EXPORT" columns to enable a realistic interpretation of the yield balance.
(3) Surplusses indicated by a+ and deficits by a -.
(4) 30 million m^3/a from the Berg upstream of Voëlvlei.
(5) The impact of the ecological Reserve of the Berg upstream of Voëlvlei of 11,7 million m^3/a is not included in the total because it contributes to the Reserve downstream.
(6) Imports of 5 million m^3/a from the Wit River (Breede WMA), 4 million m^3/a from Witbrug (Breede WMA), 0,6 million from the Breede for Franschhoek, and 47 million m^3/a from Theewaterskloof Dam (Breede WMA) = 56,6 million m^3/a - 25 million m^3/a winter water from the Berg River stored in Theewaterskloof Dam = 31,6 million m^3/a.
(7) Exports comprise 67 million m^3/a from Voëlvlei to Cape Town, 40 million m^3/a from Wemmershoek to Cape Town, 14 million m^3/a via Vredenburg/Saldanha and Swartland Schemes, and 16 million m^3/a from Voëlvlei to the Lower Berg Irrigation District.

CHAPTER 8: COSTS OF WATER RESOURCE DEVELOPMENT

Costs of developing the water resources of the Berg WMA have been investigated in a number of studies, namely:

- The Skuifraam Water Supply Scheme comprising Skuifraam Dam and Skuifraam Supplement Scheme (DWAF, 2000c), at feasibility level.
- The Voëlvlei Scheme (DWAF, 2001), at feasibility level.
- The Integrated Water Resources Planning Study for the City of Cape Town (City of Cape Town, 2001). This included the Lourens River diversion, Eerste River diversion, Cape Flats Aquifer and re-use of treated effluent and was subsequently expanded to include deep wells in the TMG Aquifer, the Voëlvlei Augmentation Scheme and Desalination.

As the cost estimates made for these studies were for development of the water resources to their optimum economical potential, they have been used to derive an estimate of the cost of fully developing the water resources.

The cost estimates are for development of the infrastructure components listed below.

- Voëlvlei Augmentation Scheme (additional yield of 30 million m^3/a).
- Skuifraam Dam (capacity 126 million m^3, yield approximately 56 million m^3/a).
- Skuifraam Supplement Scheme (additional yield of approximately 24 million m^3/a).
- Lourens River diversion (additional yield of approximately 19 million m^3/a).
- Eerste River diversion (additional yield of approximately 8 million m^3/a).
- Cape Flats Aquifer well field (estimated yield of approximately 18 million m^3/a).

In addition, it has been assumed that the full groundwater potential of the Berg River catchment downstream of Voëlvlei, and of the Diep River and West Coast catchments could be developed through small schemes to provide an additional 87 million m^3/a of yield. The cost of developing this resource is estimated to be R393 million, using the costing data shown in Diagram 8.1. Average borehole yields of 1,4 ℓ/s were assumed for Catchments G10K, L, M and G30A, giving a cost of R5/m^3/a of production borehole capacity. For Catchments G21A to G21F, an average yield of 2,5 ℓ/s at a cost of R3,50/m^3/a of production borehole capacity was assumed. It was also assumed that the remaining 11 million m^3/a of potential groundwater yield in Catchments G22A to G22D, after development of the Cape Flats Wellfield Scheme, would be developed as diffuse boreholes with average yields of 1,4 ℓ/s at a cost of R5/m^3/a of borehole capacity. The cost of this would be R55 million.

As mentioned previously, the development of deep wells into the TMG Aquifer now seems more likely and it might be less costly to develop as individual borehole yields would be considerably larger.

The estimated combined capital cost of developing the surface water and groundwater resources to their full economical potential of an additional 253 million m^3/a of yield is R1 978 million at 2000 price levels. The estimated capital costs are summarised in Table 8.1.

It has also been estimated that some 62 million m^3/a of treated sewage effluent that is currently discharged to sea could be treated to potable standard and re-used at a capital cost of the reclamation works of R1 056 million.

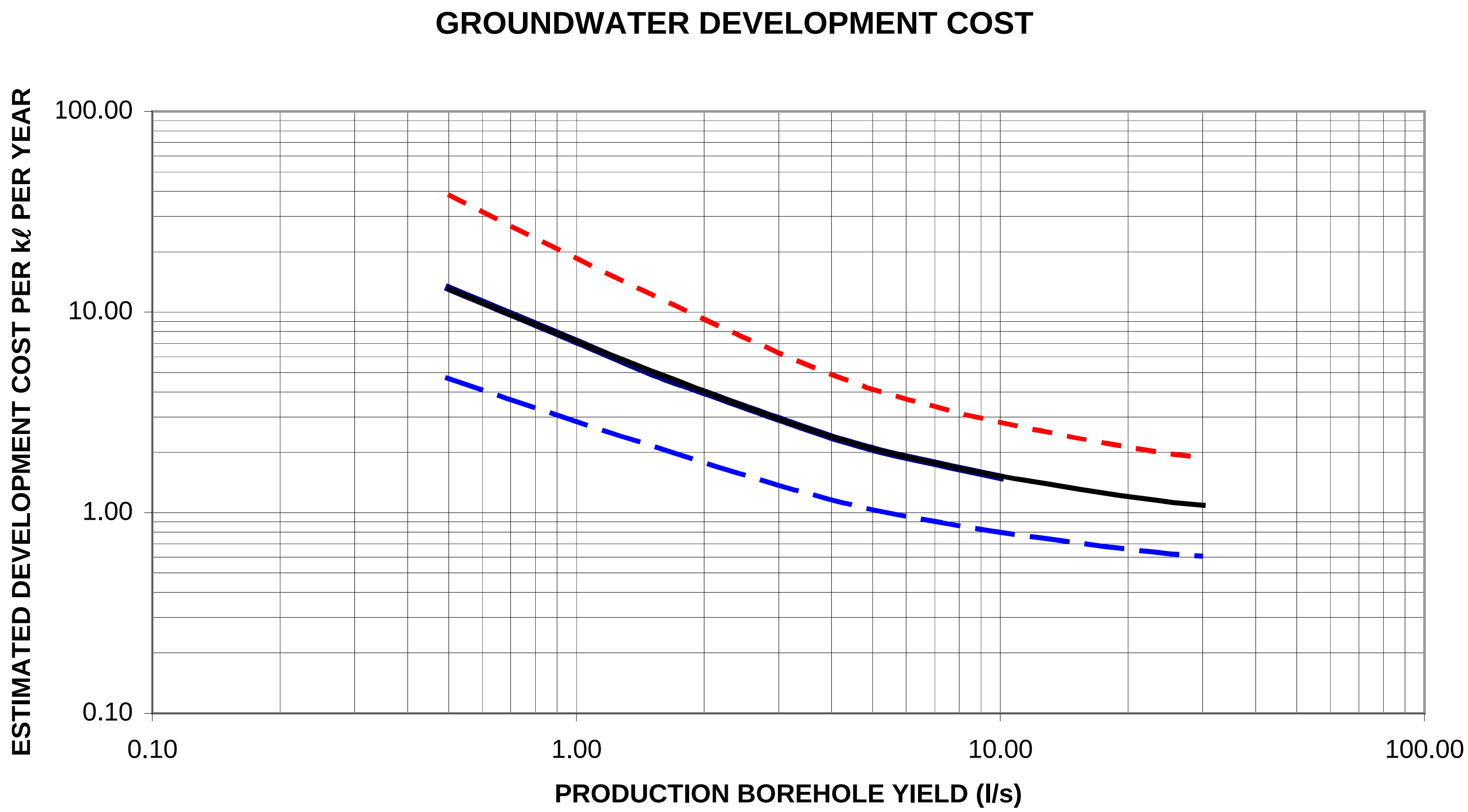
GROUNDWATER DEVELOPMENT COST
ESTIMATED DEVELOPMENT COST PER kℓ PER YEAR
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
PRODUCTION BOREHOLE YIELD (l/s)

Diagram 8.1

TABLE 8.1: COSTS OF FUTURE WATER RESOURCE DEVELOPMENT

CATCHMENT NO.	SCHEME	STORAGE VOLUME (million m³/a)	INCREMENTAL SURFACE WATER YIELD (million m³/a)	WELLFIELD YIELD (million m³/a)	COSTS (R million) (3)			
					DAMS	WELLFIELDS	WEIRS,CANALS AND PIPELINES	TOTALS
G10A	Skuifraam Dam	126	56	-	890	-	-	890
G10C	Skuifraam Supplement		24	-		-	167	167
G10F	Voëlvlei		30	-			200	200
G22D	Wellfield Cape Flats	-	-	18	-	161	-	161
G22H	Eerste River diversion		8	-			77	77
G22J	Lourens River diversion		19	-			35	35
TOTALS FOR MAJOR SCHEMES		**126**	**137**	**18**	**890**	**161**	**479**	**1 530**
G10K, L, M, G30A	Small groundwater schemes			59 (1)		295		295
G21A to G21F	Small groundwater schemes			28 (2)		98		98
G22A to G22D	Small groundwater schemes			11 (1)		55		
TOTALS FOR SMALL GROUNDWATER SCHEMES				**98**	**--**	**448**	**--**	**448**
TOTALS		**126**	**137**	**116**	**890**	**609**	**479**	**1 978**

(1) Assumed average yield of 1,4 ℓ/s.
(2) Assumed average yield of 2,5 ℓ /s.
(3) Costs at year 2000 price levels.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

In this chapter the main conclusions that can be drawn from the information gathered in this situation assessment are listed, followed by a discussion of requirements for additional data and, finally, recommendations on the action needed to obtain the additional data.

(i) The Berg WMA covers an area of 13 000 km^2 in which the mean annual rainfall ranges from a maximum of about 3 200 mm in the high mountains in the north-eastern corner of the WMA to less than 300 mm in the north-west. The rainfall occurs mainly during the winter months.

(ii) The geology of the WMA is dominated by compact sedimentary strata of the Cape Supergroup with Table Mountain Sandstone forming the mountains along the eastern boundary, the mountains of the Cape Peninsula, and a few smaller outcrops of high ground. Sand dune areas, mainly underlain by Malmesbury shales, occur along parts of the western and southern coasts, and the rolling hills of the central area consist mainly of Malmesbury shales. Surface water originating from runoff from the Table Mountain Sandstone areas is of low natural salinity, while that from areas where Malmesbury shales occur is moderately saline. Groundwater is similarly affected by the geological strata.

(iii) Water quality in the Lourens River, the lower reaches of the Cape Peninsula rivers, and the Diep River, is adversely affected by wash-off from urban areas and return flows of water carrying waste. Water quality in the middle and lower reaches of the Berg River is adversely affected by nutrients from agricultural land.

(iv) For purposes of determining the ecological flow requirements of the rivers of the WMA, most catchments have been allocated a PESC of Class D : largely modified, with low ecological flow requirements. The lower Berg River and its tributaries, the lower Diep River, the Steenbras River and the Cape Peninsula rivers have been given PESCs of Class C : moderately modified, with higher ecological flow requirements.

(v) The population of the WMA in 1995 was approximately 3 247 000 people. About 95% of the population lived in urban areas.

(vi) The GGP of the WMA in 1997 was R63,8 bn with the most important economic sectors, in terms of their contributions to GGP being Manufacturing (25,4%), Transport (20,6%), Financial Services (17,6%) and Government (15,0%). Transport has a high comparative advantage relative to other WMAs.

(vii) Land-use is predominantly for rough grazing for livestock, about 75% of the surface area of the WMA being used for this purpose. The remainder is used for urban areas (4%), dryland farming (12%), irrigated agriculture (4%), nature reserves (4%), and afforestation (1%).

(viii) There were about 296 000 head of livestock in the WMA in 1995, with sheep making up 68% of the livestock numbers and cattle and pigs each accounting for 15% of the numbers.

(ix) Water related infrastructure for urban, irrigation, and rural domestic requirements is well developed.

(x) The combined capacities of regional potable water supply schemes and individual town schemes totalled 333 million m^3/a in 1995 and provided water to an estimated 95% of the population of the WMA.

(xi) A total of 20 dams, both large and small provide water for the town supplies and some of these provide water for irrigation as well. Nineteen of the dams are in the Berg WMA and one, Theewaterskloof, is in the Breede WMA. The 19 dams in the Berg WMA have a capacity of 297 million m^3 and a 1:50 year yield of approximately 263 million m^3/a.

(xii) Because most of the rainfall, and hence most of the flow in the rivers, occurs between the winter months of May and October each year, infrastructure for irrigation has been developed to store runoff that occurs during the winter months and distribute it to irrigated lands during the remainder of the year.

(xiii) Two Government Water Supply Schemes, namely the Berg River/Riviersonderend Government Water Scheme and the Voëlvlei Government Water Scheme provide large volumes of water for irrigation as well as for urban supplies. In addition, farm dams with a combined capacity of 104 million m^3 store water for irrigation.

(xiv) Allocations of water for irrigation from Government Water Supply Schemes totalled 142 million m^3/a in 1995, which was 41% of the average irrigation water requirement of the whole WMA of 345 million m^3/a. In normal years, only about 60% of the water allocated is used for irrigation. This amounts to about 25% of the total irrigation requirement of the WMA and the remainder is provided from excess winter water, pumped from the main rivers, and from the farmers' own sources.

(xv) Water requirements in the WMA in 1995 were estimated to total 839 million m^3, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sectors were the urban and rural domestic sector, which accounted for 43% of the total consumptive requirement (i.e. the requirement excluding the ecological Reserve) and the agricultural sector which accounted for 42%. The next biggest water user was alien vegetation (10%), followed by afforestation (3%), with river losses and bulk water use making up the remaining 2%. With the requirements of the ecological Reserve added, the total water requirement becomes 960 million m^3.

(xvi) The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, is 705 million m^3/a. The estimates of the impacts on yield are at low levels of confidence.

(xvii) There is scope for reducing urban water requirements by means of a water conservation and demand management programme. There is also scope for improving the efficiency of agricultural water use, particularly by reducing conveyance losses.

(xviii) The natural MAR of the Berg WMA was 1 407 million m^3, and the yield developed from surface water resources in 1995 was 409 million m^3/a at 1:50 year assurance. Some 44% of the developed surface water yield was from farm dams and run-of-river abstractions, and 56% from major dams. In addition, boreholes with an estimated yield of 57 million m^3/a had been developed, bringing the total developed yield to 466 million m^3/a at 1:50 year assurance.

(xix) Comparison of the equivalent 1:50 year assurance water requirements of 705 million m^3/a with the developed yield of 466 million m^3/a, shows a deficit of 239 million m^3/a, but re-usable return flows of 49 million m^3/a reduce the deficit to 190 million m^3/a. Imports of water of 171 million m^3/a from the Breede WMA further reduce the deficit to 19 million m^3/a. The deficit of 19 million m^3/a is equal to the estimated impact of the ecological Reserve on the 1:50 year yield of the water resources of the WMA. This is to be expected as the ecological Reserve was not implemented in 1995 and the shortfall between the yield of the water resources of the Berg WMA and the water requirements was met by imports from the Breede WMA.

(xx) The maximum potential 1:50 year yield of the water resources of the WMA is estimated to be 719 million m^3/a, which is 253 million m^3/a more than the developed 1:50 year yield in 1995. The proportion of this amount that will be available for consumptive water use after the ecological Reserve has been provided for is uncertain because of a lack of reliable information on the ecological flow requirements of the rivers and of the Berg River estuary.

(xxi) Studies carried out as part of the Skuifraam Dam, Skuifraam Supplement, Voëlvlei Scheme, Eerste River and Lourens River diversions show that additional yield of 137 million m^3/a could be developed in large schemes in the Berg WMA, while groundwater appears to have the potential to provide an additional 116 million m^3/a, mainly in small diffuse schemes.

(xxii) The cost of developing an additional 253 million m^3/a of yield to utilise the full potential of the water resources of the Berg WMA is roughly estimated to be R1 978 million at year 2000 price levels, including VAT.

(xxiii) A further yield of 62 million m^3/a from treated wastewater effluent, is also possible. Currently 135 million m^3/a of effluent is not re-used. However, of this, only 62 million m^3 has been considered to be cost effectively re-usable.

(xxiv) The requirements of the Cape Metropolitan Area for water for urban use exceed the quantity that can be provided by the water resources owned by the City of Cape Town and the allocations of water from State owned dams that have been made to it. The shortfall is made up at present by providing the City of Cape Town with additional water from State owned dams that has been allocated to agriculture, but not yet used, because the farmers have not fully utilised their water allocations.

This assessment has indicated that if irrigation allocations were fully utilised and the currently estimated requirements of the ecological Reserve were fully implemented, the water resources of the Berg WMA would be stressed in terms of the levels of assurance at which the required quantities of water could be provided to consumers.

(xxv) As it is known that the urban water requirements of both the Cape Metropolitan Area and the Vredenburg/Saldanha area have continued to grow steadily since 1995, and irrigation water requirements are also increasing as farmers develop more land and use the water allocations that they have previously acquired, it is clear that the assurance at which the water resources as developed in 1995 can meet requirements will diminish steadily.

(xxvi) To counter this, imports of water via the Palmiet Scheme began in 1997 and planning for the construction of a new dam on the Berg River at Skuifraam is well advanced. However, even if the rate of growth in urban water requirements is substantially reduced as a result of the successful implementation of water conservation and demand management, but existing water allocations for agriculture are all utilised, it will be necessary to construct additional schemes to keep pace with continuing growth in water requirements.

(xxvii) As the level of development of the water resources approaches their full potential yield it will become increasingly important to have accurate information on the amounts of abstractions of water from the streams and rivers of the catchments to be developed. This will be required to derive the reliable information on streamflow at the sites of the proposed new schemes that is needed to ensure that they are economically designed.

It is apparent from the above conclusions that the available data on the following aspects is inadequate :

- The quantity of water abstracted for irrigation from farmers' own sources and from excess winter flow in the main rivers.

- The ecological Reserves for the rivers of the WMA and the Berg River estuary, and their impacts on the utilisable yields of the rivers.

- The impacts of alien vegetation and afforestation on the availability of water to meet other requirements.

With regard to the use of water for irrigation, the quantity of water obtained from sources other than Government Water Schemes cannot be reliably calculated from the total irrigation requirements given in this report because the requirements are estimates only, derived from average climatic data and estimated areas of irrigated land. Therefore, it is recommended that, in order to accurately determine what quantity of water is used for irrigation, the licensing of water use for this purpose should be made compulsory in the catchments of the Berg River, the Eerste River, and the Lourens River.

It is further recommended that, in order to verify the results of the licensing process, new coverages of aerial photography of the catchments should be obtained and areas of irrigated land in each quaternary catchment measured from them.

The information obtained should be adjusted to take account of cropping patterns. Thereafter it should be used in the Water Resources Yield Model, configured to represent the catchments, to determine the yields from run-of-river flow and farm dams that can be obtained at various assurances of supply. The results of this analysis would enable the determination of :

(a) reliable values for total irrigation water requirements in each quaternary catchment;
(b) the quantity of water that would be required by irrigators from the Government Water Schemes during severe droughts, and
(c) the quantity of water available in the rivers for the development of additional yield.

Reliable information on the requirements of the ecological Reserve will also be needed for the successful performance of the analysis described above. As part of this situation assessment, desktop determinations of the requirements at the outlet of each quaternary catchment were made. These provided estimates of annual requirements which are adequate for a situation assessment, but any more detailed analysis will require monthly flow patterns, at least.

It is understood that in recent studies sufficient work has been done on the main stem of the Berg River between the proposed Skuifraam Dam site and the vicinity of Voëlvlei Dam for the

Reserve to be determined at the comprehensive level. Therefore, the necessary information on ecological flow requirements will be available for this important river reach once this has been done. However, considerable quantities of water are abstracted from the tributaries of the Berg for irrigation use and it is recommended that sufficient field work should be carried out to review the desktop ecological classifications of the rivers that were made for this assessment. Once this has been done, the simulation model (Hughes and Munster, 1999) or actual IFR determinations should be used to obtain sequences of monthly flow requirements for use in the system model. Similar work should be carried out for the Eerste and Lourens Rivers, but the results of separate more detailed studies that have been carried out on sections of these rivers should be used as well.

There does not appear to be a need for additional work on the ecological flow requirements of the other rivers of the WMA at this stage, because the water abstractions from the rivers are low and further significant use and development of their yield seems unlikely.

A very important consideration is that the freshwater requirements of the Berg River Estuary have not been taken into account in this situation assessment because very little information is available. As this is an estuary of high conservation value, it is important that its water requirements be provided for when any further development of the yield of the Berg River takes place. As the impact of the requirements of the estuary on the run-of-river yield may be higher than the impact of the ecological flow requirements of the river itself, it is recommended that a determination of the flow requirements of the estuary at the intermediate level be carried out as soon as possible. The impacts of groundwater abstraction on the estuary should also be determined.

The data on areas of afforestation per quaternary catchment that are contained in the WSAM database are thought to be reliable. These should be included in the configuration of the Water Resources Yield Model described above, and the impacts of afforestation on run-of-river yields determined.

Similarly, areas of alien vegetation should be obtained from the aerial photography referred to above, and condensed areas included in the yield model to allow the impacts of alien vegetation on run-of-river yield to be determined.

In summary, therefore, it is recommended that :

- Compulsory licensing of water use for irrigation be implemented in the catchments of the Berg, Eerste and Lourens Rivers.

- New aerial photography of the same catchments should be obtained and used to determine irrigated areas in each quaternary catchment for purposes of verifying the licensing process, and also used to determine areas of alien vegetation.

- Detailed work that has been carried out in separate studies on the ecological flow requirements of some river reaches should be used to derive monthly flow sequences of ecological flow requirements.

- In the quaternary sub-catchments of the Berg, Eerste and Lourens Rivers where more detailed work has not been done, the ecological river classifications determined in this study should be verified by limited field work, and monthly sequences of ecological flow requirements determined using the simulation model.

- A determination of the ecological freshwater flow requirements of the Berg River Estuary should be made at the intermediate level and monthly flow sequences developed.

- The information obtained as described above should be used to configure the Water Resources Yield Model to determine :

  - total irrigation water requirements in each quaternary catchment,
  - the quantity of water that would be required by irrigators from Government Water Schemes during severe droughts,
  - the quantity of water available in the rivers for the development of additional yield after allowing for the effects of afforestation and alien vegetation.

In terms of priorities for carrying out this work, the Berg River catchment should take precedence over the other catchments in this WMA because further development of the yield of its water resources will be required sooner.

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APPENDICES

LIST OF CONTENTS

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

ABBREVIATIONS AND ACRONYMS

AEMC	Attainable Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TRC	Transitional Rural Council
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
m^3	cubic metre
$10^6 m^3$	million cubic metres
$10^6 m^3/a$	million cubic metres per year
%	percent

APPENDIX A

DEMOGRAPHIC DATA

Listing of urban, rural and total populations per quaternary catchment as contained in the database of the Water Situation Assessment Model.

BERG WATER MANAGEMENT AREA

APPENDIX A

DEMOGRAPHIC DATA PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	OPOPi	oPORi	TOTAL POPULATION
	URBAN POPULATION	RURAL POPULATION	
	Number	Number	Number
G10A	4 345	3 829	8 174
G10B	0	488	488
G10C	113 354	18 684	132 038
G10D	33 311	18 457	51 768
G10E	4 538	6 098	10 636
G10F	8 593	5 599	14 193
G10G	0	1 039	1 039
G10H	11 683	2 829	14 512
G10J	8 062	6 500	14 563
G10K	456	6 261	6 717
G10L	16 324	6 639	22 963
G10M	89 462	2 729	92 191
G21A	730	6 155	6 884
G21B	0	3 704	3 704
G21C	0	3 071	3 071
G21D	37 299	11 364	48 663
G21E	0	15 858	15 858
G21F	0	3 773	3 773
G22A	0	489	489
G22B	2 684 687	96	2 684 783
G22C	0	2 878	2 878
G22D	0	2 301	2 301
G22E	0	10 607	10 607
G22F	51 447	866	52 313
G22G	13 138	6 485	19 623
G22H	0	15 397	15 397
G22J	0	4 294	4 294
G22K	0	2 560	2 560
G40A	0	563	563
TOTALS	3 077 429	169 613	3 247 042

APPENDIX B

SUPPLEMENTARY ECONOMIC DATA

APPENDIX B.1 `	**Graphs of gross geographic product, labour and shift-share**
APPENDIX B.2	**Water Management Areas in national context**
APPENDIX B.3	**Economic sector description**
APPENDIX B.4	**Economic information system**

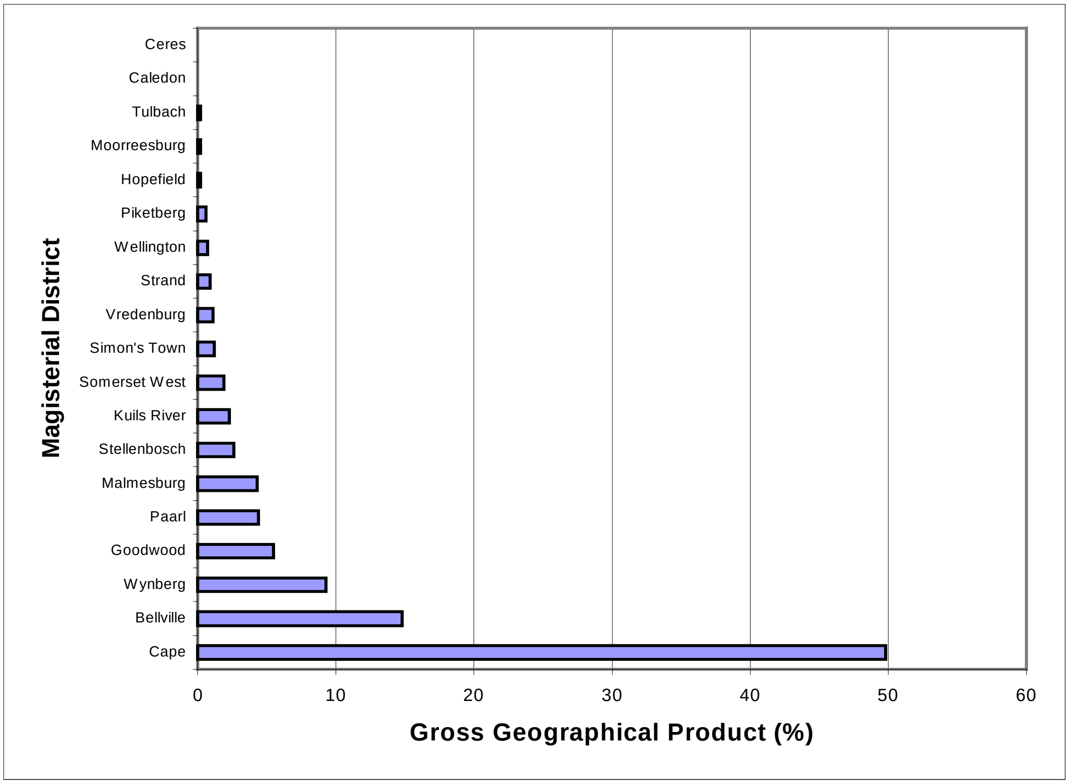
APPENDIX B.1

GRAPHS: GROSS GEOGRAPHIC PRODUCT, LABOUR AND SHIFT-SHARE

APPENDIX B.1
DESCRIPTION OF GRAPHS

Diagram No	Graphic Illustration	Description
B.1	• **Gross Geographic Product**: ⇨ Contribution by Magisterial District to Berg Economy, 1997 (%)	Each WMA comprises a number of Magisterial Districts. This graph illustrates the percentage contribution of each MD to the WMA economy as a whole. It shows which are the most important sub-economies in the region.
B.2	⇨ Contribution by sector to National Economy, 1988 and 1997 (%)	This graph illustrates the percentage contribution of each sector in the WMA economy, e.g. agriculture, to the corresponding sector in the national economy.
B.3	• **Labour Force Characteristics**: ⇨ Composition of Berg Labour Force 1994 (%)	The total labour force may be divided into three main categories, namely formal employment, informal employment and unemployment, as outlined in this graph.
B.4	⇨ Contribution by Sector to Berg Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	⇨ Contribution by Sectors of Berg Employment to National Sectoral Employment, 1980 and 1994 (%)	Similar to the production function (i.e. GGP), this graph illustrates the percentage contribution of each sector in the WMA economy, e.g. mining, to the corresponding sector in the national economy.
B.6	⇨ Compound Annual Employment Growth by Sector of Berg versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
B.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 B.1: Contribution by Magisterial District to Berg economy, 1997 (%)



FigureB.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

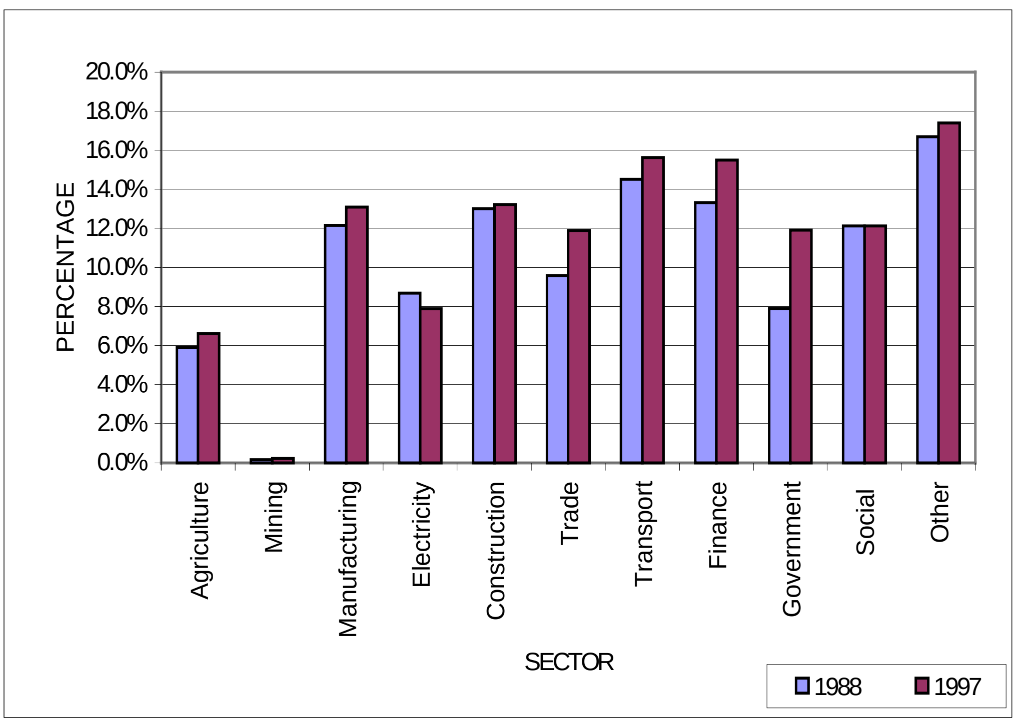


Figure B.3: Composition of Berg Labour Force, 1994 (%)

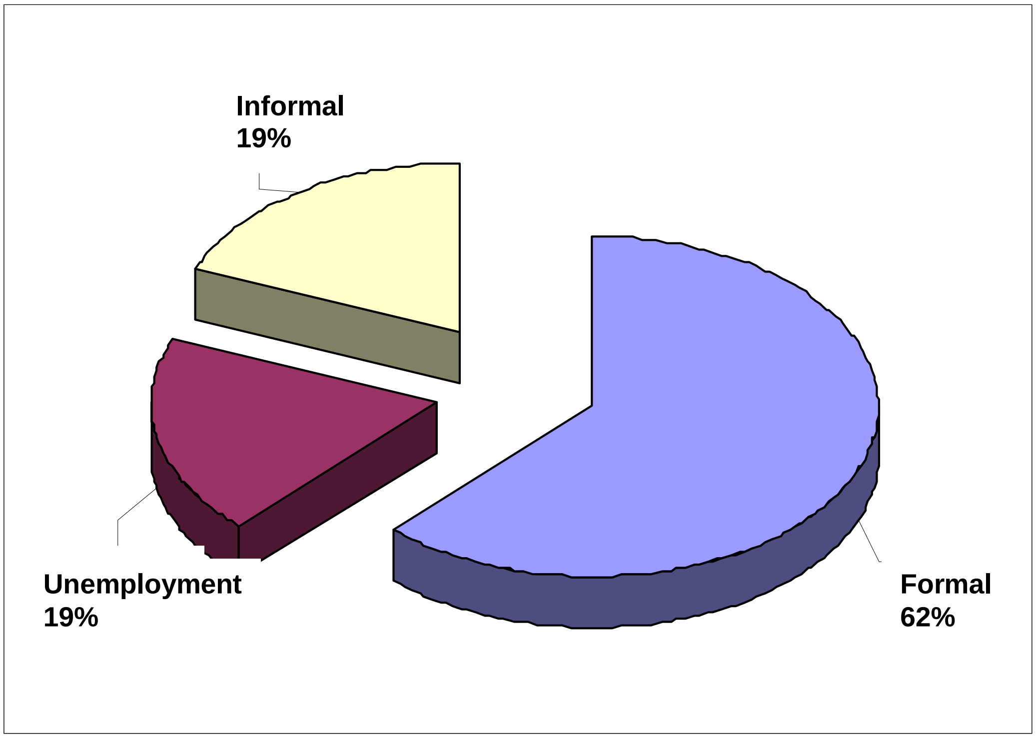


Figure B.4: Contribution by Sector to Berg Employment, 1980 and 1994 (%)

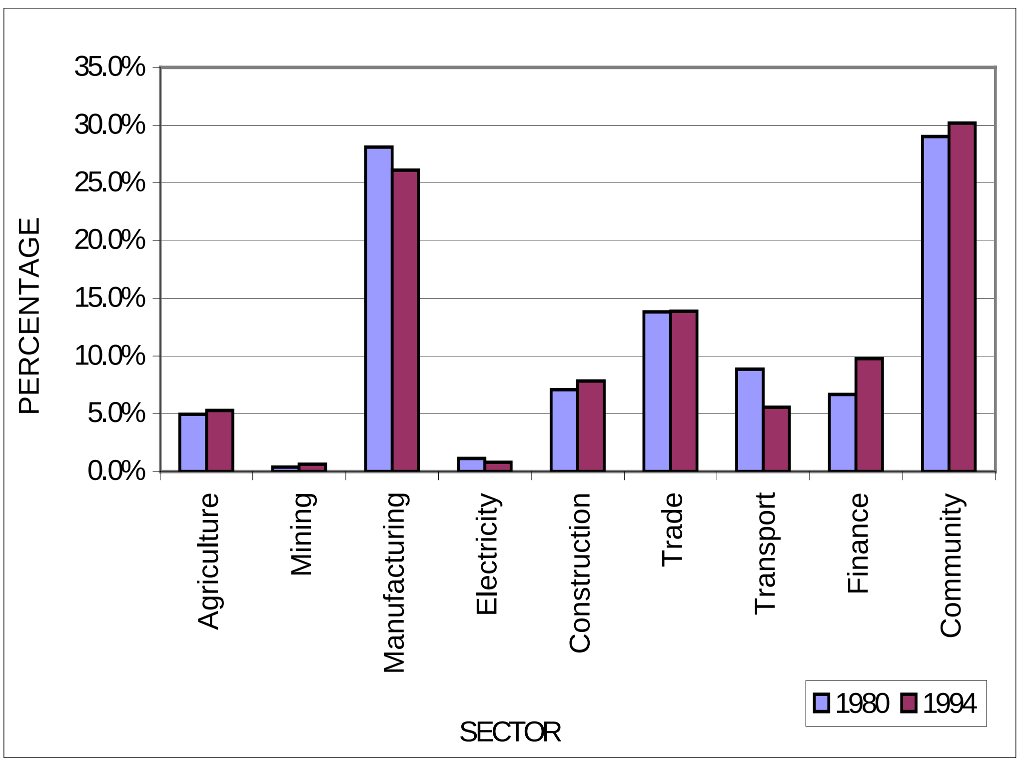


Figure B.5: Contribution by Sectors of Berg Employment to National Sectoral Employment, 1980 and 1994(%)

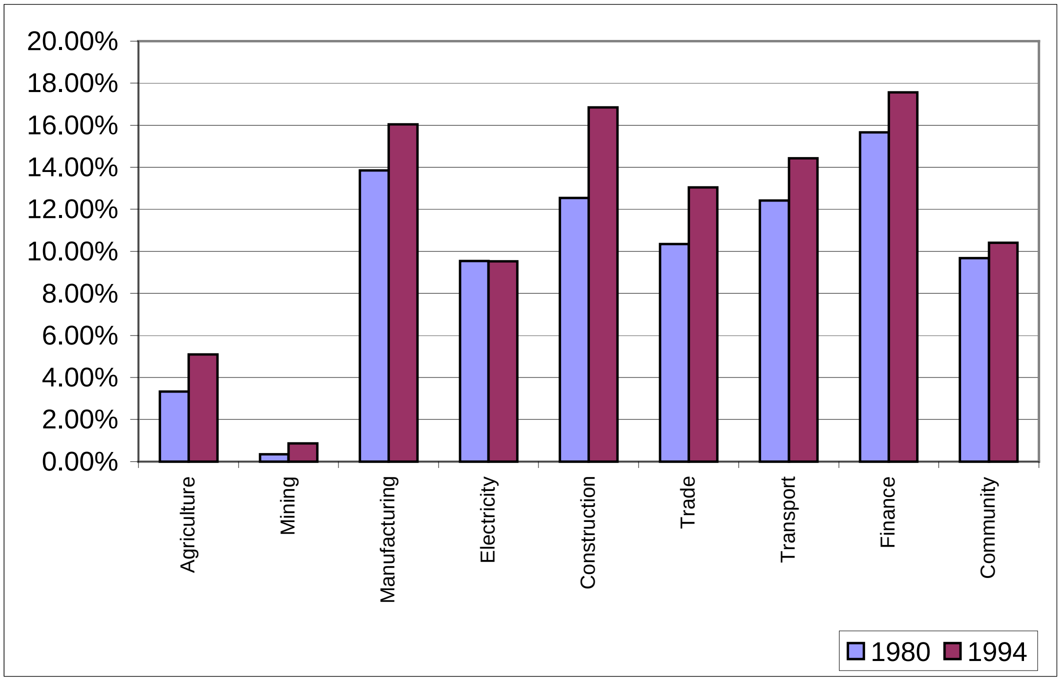


Figure B.6: Average Annual Employment Growth by Sector of Berg versus South Africa, 1980 to 1994 (%)

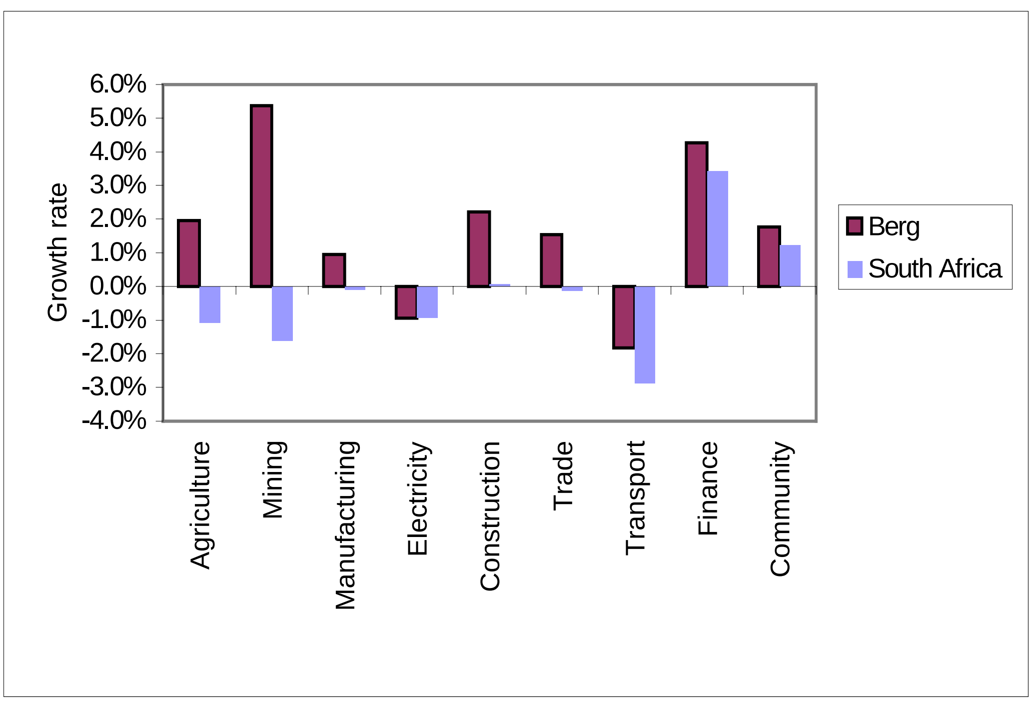
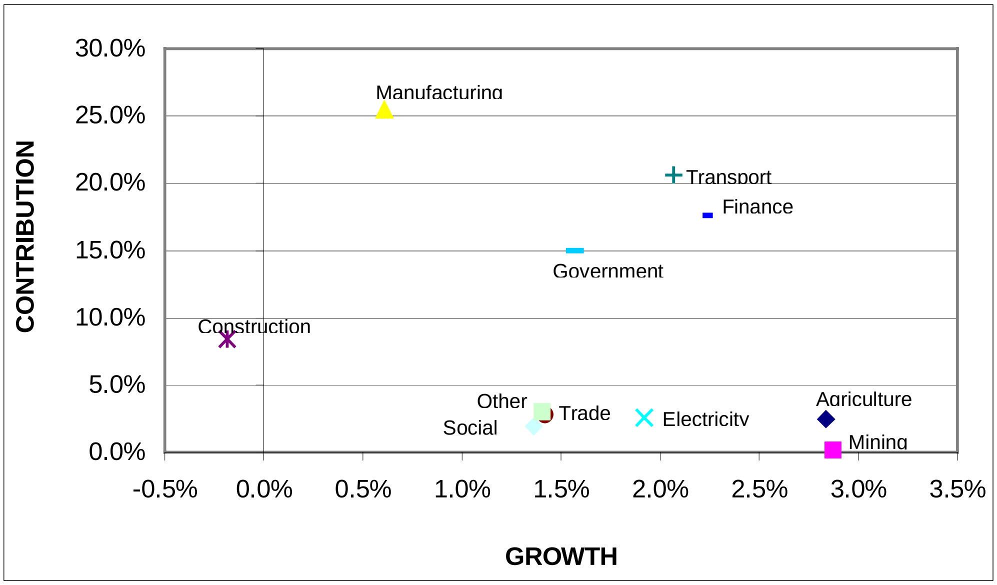


Figure B.7: Shift-Share Analysis, 1997



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B.1 INTRODUCTION

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

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

B.2 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL ECONOMY

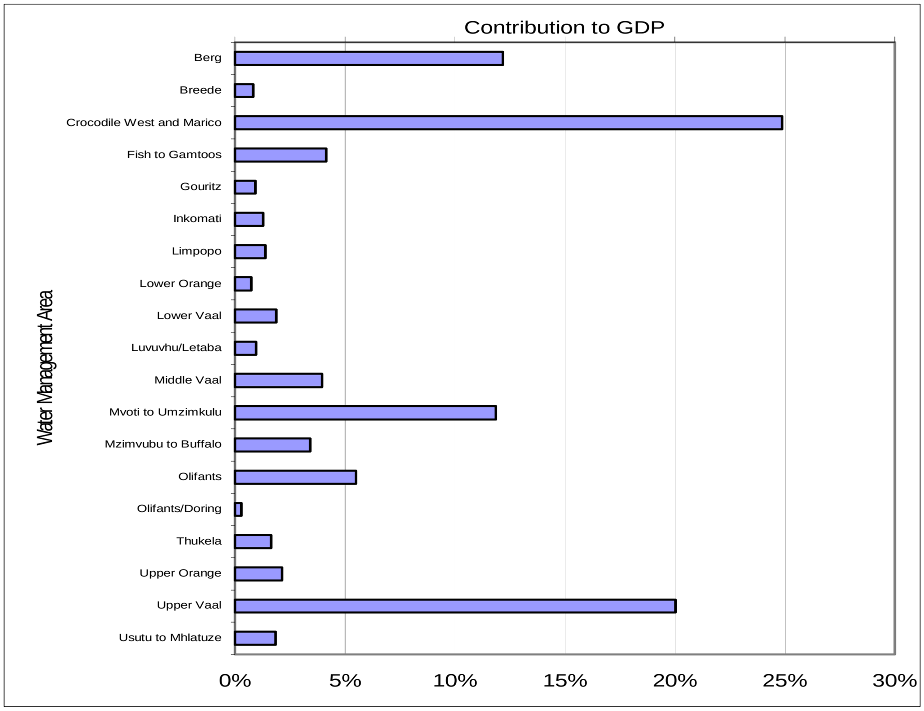
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- The second largest WMA to the national economy, is the Upper Vaal, which contributes 16.6% to GDP. This WMA comprises mainly portions of Johannesburg, Vereeniging and Vanderbijlpark.

- The Berg WMA contributes 11.25% to the GDP of the national economy and comprises mainly the Cape Metropolitan Area (CMA).

- Mvoti to Umzimkulu WMA makes the fourth largest contribution of 10.72% to the GDP of the national economy. This WMA includes the Durban-Pinetown Metropolitan Area.

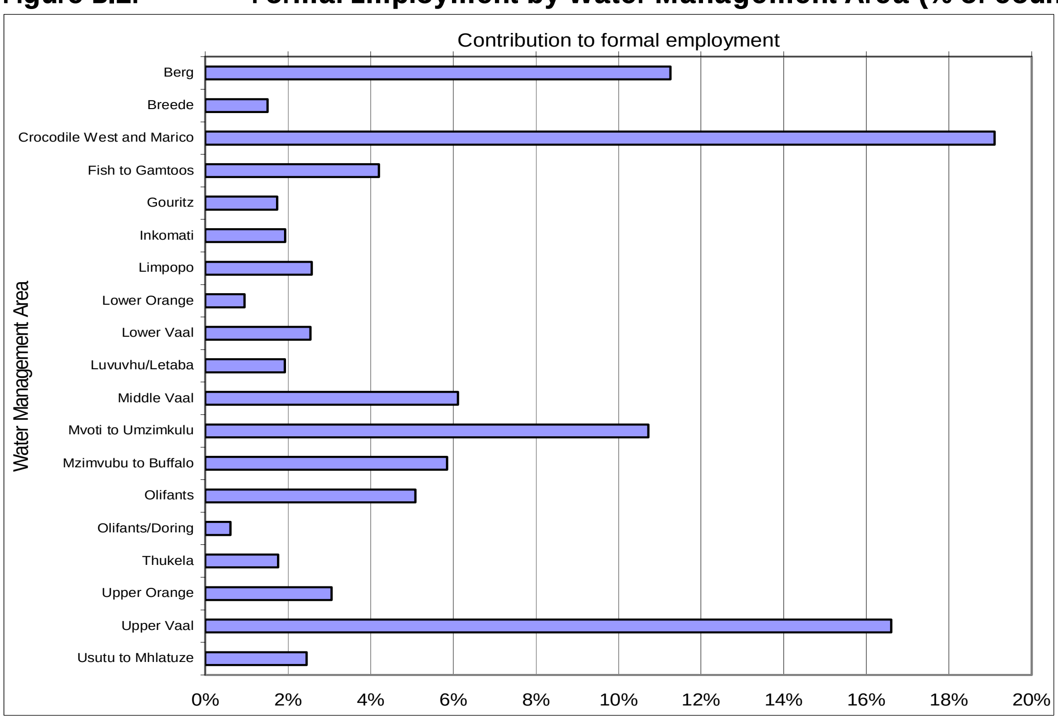
Figure B.1: Total GDP by Water Management Area (% of Country)



B.3 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL EMPLOYMENT

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

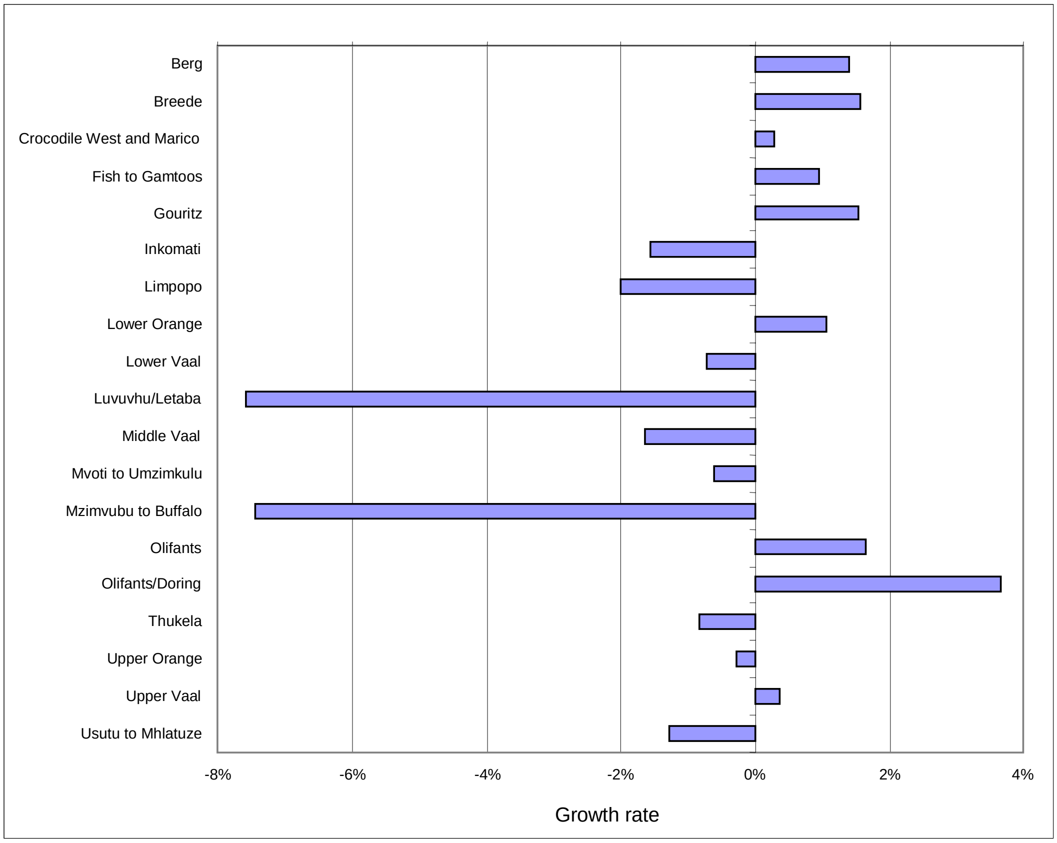
Figure B.2: Formal Employment by Water Management Area (% of country)



B.4 ECONOMIC GROWTH BY WATER MANAGEMENT AREA

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

Figure B.3: Average Annual Economic Growth by Water Management Area, 1988-1997 (%)



APPENDIX B.3
ECONOMIC SECTOR DESCRIPTION

ECONOMIC SECTOR DESCRIPTION

- **Agriculture:** This sector includes agriculture, hunting and related services. It comprises activities such as growing of crops, market gardening, horticulture, mixed farming, production of organic 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

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.

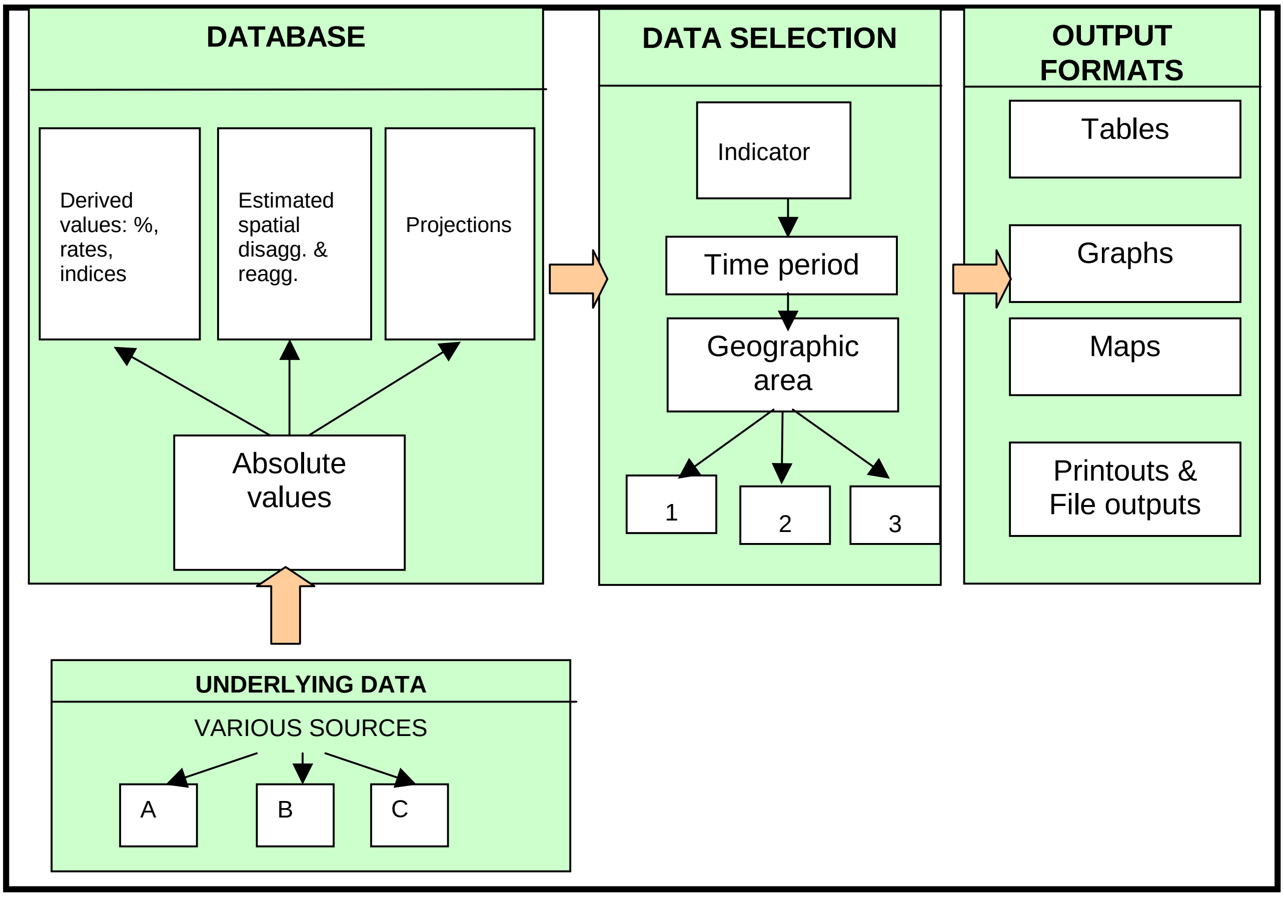
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service 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

Not used

APPENDIX D

LAND USE DATA

APPENDIX D.1	**Listing per quaternary catchment of land use data contained in the database of the Water Situation Assessment Model.**
APPENDIX D.2	**Conversion of mature livestock and game populations to Equivalent Large Stock Units.**
APPENDIX D.3	**Tree species in commercial forests.**

BERG WATER MANAGEMENT AREA

APPENDIX D.1

LISTING PER QUATERNARY CATCHMENT OF LAND USE DATA CONTAINED IN THE DATABASE OF THE WATER SITUATION ASSESSMENT MODEL

QUATERNARY CATCHMENT	aAAi	aFCAi	A FINi	A LSAi	A NAEi	ORSUi
	AREA UNDER ALIEN VEGETATION	AREA UNDER AFFORESTATION	INDIGENOUS FOREST AREA	FIELD AREA IRRIGATED	URBAN AREAS	NUMBER OF LARGE STOCK UNITS
	km^2	km^2	km^2	km^2	km^2	km^2
G10A	12,66	34,97	0,00	17,83	1,78	5280
G10B	19,82	8,44	0,00	2,72	0,00	3879
G10C	8,34	9,25	0,00	92,07	15,85	9984
G10D	23,21	1,66	0,00	131,89	8,94	17312
G10E	8,28	19,69	0,00	35,95	1,30	5864
G10F	16,23	1,45	0,00	20,86	3,75	11771
G10G	0,76	0,00	0,00	0,00	0,00	2670
G10H	58,26	1,32	0,00	7,01	3,39	9574
G10J	37,49	0,08	0,00	39,66	6,06	21177
G10K	243,90	0,00	0,00	46,25	0,54	21811
G10L	181,50	0,24	0,00	0,00	3,43	44542
G10M	408,40	0,00	0,00	0,00	18,49	34146
G21A	135,10	0,00	0,00	0,00	1,82	14920
G21B	67,62	0,04	0,00	0,00	13,41	8644
G21C	8,43	0,00	0,00	10,96	0,28	7133
G21D	55,40	2,32	0,00	8,97	5,72	14140
G21E	8,89	0,13	0,00	43,26	10,59	17050
G21F	21,40	0,00	0,00	4,57	7,95	6484
G22A	24,55	0,05	0,00	0,00	16,74	752
G22B	8,46	2,38	0,00	0,00	29,65	1860
G22C	2,32	0,76	0,00	3,24	169,50	5671
G22D	5,53	7,97	0,00	10,62	109,10	4949
G22E	0,00	0,16	0,00	20,85	82,24	8426
G22F	1,76	4,09	0,00	1,90	3,36	1850
G22G	0,28	2,47	0,00	24,22	6,61	2995
G22H	0,58	3,19	0,00	28,79	7,48	6598
G22J	8,08	10,53	0,00	8,61	22,92	3889
G22K	7,92	0,00	0,00	2,79	7,52	1980
G40A	0,23	8,58	0,00	0,00	0,00	1366
TOTALS	**1375,40**	**119,75**	**0,00**	**563,02**	**558,42**	**296715**

BERG WATER MANAGEMENT AREA

APPENDIX D.2

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

SPECIES	GROUP *	NUMBER PER ELSU
Livestock :		
Cattle	L	0,85
Sheep	S	6,5
Goats	S	5,8
Horses	L	1
Donkeys / mules	S	1,1
Pigs	S	4
Game :		
Black Wildebeest	LA	3,3
Blesbuck	SA	5,1
Blou Wildebeest	LA	2,4
Buffalo	BG	1
Eland	BG	1
Elephant	BG	0,3
Gemsbok	LA	2,2
Giraffe	BG	0,7
Hippopotamus	BG	0,4
Impala	SA	7
Kudu	LA	2,2
Nyala	SA	3,3
Ostrich	--	2,7
Red Hartebeest	LA	2,8
Roan Antelope	LA	2
Sable Antelope	LA	2
Southern Reedbuck	SA	7,7
Springbok	SA	10,3
Tsessebe	LA	2,8
Warthog	O	5
Waerbuck	SA	2,4
Rhinoceros	BG	0,4
Zebra	O	1,6

* Groups (in terms of water consumption :
L = cattle and horses; S = small livestock; LA = large antelope; SA = small antelope; BG = big game;
O = other game.

BERG WATER MANAGEMENT AREA

APPENDIX D.3

TREE SPECIES IN COMMERCIAL FORESTS PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	AFCAi AREA UNDER AFFORESTATION km^2	SPECIES
G10A	34,97	Pine
G10B	8,44	Pine
G10C	9,25	Pine
G10D	1,66	Pine
G10E	19,69	Pine
G10F	1,45	Pine
G10G	0,00	
G10H	1,32	Pine
G10J	0,08	Pine
G10K	0,00	
G10L	0,24	Pine
G10M	0,00	
G21A	0,00	
G21B	0,04	Pine
G21C	0,00	
G21D	2,32	Pine
Pine G21E	0,13	Pine
G21F	0,00	
G2 Pine 2A	0,05	Pine
G22B	2,38	Pine
G22C	0,76	Pine
G22D	7,97	Pine
G22E	0,16	Pine
G22F	4,09	Pine
G22G	2,47	Pine
G22H	3,19	Pine
G22J	10,53	Pine
G22K	0,00	
G40A	8,58	Pine
TOTALS	**119,75**	

APPENDIX E

WATER RELATED INFRASTRUCTURE

APPENDIX E.1	**Existing water supply schemes.**
APPENDIX E.2	**Main dams.**
APPENDIX E.3	**Farm dam data per quaternary catchment.**

BERG WATER MANAGEMENT AREA

APPENDIX E.1

EXISTING WATER SUPPLY SCHEMES

SCHEME NAME	CONSUMERS SUPPLIED			RAW WATER SOURCE/YIELD	WATER TREATMENT WORKS			SOURCE OF DATA	RELIABILITY OF DATA
	URBAN/DOMESTIC/MINING/ INDUSTRIAL	IRRIGATION	CATCHMENT		NAME	CAPACITY (Mℓ/d)	OWNER		
Table Mountain and Southern Peninsula Water Supply Scheme	Cape Town Metropolitan Area (6,85 million m^3/a)	Local supply from Silvermine Dam (capacity 0,08 million m^3)	G22A - G22B	Hely Hutchinson Dam Woodhead Dam De Villiers Dam Victoria Dam Alexandra Dam Albion Spring (combined yield = 5 million m^3/a) Kleinplaas Dam Lewis Gay Dam (combined yield - 1,85 million m^3/a)	Kloofnek Kloofnke Constantia Nek Constantial Nek Constantia Nek Albion Spring Brooklands Brooklands	17 17 3 3 3 4,5 5,4 5,4	CCT CCT CCT CCT CCT CCT Simon's Town Simon's Town	WCSA	Good
Steenbras Water Supply Scheme	Cape Town Metropolitan Area Strand (combined 38 million m^3/a)		G22A - G22D, G22K	Upper and Lower Steenbras Dams. Historic firm yield is 38 million m^3/a	Steenbras	150	CCT	WCSA	Good
Wemmershoek Water Supply Scheme	Cape Town Metropolitan Area Kraaifontein Brackenfell Durbanville Bellville (combined 44 million m^3/a) Paarl/Wellington (10 million m^3/a)		G22A - G22D G10C, G10D, G22E	Wemmershoek Dam (1:50 yield = 54 million m^3/a)	Wemmershoek Wemmershoek Pre-treatment	270 140	CCT CCT	WCSA	Good
Voëlvlei Government Water Supply Scheme	Cape Town Metropolitan Area including 4 million m^3/a allocation to Krantzkop Arms Factory Berg River Government Water Scheme (comprises Swartland and Saldanha Schemes totalling 19 million m^3/a)	Berg and Eerste River riparian irrigation (16 million m^3/a)	G22A - G22D, G10L, G10M, G10D, G21C, G21D, G21A	Voëlvlei and Misverstand Dams (1:50 year yield is 105 million m^3/a)	Voëlvlei Swartland Withoogte	273 23 32	CCT West Coast District Council West Coast District Council	WCSA	Good
RSE/Berg Government Water Scheme	Cape Town Metropolitan Area and Cape Flats Stellenbosch Bellville Brackenfell Kraaifontein Durbanville (combined 148 million m^3/a)	Berg River irrigation areas (43 million m^3/a) Eerste River irrigation areas (19 illion m^3/a)	G22A - G22E, G22G	Theewaterskloof (RSE historical supply = 186 million m^3/a) Kleinplaas Dam (historical supply = 24 million m^3/a) (combined 210 million m^3/a)	Wemmershoek Wemmershoek Pre-treatment Blackheath/Faure (not operational in 1995)	270 140 400 n/a	CCT CCT CCT N/a	WCSA	Good

SCHEME NAME	CONSUMERS SUPPLIED			RAW WATER SOURCE/YIELD	WATER TREATMENT WORKS			SOURCE OF DATA	RELIABILITY OF DATA
	URBAN/DOMESTIC/MINING/ INDUSTRIAL	IRRIGATION	CATCHMENT		NAME	CAPACITY (Mℓ/d)	OWNER		
Atlantis	Atlantis (4,4 million m^3/a)		G21B	36 boreholes in two wellfields (Silverstroom and Witsands). Yield is 4,4 million m^3/a.	N/a	N/a		WCSA	Good
Paarl	Domestic to Paarl (2,8 million m^3/a). Supplement to Wemmershoek supply.			Nantes Dam Bethel Dam (0,5 million m^3/a at 95% assurance) Berg River Pumpstation (Yield = 2,3 million m^3/a)	Paarlberg (chlorination only)		Paarl Municipality	WCSA	Good
Somerset West	Domestic to Somerset West			Pumping from Lourens River into Land-en-Zeezicht Dam. (Capacity 0,45 million m^3)	Land-en-Zeezicht	14	Somerset West	WCSA	Fair
Strand	Domestic to Strand. Supplement to Wemmershoek supply.			Lourens River	Strand	2,4	Strand	WCSA	Fair
Stellenbosch	Domestic			Jonkershoek River Theewaterskloof RSE	Idas Valley paradyskloof	24 10	Stellenbosch Stellenbosch	WCSA	Good
Wellington	Domestic from Antoniesvlei to Supplement Wemmershoek.			Antoniesvlei, yield varies between 1 Mℓ/d (summer) and 2,3 Mℓ/d (winter).	N/a	N/a	N/a	WCSA	Good
Inter-basin transfer via Artois Canal at Mitchell's Pass		Transkei between Breede WMA and Berg WMA		From H10E (Breede WMA) to G10D (Berg WMA)	N/a	N/a	N/a	Ninham Shand files	Good
Inter-basin transfer from Upper Wit River in Bain's Kloof to Wellington.		Transfer between Breede WMA and Berg WMA		From H10E (Breede WMA) to G10D (Berg WMA).	N/a	N/a	N/a	Ninham Shand files	Good
Pniel	Pniel domestic use			Treated water supplied from Stellenbosch. Supplemented by local mountain streams. Consumption in 1995 not available. 2000 consumption = 104 500 kℓ/month.	N/a	N/a	N/a	Municipality	Fair
Franschhoek	Domestic use			Streams in Mont Rochelle Nature Reserve feed 6 reservoirs (capacity 3,5 million m^3). 1995 figures not available. 2001 November consumption = 47 800 m^3/month.	N/a	N/a	N/a	Municipality	Fair
Saron	Domestic use			April 2001 consumption figures = 12 800 m^3/month.				Ninham Shand files	Incomplete
Eendekuil	Domestic use			Two small dams store water from mountain streams.	N/a	N/a	N/a	Municipality	Incomplete
Porterville	Domestic use			Supply from mountain spring. In 1995, supply varied between 1300 - 1590 kℓ/day.	N/a	N/a	N/a	Municipality	Fair

BERG WATER MANAGEMENT AREA

APPENDIX E.2

MAIN DAMS

NAME	STORAGE CAPACITY				YIELD					FULL SUPPLY SURFACE AREA (km^2)	CATCHMENT	CO-ORDINATES		RELIABILITY OF DATA
	DEAD (million m^3)	LIVE (million m^3)	TOTAL (million m^3)	DATE DETERMINED	DOMESTIC SUPPLIES (million m^3/a)	IRRIGATION (million m^3/a	OTHER (million m^3/a)	SURPLUS (million m^3/a)	TOTAL (million m^3/a)			LAT.	LONG.	
Wemmershoek	0,10	58,80	58,90	1984	54				54	2,96	G10B	33º 49' 56"	19º 05' 00"	High
Voëlvlei	8,10	104,10	172,20	1977	89	16			105	15,73	G10F	33º 21' 05"	19º 01' 12"	High
Misverstand	1,50	6,10	7,60	1977	0	5			5	2,49	G10J	33º 01' 39"	18º 47' 25"	High
Kleinplaas	0,02	0,35	0,37	1983	24				24	0,08	G22F	33º 58' 28"	18º 56' 37"	High
Steenbras Upper	0,00	31,80	31,80	1988	38				38	2,70	G40A	34º 10' 06"	18º 54' 00"	High
Steenbras Lower	0,00	33,70	33,70	1954 Raised						3,80	G40A	34º 11' 13"	18º 51' 10"	High

BERG WATER MANAGEMENT AREA

APPENDIX E.3

FARM DAM DATA
PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	ODISi	ADMIi	ODIEo
	FULL SUPPLY CAPACITY (million m^3)	FULL SUPPLY AREA km^2	EVAPORATION LOSSES (million m^3)
G10A	0,64	0,17	0,02
G10B	0,00	0,00	0,00
G10C	15,35	2,59	1,58
G10D	21,00	5,73	5,13
G10E	14,03	4,38	2,41
G10F	2,43	0,63	0,64
G10G	0,00	0,00	0,00
G10H	1,32	0,28	0,30
G10J	8,07	2,08	2,14
G10K	6,25	1,45	1,49
G10L	1,64	0,76	0,74
G10M	0,00	0,00	0,00
G21A	0,06	0,02	0,02
G21B	0,00	0,00	0,00
G21C	1,08	0,27	0,25
G21D	0,29	0,08	0,07
G21E	2,24	0,82	0,71
G21F	0,31	0,04	0,04
G22A	1,60	0,24	0,03
G22B	0,00	0,00	0,20
G22C	1,53	0,28	0,22
G22D	0,21	0,04	0,05
G22E	1,46	0,25	0,19
G22F	0,50	0,07	0,03
G22G	4,49	1,37	1,18
G22H	7,74	2,39	1,72
G22J	7,20	0,76	0,41
G22K	0,20	0,05	0,26
G40A	0,00	0,00	0,00
TOTALS	**99,63**	**24,75**	**19,81**

APPENDIX F

WATER REQUIREMENTS

APPENDIX F.1	**Urban water requirements per quaternary catchment.**
APPENDIX F.2	**Rural water requirements per quaternary catchment.**
APPENDIX F.3	**Bulk water requirements per quaternary catchment.**
APPENDIX F.4	**Irrigation water requirements per quaternary catchment.**
APPENDIX F.5	**Streamflow reduction activity water requirements per quaternary catchment.**
APPENDIX F.6	**Notes on proceedings of the workshops on ecological flow requirements.**
APPENDIX F.7	**Assumed rural domestic per capita requirements**

BERG WATER MANAGEMENT AREA

APPENDIX F.1

URBAN WATER REQUIREMENTS PER QUATERNARY CATCHMENT

1	4	3	2	6	8	10	1		7	9	5
	fNUIi	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTFo	oUTLo
Areas	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Indirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	Factor	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
G10A	0.20	0.05	0.11	0.49	0.06	4345	0.25	0.10	0.25	0.00	0.12
G10B	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G10C	0.20	0.05	3.89	11.53	0.77	113354	4.81	3.67	5.83	0.00	2.80
G10D	0.20	0.05	1.83	5.35	0.39	33311	2.21	1.72	2.76	0.00	1.30
G10E	0.20	0.05	0.11	0.50	0.06	4538	0.26	0.11	0.24	0.00	0.12
G10F	0.20	0.05	0.18	0.82	0.15	8593	0.43	0.17	0.38	0.00	0.20
G10G	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G10H	0.20	0.05	0.31	1.39	0.13	11683	0.72	0.29	0.70	0.00	0.34
G10J	0.20	0.05	0.25	1.12	0.25	8062	0.58	0.24	0.60	0.00	0.27
G10K	0.20	0.05	0.01	0.08	0.02	456	0.04	0.02	0.02	0.00	0.02
G10L	0.20	0.05	0.27	2.74	0.13	16324	1.42	0.56	0.64	0.00	0.66
G10M	0.20	0.05	1.34	13.65	0.55	89462	7.06	2.86	2.81	0.00	3.30
G21A	0.20	0.05	0.01	0.15	0.07	730	0.08	0.03	0.03	0.00	0.04
G21B	0.20	0.05	0.00	0.00	0.53	0	0.00	0.00	0.00	0.00	0.00
G21C	0.20	0.07	0.00	0.00	0.01	0	0.00	0.00	0.00	0.00	0.00
G21D	0.20	0.07	0.67	4.48	0.25	37299	1.84	1.43	1.02	0.00	1.08
G21E	0.20	0.07	0.00	0.00	0.49	0	0.00	0.00	0.00	0.00	0.00
G21F	0.20	0.07	0.00	0.00	0.35	0	0.00	0.00	0.00	0.00	0.00
G22A	0.20	0.10	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22B	0.20	0.10	83.24	299.87	0.00	2684687	121.91	81.30	142.21	0.00	86.00
G22C	0.20	0.10	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22D	0.20	0.10	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22E	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22F	0.20	0.05	3.00	9.42	0.00	51447	3.91	2.97	4.81	0.00	2.25
G22G	0.20	0.05	0.23	1.11	0.00	13138	0.58	0.23	0.42	0.00	0.27
G22H	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22J	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G22K	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
G40A	0.20	0.05	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00
TOTALS	--	--	**95.47**	**352.70**	**4.20**	**3077429**	**146.10**	**95.70**	**162.70**	**0.00**	**98.77**

BERG WATER MANAGEMENT AREA

APPENDIX F.2

RURAL WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	3	5	4	6	1		7	2	7
	gRCRo	gRIRo	gRSRo	gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consumption rate	1:50 Year Small scale irrigation	Large stock units consumption rate	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	ℓ/c/d	million m^3/a	ℓ/u/d	million m^3/a	Number	million m^3/a	million m^3/a	Number	Factor
G10A	105.5	0	47	0.27	3829	0	0	5280	0.2
G10B	98.1	0	47	0.09	488	0	0	3879	0.2
G10C	98.4	0	47	0.95	18684	0	0	9984	0.2
G10D	98.5	0	47	1.08	18457	0	0	17312	0.2
G10E	106.5	0	47	0.38	6098	0	0	5864	0.2
G10F	91.2	0	47	0.44	5599	0	0	11771	0.2
G10G	106.5	0	47	0.10	1039	0	0	2670	0.2
G10H	108.1	0	48	0.31	2829	0	0	9574	0.2
G10J	106.2	0	47	0.69	6500	0	0	21177	0.2
G10K	83.9	0	47	0.55	6261	0	0	21811	0.2
G10L	112.4	0	49	1.05	6639	0	0	44542	0.2
G10M	69.2	0	47	0.64	2729	0	0	34146	0.2
G21A	112.4	0	49	0.51	6155	0	0	14920	0.2
G21B	112.4	0	49	0.30	3704	0	0	8644	0.2
G21C	108.1	0	48	0.24	3071	0	0	7133	0.2
G21D	77.8	0	48	0.56	11364	0	0	14140	0.2
G21E	104.3	0	48	0.89	15858	0	0	17050	0.2
G21F	108.1	0	48	0.26	3773	0	0	6484	0.2
G22A	108.1	0	48	0.07	489	0	0	752	0.2
G22B	108.1	0	48	0.08	96	0	0	1860	0.2
G22C	108.1	0	48	0.45	2878	0	0	5671	0.2
G22D	108.1	0	48	0.38	2301	0	0	4949	0.2
G22E	108.1	0	48	1.18	10607	0	0	8426	0.2
G22F	105.5	0	47	0.14	866	0	0	1850	0.2
G22G	108.1	0	48	0.64	6485	0	0	2995	0.2
G22H	99.0	0	47	1.38	15397	0	0	6598	0.2
G22J	105.5	0	47	0.48	4294	0	0	3889	0.2
G22K	90.7	0	47	0.25	2560	0	0	1980	0.2
G40A	26.4	0	47	0.06	563	0	0	1366	0.2
TOTALS	--	**0**	--	**14.40**	**169613**	**0**	**0**	**296715**	--

BERG WATER MANAGEMENT AREA
APPENDIX F.3
BULK WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	3	5	4	6	1		7	2	7							
	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic water use	Return flow (mining)	Ground-water decant/ mine de-watering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
G10A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G10M	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G21F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G22K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
TOTALS	--	--	--	--	--	--	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

BERG WATER MANAGEMENT AREA
APPENDIX F.4
IRRIGATION WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Green cover area	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops	Total water use by irrigators
	km^2	km^2	km^2	km2	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a
G10A	17.83	0.00	0.00	17.83	0.20	0.20	0.20	0.75	0.00	0.00	13.94
G10B	2.72	0.00	0.00	2.72	0.20	0.20	0.20	0.75	0.00	0.00	1.58
G10C	88.96	3.11	0.00	92.07	0.20	0.20	0.20	0.75	0.75	0.00	0.00
G10D	50.29	80.22	1.38	131.89	0.20	0.20	0.20	0.75	0.75	0.75	102.50
G10E	35.95	0.00	0.00	35.95	0.20	0.20	0.20	0.79	0.00	0.00	26.27
G10F	2.27	18.58	0.01	20.86	0.20	0.20	0.20	0.75	0.75	0.75	17.86
G10G	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.00	0.00	0.00	0.00
G10H	0.10	6.91	0.00	7.01	0.20	0.20	0.20	0.84	0.75	0.00	5.55
G10J	2.59	37.08	0.00	39.66	0.20	0.20	0.20	0.75	0.75	0.00	34.40
G10K	4.13	41.38	0.73	46.25	0.10	0.10	0.10	0.85	0.75	0.75	52.80
G10L	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00
G10M	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00
G21A	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00
G21B	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00
G21C	1.67	9.29	0.00	10.96	0.10	0.10	0.10	0.75	0.75	0.00	0.00
G21D	0.88	8.04	0.05	8.97	0.10	0.10	0.10	0.75	0.75	0.75	0.00
G21E	4.66	38.37	0.23	43.26	0.10	0.10	0.10	0.75	0.75	0.75	0.00
G21F	0.10	4.47	0.00	4.57	0.10	0.10	0.10	0.75	0.75	0.00	0.00
G22A	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00
G22B	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00
G22C	0.77	2.46	0.00	3.24	0.05	0.05	0.05	0.75	0.75	0.00	1.46
G22D	1.52	0.00	9.10	10.62	0.05	0.05	0.05	0.75	0.00	0.75	4.79
G22E	20.84	0.01	0.00	20.85	0.05	0.05	0.05	0.75	0.75	0.00	9.41
G22F	1.90	0.00	0.00	1.90	0.05	0.05	0.05	0.75	0.00	0.00	0.86
G22G	24.05	0.17	0.00	24.22	0.05	0.05	0.05	0.75	0.75	0.00	10.93
G22H	28.79	0.00	0.00	28.79	0.05	0.05	0.05	0.75	0.00	0.00	13.00
G22J	8.61	0.00	0.00	8.61	0.05	0.05	0.05	0.75	0.00	0.00	3.89
G22K	2.79	0.00	0.00	2.79	0.05	0.05	0.05	0.75	0.00	0.00	1.26
G40A	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00
TOTALS	**301.42**	**250.09**	**11.50**	**563.02**	--	--	--	--	--	--	**300.50**

BERG WATER MANAGEMENT AREA

APPENDIX F.5
STREAMFLOW REDUCTION ACTIVITY WATER REQUIREMENTS PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	VLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNOFF DUE TO ALIEN VEGETATION	REDUCTION IN FUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km^2	Km^2	km^2	km^2	km^2	km^2	Million m^3/a	Million m^3/a
G10A	12,66	0,00	34,97	0,00	2,77	0,00	10,04	0,22
G10B	19,82	0,00	8,44	0,00	2,86	0,00	1,81	0,16
G10C	8,34	0,00	9,25	0,00	1,87	0,00	2,06	0,41
G10D	23,21	0,00	1,66	0,00	4,07	0,00	0,28	0,87
G10E	8,28	0,00	19,69	0,00	1,50	0,00	1,44	0,50
G10F	16,23	0,00	1,45	0,00	2,09	0,00	0,06	0,68
G10G	0,76	0,00	0,00	0,00	0,26	0,00	0,00	0,23
G10H	58,26	0,00	1,32	0,00	3,34	0,00	0,04	0,85
G10J	37,49	0,00	0,08	0,00	2,56	0,00	0,00	1,09
G10K	243,90	0,00	0,00	0,00	9,89	0,00	0,00	0,81
G10L	181,50	0,00	0,24	0,00	8,17	0,00	0,01	1,21
G10M	408,40	0,00	0,00	0,00	16,55	0,00	0,00	1,38
G21A	135,10	0,00	0,00	0,00	9,73	0,00	0,00	0,36
G21B	67,62	0,00	0,04	0,00	4,63	0,00	0,00	0,21
G21C	8,43	0,00	0,00	0,00	0,72	0,00	0,00	0,17
G21D	55,40	0,00	2,32	0,00	3,48	0,00	0,11	0,00
G21E	8,89	0,00	0,13	0,00	0,73	0,00	0,01	0,00
G21F	21,40	0,00	0,00	0,00	1,54	0,00	0,00	0,00
G22A	24,55	0,00	0,05	0,00	3,44	0,00	0,01	0,00
G22B	8,46	0,00	2,38	0,00	1,90	0,00	0,62	0,00
G22C	2,32	0,00	0,76	0,00	0,25	0,00	0,07	0,00
G22D	5,53	0,00	7,97	0,00	1,24	0,00	1,77	0,00
G22E	0,00	0,00	0,16	0,00	0,00	0,00	1,01	0,00
G22F	1,76	0,00	4,09	0,00	0,39	0,00	1,46	0,00
G22G	0,28	0,00	2,47	0,00	0,05	0,00	0,38	0,00
G22H	0,58	0,00	3,19	0,00	0,07	0,00	0,33	0,00
G22J	8,08	0,00	10,53	0,00	1,23	0,00	3,83	0,00
G22K	7,92	0,00	0,00	0,00	1,32	0,00	0,00	0,00
G40A	0,23	0,00	8,58	0,00	0,06	0,00	1,75	0,00
TOTALS	**1375,40**	**0,00**	**119,75**	**0,00**	**86,69**	**0,00**	**26,08**	10,00

APPENDIX F.6

WESTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2:

NOTES ON PROCEEDINGS

Prepared for

THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Directorate: Water Resources Planning

By

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Report No. 2949b/ 7970

April 2000

WESTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2: NOTES ON PROCEEDINGS

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Western Cape Water Resources Situation Assessment has been commissioned by the Directorate: Water Resources Planning, of the Department of Water Affairs and Forestry (DWAF) as one of several studies required to provide data for the development of a national water resource strategy in compliance with the provisions of the National Water Act No. 36 of 1998. A requirement of the study was that rough, desktop (i.e. based on available information) estimates of the ecological flow requirements of rivers should be made for each quaternary catchment in the study area (Ninham Shand, 1999) by a procedure prescribed by the Department (Kleynhans *et al.*, 1998). During these workshops, the Ecological Importance and Sensitivity Class (EI&SC) was determined in order to derive the Default Ecological Management Class (DEMC).

Subsequently, a second phase of workshops was commissioned to build on work done in Phase 1. In the Phase 2 workshops, the EI&SC and DEMC were reviewed and then the Present Ecological Status Class (PESC) and Attainable Ecological Status Class (AESC) of rivers within quaternary catchments were determined. This second round of workshops was therefore primarily concerned with assessing the present ecological status of rivers, as well as their potential for rehabilitation with respect to flow, and obtaining an Attainable Ecological Status Class for the rivers. Phase 2 also comprises a rough, desktop estimate, and is based on the methodology prescribed by the Department (Kleynhans, 1999 - see Annexure A). These notes are in respect of the second phase of workshops held for this purpose.

1.2 PARTICIPANTS

A two day workshop was held and a number of experts representing various disciplines relating to rivers and people knowledgeable of the Western Cape rivers were invited to attend. The workshop was held on 15 and 16 July 1999 at Ninham Shand in Cape Town and was facilitated by Mike Luger of Ninham Shand's Environmental Section. The delegates who took part in the workshop were as follows:

- Cate Brown of Southern Waters
- Rebecca Tharme of the Freshwater Research Unit at the University of Cape Town
- Charlie Boucher of Stellenbosch University's Botany Department
- Dean Impson of Cape Nature Conservation
- Wietsche Roets of Cape Nature Conservation
- Neels Kleynhans of DWAF (IWQS)
- Gareth McConkey of DWAF Water Quality Management (Western Cape Region)
- Gerrit van Zyl of DWAF (Western Cape Region)
- Jan van Staden of DWAF (Western Cape Region)
- Mike Luger of Ninham Shand
- Susie Tyson of Ninham Shand
- Liesl Nettmann of Ninham Shand

1.3 PURPOSE AND STRUCTURE OF THIS REPORT

The purpose of this report is to summarise the findings of the workshop. It contains information on the EI&SC, DEMC, PESC, and AESC of the main stem river in each quaternary catchment. In addition, during the workshop, issues and concerns were raised and these are summarised in order to convey these concerns to DWAF. Lastly, it was suggested at the workshop that participants should be given the opportunity to review the findings. Therefore, this draft report affords the participants the opportunity to review the findings by assessing the EI&SC, DEMC, PESC and AESC information contained in the figures and spreadsheet.

CHAPTER 2: METHODOLOGY

2.1 INTRODUCTION

The methodology utilised in the workshop is described in Kleynhans (1999 - see Annexure A). This methodology is summarised in Figure 2.1, which indicates the steps required in the determination of the AEMC.

The first step in the process is to determine the EI&SC. The EI&SC refers to the ecological importance and sensitivity of rivers, i.e. an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. Once the EI&SC has been determined, this index is used as an indicator of the DEMC. For the purposes of the National Water Act, a high EI&SC should justify the assignment of a very high DEMC, as the DEMC is defined in terms of the sensitivity of a system to disturbance and the risk of damaging the system and its capacity for self-recovery. These first two steps in assessing the AEMC were undertaken during the first phase workshop and were merely reviewed during this second phase workshop.

After the EI&SC and DEMC have been determined, the PESC needs to be assessed. This PESC is based on the present habitat integrity (i.e. ecological integrity, condition and naturalness) of the system. Using the EI&SC, DEMC and PESC, the AEMC is then determined. The AEMC is then used as an input into the hydrological model of Hughes and Munster, and is indicative of the most attainable ecological management class that can be achieved for each quaternary as a result of restoring the system from the PESC. In the context of the workshop, restoration is defined as the reestablishment of the structure and function of an ecosystem, including its natural diversity within a 5 year period as a result of changing flows only (Kleynhans, 1999).

Utilisation of this methodology was essential in order to ensure a consistent approach for each of the provinces. An updated version of the previous EcoInfo programme was used to process all the data obtained about the quaternary catchments during the workshop. The programme allowed the classes to be derived immediately as the data was entered.

2.2 GROUPING OF QUATERNARY CATCHMENTS

Due to the vast number of quaternary catchments in the Western Cape, it was decided that "like" quaternary catchments would be grouped together. Those catchments which displayed similar characteristics were therefore dealt with as one catchment, and thus only one quaternary catchment for each group was entered into the EcoInfo database. Where knowledge about riverine systems was low, the systems were compared to more well known rivers and low confidence scorings were given.

The quaternary catchment groupings are listed below. Those catchments in bold and underlined contain information in the database that is relevant for all quaternary catchments within that grouping. It was decided during the second round of workshops to subdivide certain groups so as to facilitate assessment thereof. These groups are indicated in the following list.

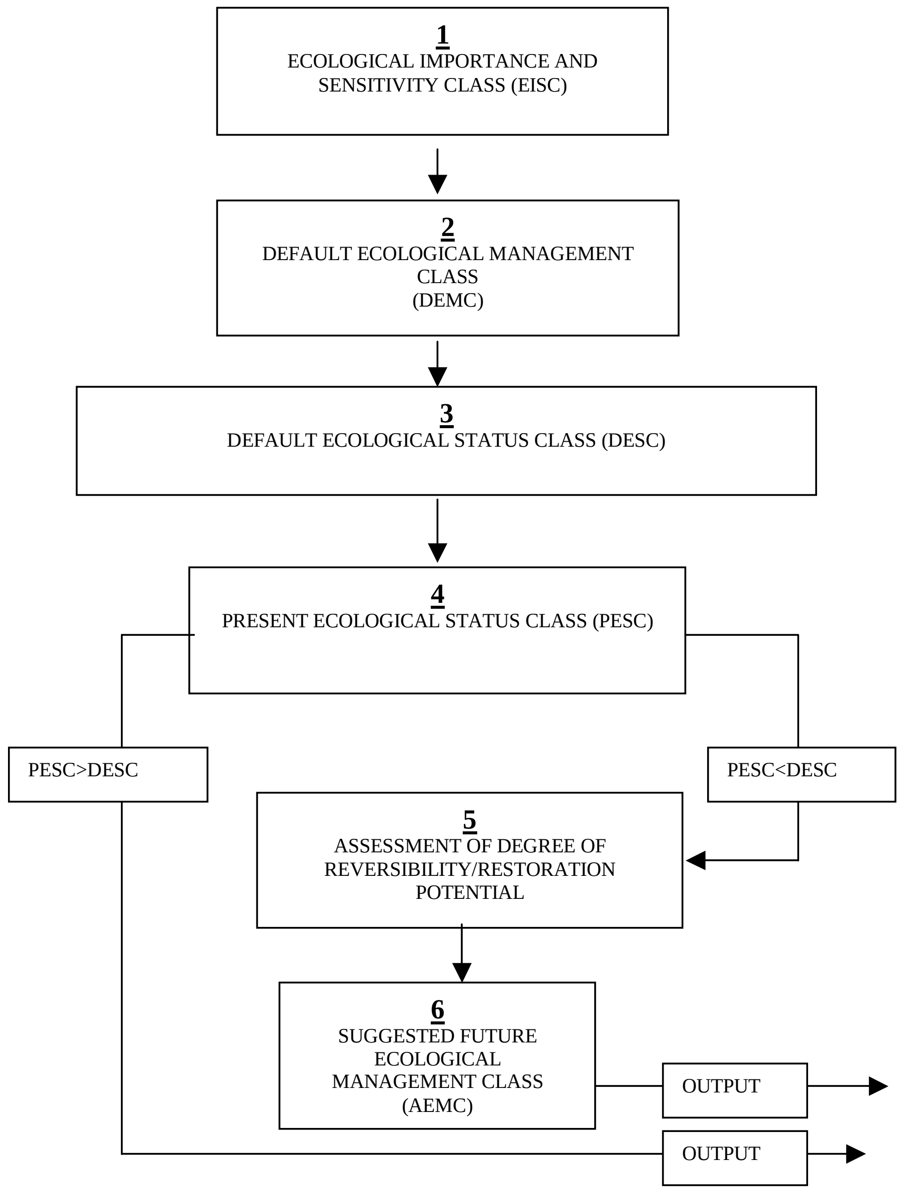


Figure 2.1 Flow Diagram indicating the sequence of steps proposed for the determination of the attainable Ecological Management Class.

- E10A, E10B
- E10C
- E10D, E10E, E10F, E10G, E10J
- E10K (gorge section and below)
- E21A, E21B, E21C, E21D
- E21E, E21F, E21G, E21H, E21J, E21K, E21L, E24A, E24B
- E22A, E22B, E22C, E22D, E22E, E22F, E23A, E23B, E23C, E23D, E23E, E23F, E23G, E23H, E23J, E23K, E24C, E24E, E24F, E24G, E24K
- E22G
- E24L, E24M, E24J, E24H
- E32A, E31B, E31C
- E33A, E33B, E33C, E33D, E31D, E31E, E31F, E31G, E31H, E32B, E32C, E32D, E32E
- E33F, E33G, E33H
- E40A, E40B
- E40C, E40D
- F60A, F60B, F60C, F60D, F60E, F40A, F40B, F40C, F40D, F40E, F40F, F40G, F40H, F50A, F50B, F50C, F50D, F50E, F50F, F50G
- G10A, G10B
- G10C
- G10D, G10F
- G10J (alone due to the presence of a downstream dam)
- G10E
- G10G

- G10L
- G10H
- G10K
- G10M (no rivers)
- G21A
- G21B
- G21D, G21C, G21E
- G21F
- G22A, G22B
- G22C, G22D
- G22E, G22G, G22H, G22J, G22K
- G22F
- G30B, G30C, G30D, G10H
- G30E, G30F, G30A
- G30G
- G30H (no rivers)
- G40A, G40B, G40D
- G40C
- G40E, G40F, G40G
- G40H, G40J, G40K, G40L
- G40M, G50A, G50B, G50C, G50D, G50E, G50F
- G50G, G50H, G50K
- G50J (no rivers)

- H10A, H10B, H10C
- H10D
- H10F, H10G
- H10E
- H10J, H10K
- H10L, H10H, H40C, H40D, H40E (mainstem of Breede River, before and after Hex River)
- H20A, H20B, H20C, H20D, H20E, H20F, H20G, H20H
- H30A, H30B
- H30E
- H40A, H40B, H30C, H30D
- H40F, H40G, H40H, H40J, H40K, H40L
- H50A, H50B, H70A
- H60A, H60B, H60C
- H60D, H60E, H60F, H60G, H60H
- H60J, H60K, H60L
- H70B, H70C, H70D, H70E, H70F
- H70G, H70H, H70J, H70K
- H80A, H80B, H80C, H90A, H90B, H90C
- H80D, H80E, H80F
- J11A, J11B, J11C, J11D, J11E, J11F, J11G, J11H, J11K, J12A, J12B, J12C, J12D, J12E, J12F, J12G, J12H, J12J, J12K, J12L, J12M, J13A, J13B, J13C (no data available for EI&SC)
- J11J

- J22A, J22B, J22C, J22D, J22E, J22F, J22G, J22H, J22J, J22K, J21A, J21B, J21C, J21D, J21E, J24A, J24B, J24C, J24D, J24E, J24F, J23A, J23B, J23C, J23D, J23E, J23F, J23G, J23H, J32A, J32B, J32C, J32D, J32E, J31A, J31B, J31C, J31D

- J23J, J25A, J25B, J25C, J25D (possibly B/ A due to pristine nature of tributaries and rugged terrain)

- J25E, J35A, J35B, J35C, J35D, J35E, J35F, J33A, J33B, J33C, J33D, J33E, J33F

- J34A, J34B, J34C, J34D, J34E, J34F

- J40A, J40B, J40C, J40D, J40E

- K10A, K10B, K10C, K10D, K10E, K10F, K20A, K30A, K30B, K30C

- K30D, K40A, K40B, K40C, K40D, K40E, K50A, K50B, K60A, K60B, K60C, K60D, K60E, K60F, K60G, K70A, K70B

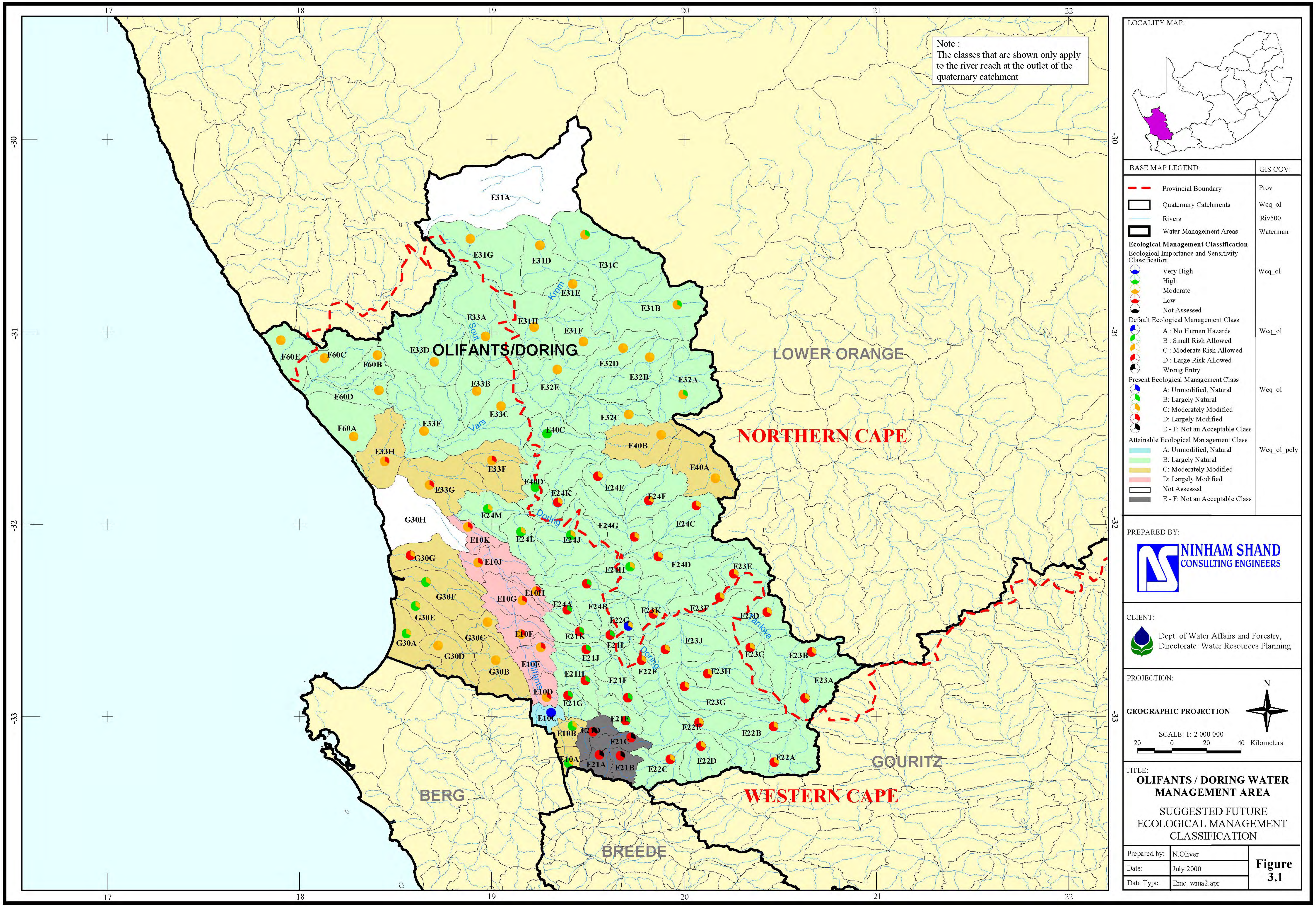
CHAPTER 3: RESULTS OF THE WORKSHOP

3.1 INTRODUCTION

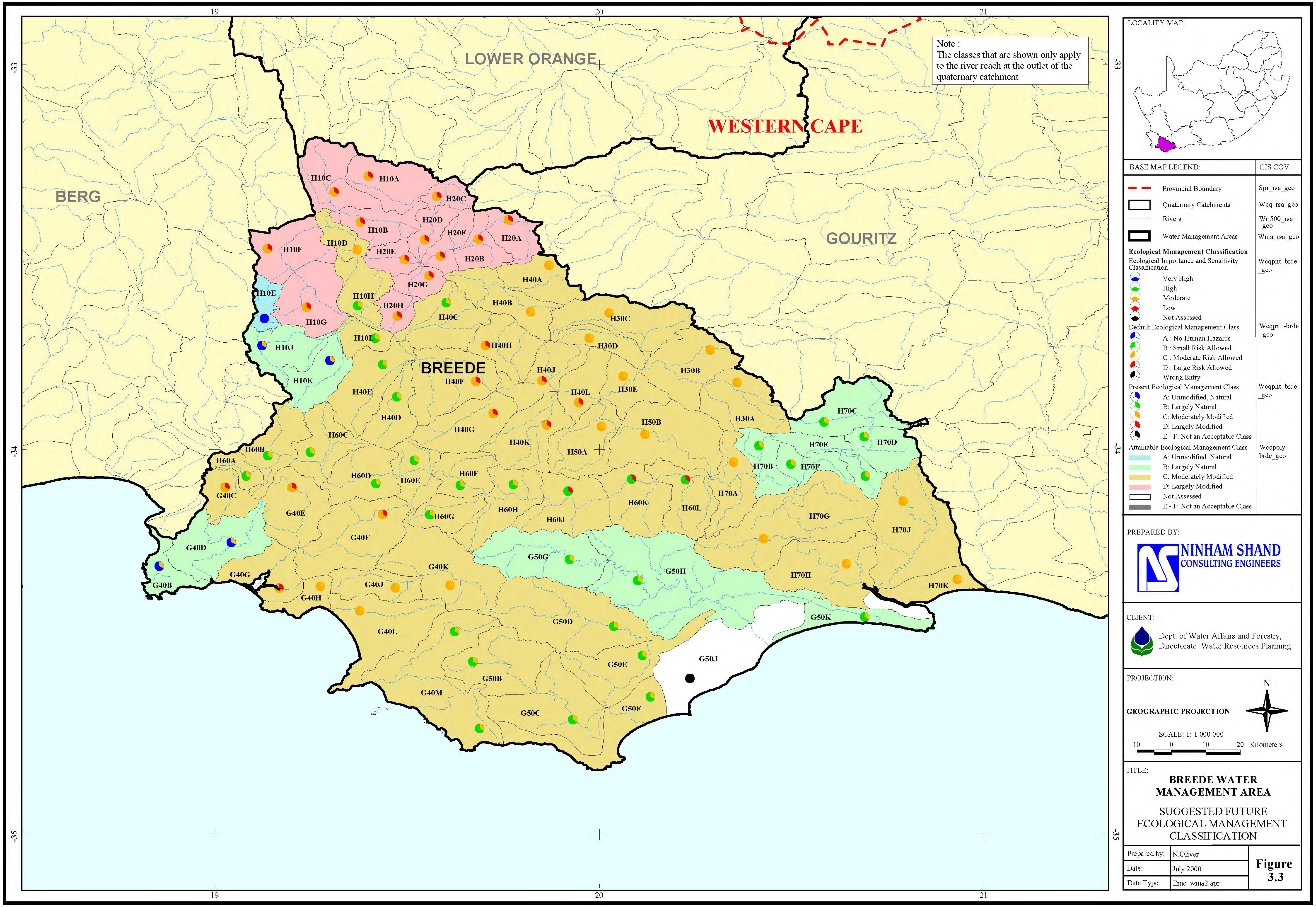
During the previous workshop, a number of participants requested that the results of the workshop be reviewed once they have been captured and made available by DWAF in a GIS format. The primary reason for this request can be attributed to the conservative EI&SC which the Ecoinfo programme derived from information put into the different categories. Participants felt that the DEMC were sometimes not reflective of the river, and also wanted to get an overall picture of the quaternary catchments for the Western Cape.

3.2 MANAGEMENT CLASSES

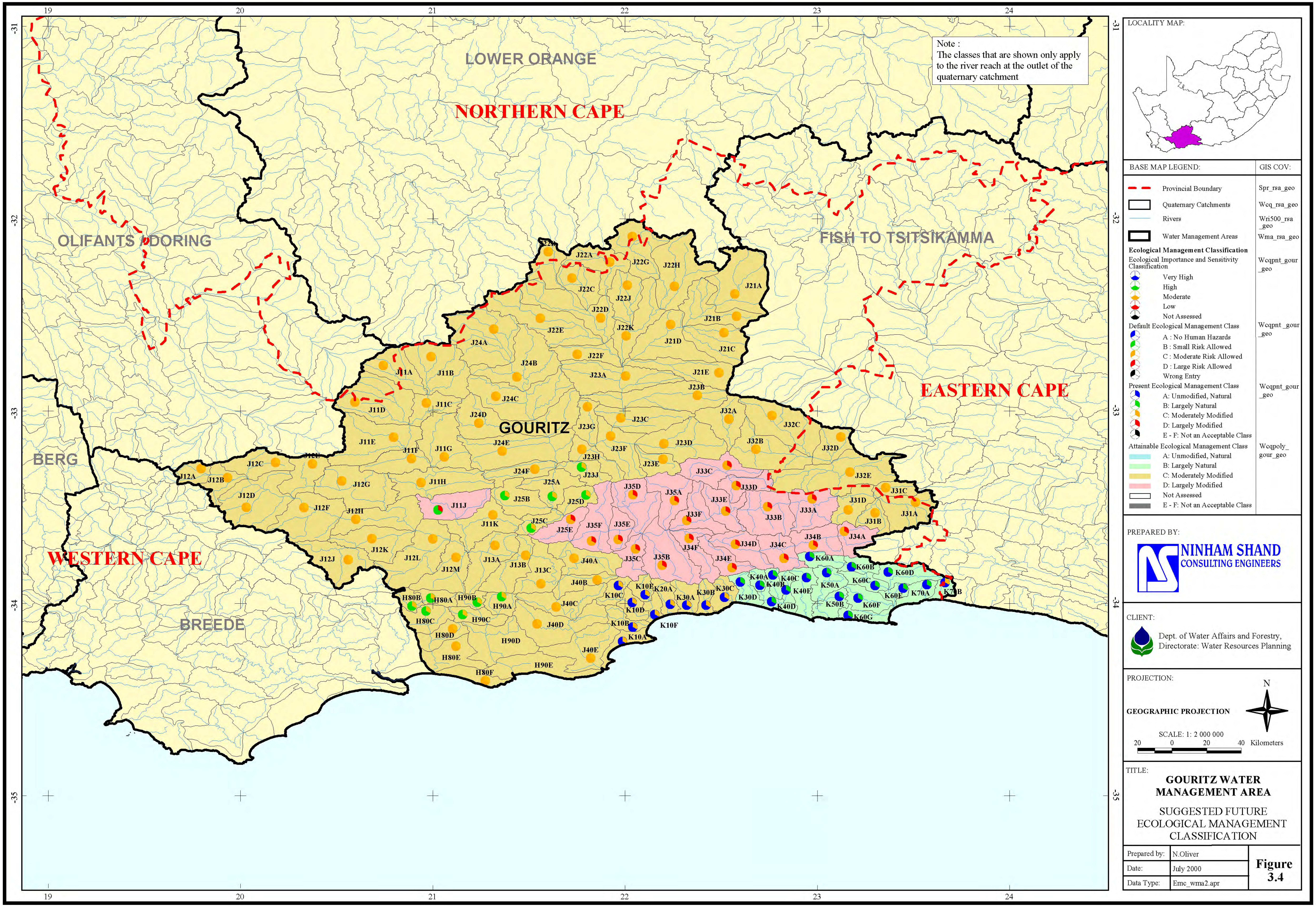
Since the abovementioned information was not available in GIS format prior to the Phase 2 workshops, this report contains a summary of the EI&SC and DEMC, as well as the PESC and AESC in both GIS format (see Figures 3.1 to 3.4) and the data entered in the Ecoinfo programme on CD Rom (see Annexure B).


Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
OLIFANTS/DORING
LOWER ORANGE
NORTHERN CAPE
GOURITZ
WESTERN CAPE
BERG
BREEDE
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary Prov
Quaternary Catchments Wcq_ol
Rivers Riv500
Water Management Areas Waterman
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Very High
High
Moderate
Low
Not Assessed
Wcq_ol
Default Ecological Management Class
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Wcq_ol
Present Ecological Management Class
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Wcq_ol
Attainable Ecological Management Class
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
Wcq_ol_poly
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
OLIFANTS / DORING WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Emc_wma2.apr
Figure 3.1

18
19
-33
-34
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
WESTERN CAPE
OLIFANTS / DOORN
GOURITZ
BREEDE
BERG
G30A
G10K
G10M
G10H
G10G
G10J
G10L
G10E
G10F
G21A
G21C
G21D
G10D
G21B
G21E
G21F
G10C
G10B
G22G
G22C
G10A
G22B
G22E
G22H
G22F
G22D
G22J
G22K
G40A
G22A
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Wcqpnt1_berg_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Wcqpnt1_berg_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Status Class
Wcqpnt1_berg_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Wcqberg_sass_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 1 000 000
10 0 10 20 Kilometers
TITLE:
BERG WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Environmental.apr
Figure 3.2



19
20
21
-33
-34
-35
LOWER ORANGE
BERG
GOURITZ
WESTERN CAPE
BREEDE
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
H10A
H10B
H10C
H10D
H10E
H10F
H10G
H10H
H10J
H10K
H20A
H20B
H20C
H20D
H20E
H20F
H20G
H20H
H30A
H30B
H30C
H30D
H30E
H40A
H40B
H40C
H40D
H40E
H40F
H40G
H40H
H40J
H40K
H40L
H50A
H50B
H60A
H60B
H60C
H60D
H60E
H60F
H60G
H60H
H60J
H60K
H60L
H70A
H70B
H70C
H70D
H70E
H70F
H70G
H70H
H70J
H70K
G40B
G40C
G40D
G40E
G40F
G40G
G40H
G40J
G40K
G40L
G40M
G50B
G50C
G50D
G50E
G50F
G50G
G50H
G50J
G50K
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Wcqpnt_brde_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Wcqpnt -brde_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
Wcqpnt_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Wcqpoly_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 1 000 000
10 0 10 20 Kilometers
TITLE:
BREEDE WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.3



LOWER ORANGE
NORTHERN CAPE
OLIFANTS / DORING
FISH TO TSITSIKAMMA
EASTERN CAPE
GOURITZ
BERG
WESTERN CAPE
BREEDE
Note : The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Wcqpnt_gour_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Wcqpnt_gour_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
Wcqpnt_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Wcqpoly_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
GOURITZ WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.4

CHAPTER 4: DISCUSSION

4.1 COMMENTS AND OBSERVATIONS BY PARTICIPANTS

The participants made the following comments with regard to the methodology and the updated EcoInfo computer programme in particular. At the end of the workshop the participants were encouraged to provide feedback on the strengths and weaknesses of the process. These are:

- The computer programme tended to crash and over-writing of previous data caused problems. As a result, there was a lack of confidence in the computer programme.

- There were problems with the data from the previous workshop, as data had not been converted to the requested GIS format. Furthermore, data seemed to be missing from the DWAF report on the Western Cape rivers.

- Accuracy of assessments was facilitated by the diverse number of experts involved in the decision-making process. However, it was viewed by some that in most cases only one expert per field was present which makes it difficult to verify the results obtained.

- A lack of knowledge of inland and middle-eastern (e.g. the Klein Karoo) areas as well as the Gouritz area has made it difficult to assess these areas accurately. The concern is that this will affect the overall accuracy of the results obtained. An in-depth study of the unfamiliar areas is necessary to improve the data. Areas rated with a confidence level of “1" or “2" are those quaternaries where there is a lack of information.

- A request by participants is that the information contained in the water quality database, as well as other information regarding the issues concerned, be expanded and made available for detailed research.

- The scoring system is regarded as being easy to use and general consensus regarding areas discussed was reached within a short time frame. However, greater clarification regarding the confidence scoring system is necessary in order to facilitate evaluation.

- The upgrading of rivers to a higher class is decided by the possible improvement of flow modification. This leaves doubt as to how the other criteria should be addressed. It was felt that by removing invasive vegetation and reducing bulldozing of river beds flow would improve, yet these options were not addressed. Very few rivers have the potential to be upgraded over the specified five year period as the majority require upgrading over ten years or more.

- Groupings of various catchments are too big, thus a very broad assessment was made resulting in inaccuracies. A number of quaternaries are linked together but only the main stem river was taken into account. This could result in the inaccurate scoring of the tributaries.

- The format of the methodology paper should be made clearer and user-friendly tables should be included, especially for EI&SC and DEMC. Furthermore, if the GIS layout of the results from the previous workshop had been available it would have aided the process greatly.

- The confidence levels need to be attached to all classes and a confidence level common denominator given.

- Ideally, rivers should be grouped according to ecotones rather than quaternary hydrological catchments as they are ecologically inappropriate, but it is acknowledged that this would not meet the requirements of the water balance model.

- The results should be reviewed by participants on a GIS database before the data is used for the national water balance.

- The overall workshop is still a lengthy process.

CHAPTER 5: CONCLUSIONS

5.1 CONCLUSIONS

This report has described the methodology used during the workshop and also presented the observations made by participants regarding the process and the methodology. Comments on the process, as well as recommendations, can be viewed in Chapter 4. This draft report will be finalised once the results of the study have been reviewed by the workshop participants.

It should be reiterated (from Kleynhans, 1999) that the estimates originating from the application of this procedure only be used for broad, very general planning purposes. In addition, the confidence levels assigned to the various classes are highly variable, depending on the level of knowledge of participants, and this, as well as the comments given regarding each quaternary, should be borne in mind when utilising the data. In all cases where information requirements go beyond the general planning level, the procedures being developed for the determination of the preliminary, intermediate, or full reserve should be applied.

REFERENCES

Kleynhans, C.J. 1999. *A procedure for the determination of the ecological reserve for the purpose of the National Water Balance Model for South African rivers.* Department of Water Affairs and Forestry.

Ninham Shand, 1999. *Western Cape water resources situation assessment: Workshop on ecological flow requirements: notes on proceedings.* Prepared for the Department of Water Affairs and Forestry. Report No. 2949/ 7970

BERG WATER MANAGEMENT AREA

APPENDIX F7

ASSUMED RURAL DOMESTIC PER CAPITA WATER REQUIREMENTS PER QUATERNARY

	PER CAPITA PER DAY RURAL USAGE					
	30	30	30	100	l/c/d	
Quaternary	Rural %	Advanced Rural %	Developing Urban %	Farming %	Comments	Average Consumption l/c/d
G10A	0	0	0	100		100
G10B	0	0	10	90	Wemmershoek	93
G10C	0	0	10	90	Kylemore	93
G10D	0	0	10	90	Windmeul, Daljosaphat	93
G10E	0	0	0	100		100
G10F	0	0	20	80	Voelvlei, Hermon	86
G10G	0	0	0	100		100
G10H	0	0	0	100		100
G10J	0	0	0	100		100
G10K	0	0	30	70	Wittewater	79
G10L	0	0	0	100		100
G10M	0	0	50	50	Paternoster	65
G21A	0	0	0	100		100
G21B	0	0	0	100		100
G21C	0	0	0	100		100
G21D	0	20	20	60	Abbotsdale, Pella,etc	72
G21E	0	0	5	95	Klipheuwel, Klapmuts	96.5
G21F	0	0	0	100		100
G22A	0	0	0	0	All urban	0
G22B	0	0	0	0	All urban	0
G22C	0	0	0	0	All urban	0
G22D	0	0	0	100		100
G22E	0	0	0	100		100
G22F	0	0	0	100		100
G22G	0	0	0	100		100
G22H	0	0	10	90	Lynedoch, Jamestown.etc	93
G22J	0	0	0	100		100
G22K	0	0	20	80	Sir Lowry's Pass Village	86
G40A	0	0	0	0	No farming	0

APPENDIX G

WATER RESOURCES

APPENDIX G.1	**Hydrological data per quaternary catchment.**
APPENDIX G.2	**Potential vulnerability of surface water and groundwater to microbial contamination.**
APPENDIX G.3	**Sedimentation data.**
APPENDIX G.4	**Groundwater.**
APPENDIX G.5	**Water quality information.**

BERG WATER MANAGEMENT AREA

APPENDIX G.1

HYDROLOGICAL DATA PER QUATERNARY CATCHMENT

1	2	6	4	3	5
Areas	aMTCi	eMRTo	oMAEi	oMAPi	oMARi
	Catchment area	Natural mean annual runoff (accumulative)	Mean annual evaporation	Mean annual precipitation	Natural mean annual runoff (incremental)
	km^2	million m^3	mm	mm	million m^3
G10A	172	183.60	1475	1580	183.60
G10B	126	93.09	1515	1245	93.09
G10C	328	424.29	1500	1009	147.60
G10D	688	539.69	1595	625	115.40
G10E	394	67.74	1635	640	67.74
G10F	539	668.16	1615	515	60.73
G10G	186	124.30	1640	1285	124.30
G10H	675	21.20	1615	411	21.20
G10J	868	848.58	1605	447	34.92
G10K	1176	25.17	1520	382	25.17
G10L	1755	50.58	1485	390	50.58
G10M	2005	941.78	1460	300	17.45
G21A	523	16.65	1450	408	16.65
G21B	304	9.64	1445	424	9.64
G21C	244	9.49	1560	523	9.49
G21D	484	24.14	1490	477	14.65
G21E	531	22.66	1485	531	22.66
G21F	242	55.00	1430	488	8.20
G22A	238	31.60	1400	684	31.60
G22B	109	32.55	1400	923	32.55
G22C	254	23.29	1400	605	23.29
G22D	246	40.89	1400	738	40.89
G22E	271	20.72	1410	572	20.72
G22F	66	59.09	1450	1465	59.09
G22G	106	75.50	1455	754	16.41
G22H	227	121.16	1415	669	24.94
G22J	128	60.29	1410	1002	60.29
G22K	80	24.00	1400	769	24.00
G40A	72	50.00	1405	1121	50.00
TOTALS	**13037**	**1406.85**	**--**	**--**	**1406.85**

APPENDIX G.2

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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LIST OF FIGURES

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ACKNOWLEDGEMENT

The support of Mr Julian Conrad of Environmentek, CSIR for providing the GIS DRASTIC coverages. His help is fully acknowledged and appreciated.

GLOSSARY

Aquifer	Strata, or a group of interconnected strata, comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes
Contamination	Introduction into the environment of an anthropogenic substance
DRASTIC	Numerical method that describes groundwater characteristics, using: water depth, recharge, aquifer media, soil media, topography, impact on vadose zone, and conductivity
Faecal	Material that contains bodily waste matter derived from ingested food and secretions from the intestines, of all warm-blooded animals including humans
Fitness for use	Assessment of the quality of water based on the chemical, physical and biological requirements of users
Groundwater	Subsurface water occupying voids within a geological stratum
Microbial	Microscopic organism that is disease causing
Ratio	Mathematical relationship defined by dividing one number by another number
Rating	Classification according to order, or grade
Vadose zone	Part of the geological stratum above the saturated zone where voids contain both air and water
Vulnerability	In the context of this report, it is the capability of surface water or groundwater resources to become contaminated

1. INTRODUCTION

The purpose of the Water Resources Situation Assessments is to prepare an overview of the water resources in South Africa. This will take account of the availability and requirements for water, as well as deal with issues such as water quality. The country has been divided into nineteen water management areas. Eight separate studies are being carried out within catchment boundaries that roughly approximate provincial borders. Once these studies have been completed, all information will also be synthesized into a single report for the whole country.

This report describes the method used to prepare a series of maps that show the microbial rating of surface water and groundwater resources in South Africa. Maps are produced at a quaternary catchment scale. It is intended that the appropriate portions of the maps be incorporated into each of the Water Management Area reports.

The microbial information provided in this report is intended for planning purposes, and is not suitable for detailed water quality assessment. The maps provide a comparative rating of the faecal contamination status of the surface water and groundwater resources in South Africa.

This report contains five sections:

- Section One: Introduction
- Section Two: Mapping of surface contamination
- Section Three: Mapping of Groundwater Resources
- Section Four: Conclusions and Recommendations
- Section Five: References

2. MAPPING SURFACE WATER RESOURCES

2.1 Background

The water resources of South Africa have come under increasing influence from faecal contamination as a result of increased urban development and lack of appropriate sanitation. Due to increased use of contaminated water for domestic consumption, people are at serious risk of contracting water-borne disease (e.g. gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis). The Department of Water Affairs and Forestry (DWAF) is the custodian of the national water resources and should ensure *fitness for use* of the water resources. Thus, the Department has developed a monitoring system to provide the necessary management information to assess and control the health hazard in selected areas. This project is called the National Microbiological Monitoring Programme (NMMP).

As part of the NMMP, a screening exercise was carried out to determine the number of catchments that experience faecal contamination. A short-list of tertiary catchment areas was compiled. Data from the database of the Directorate: Water Services Planning of DWAF was used to prioritize catchments to assess the overall health hazard (see Figure 1).

Ratings for land use activity were assigned using the method developed by Goodmin & Wright (1991), IWQS (1996), and Murray (1999). Ratings for land and water use were combined to establish an overall rating. Water use was considered to have a higher effect than the land use so that a 60:40 weighting was used (see Equation 1).

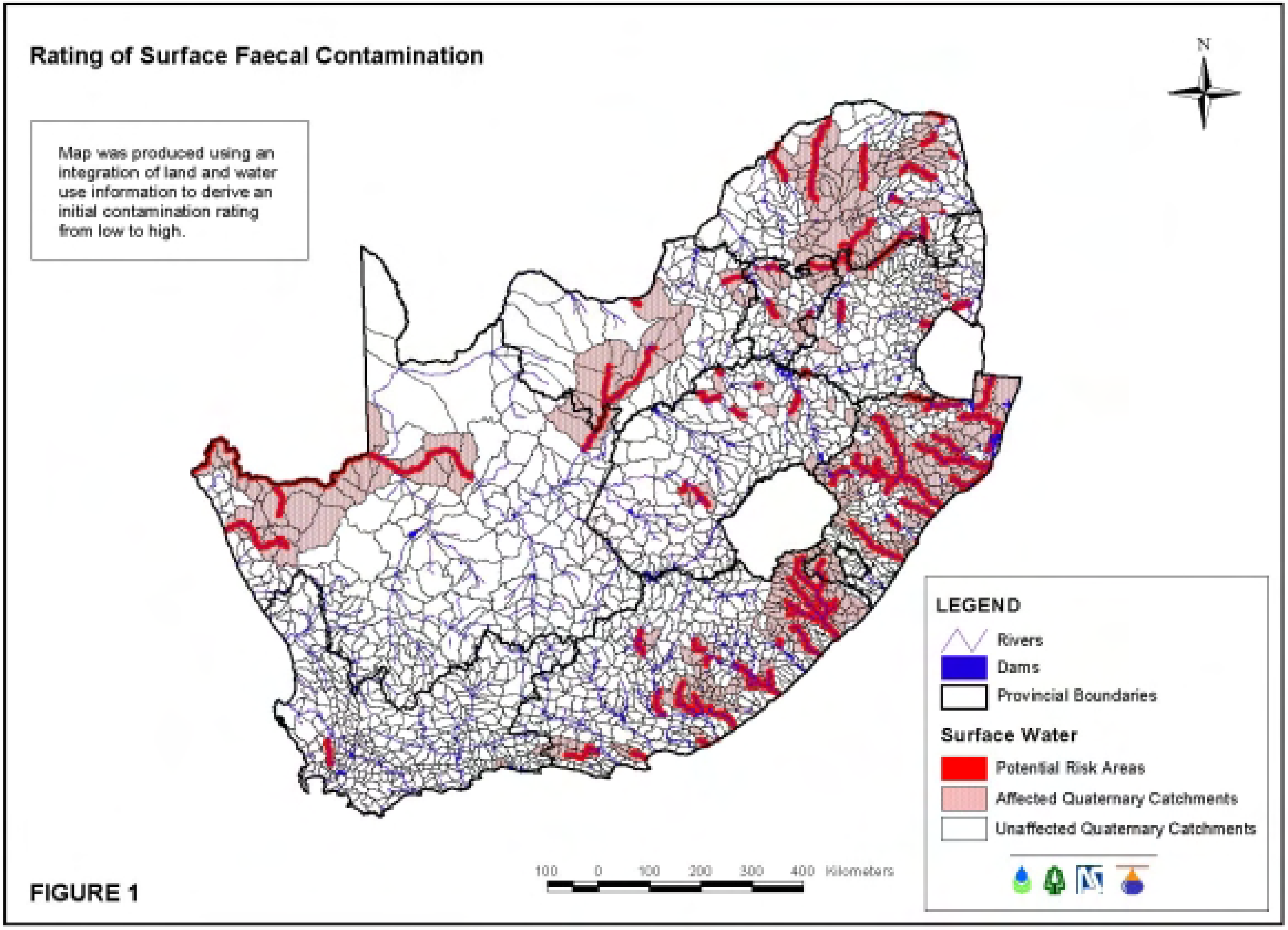
$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

Where OR = Area Rating (no units)
TLU = Total land use rating for area (no units)
TWU = Total water use rating for area (no units)

Each area was assigned a rating to indicate low (1), medium (2) or high (3) potential risk to users in the catchment area. The following values were used to designate each class:

Low	OR = 0 to 1000
Medium	OR = 1001 to100 000
High	OR > 100 000 ....(2)

Figure 1 shows the surface faecal contamination map for priority rated catchments in South Africa.



Rating of Surface Faecal Contamination

FIGURE 1

2.2 Surface faecal contamination

Figure 2 shows the potential surface faecal contamination map, developed using average population density (for a quaternary) and degree of sanitation (Venter, 1998). The land use rating is given by:

$$LU = SA + PD \qquad .... (3)$$

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:

$$TLU = (LU_n) \qquad .... (4)$$

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).

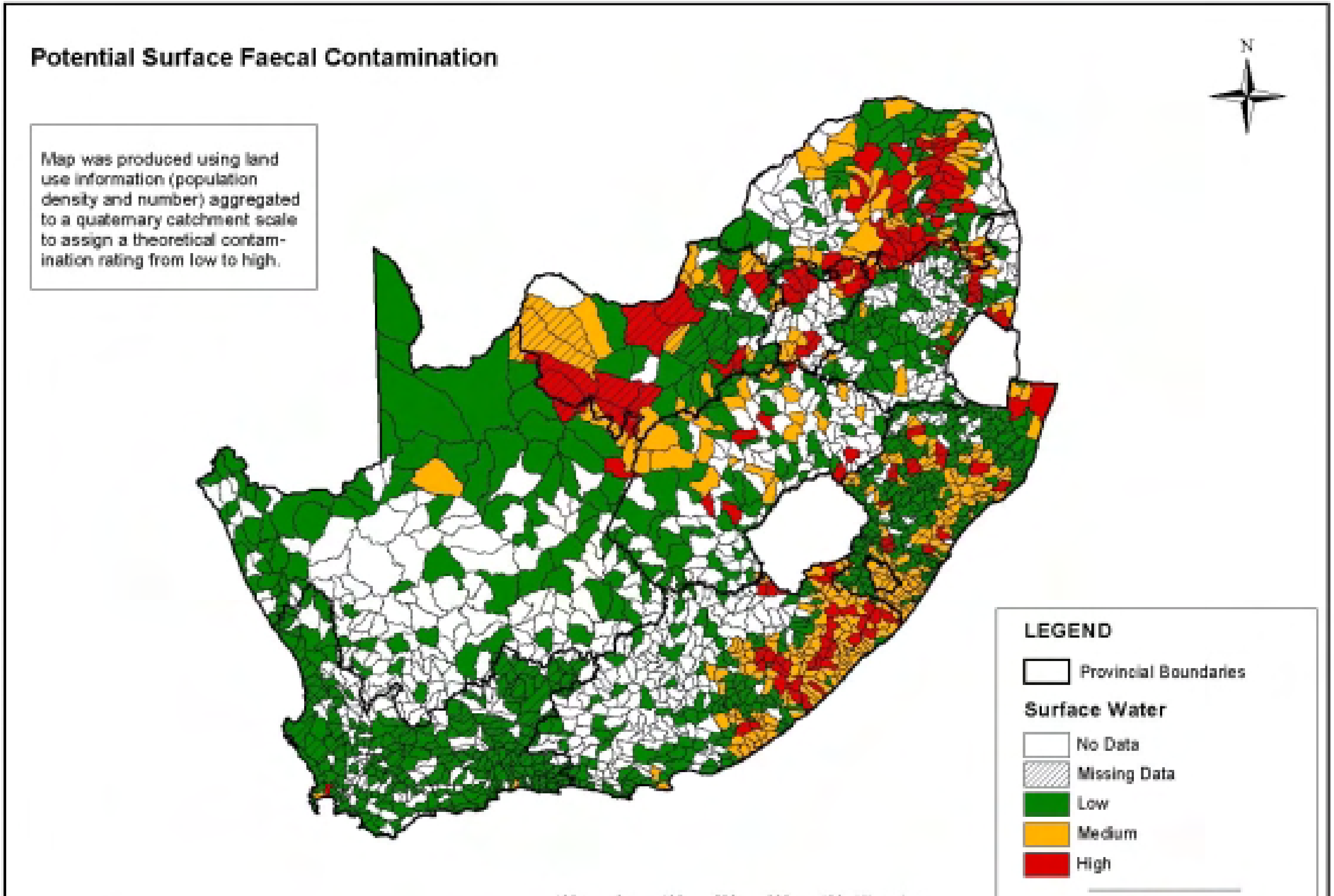

Potential Surface Faecal Contamination
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
N
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
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.

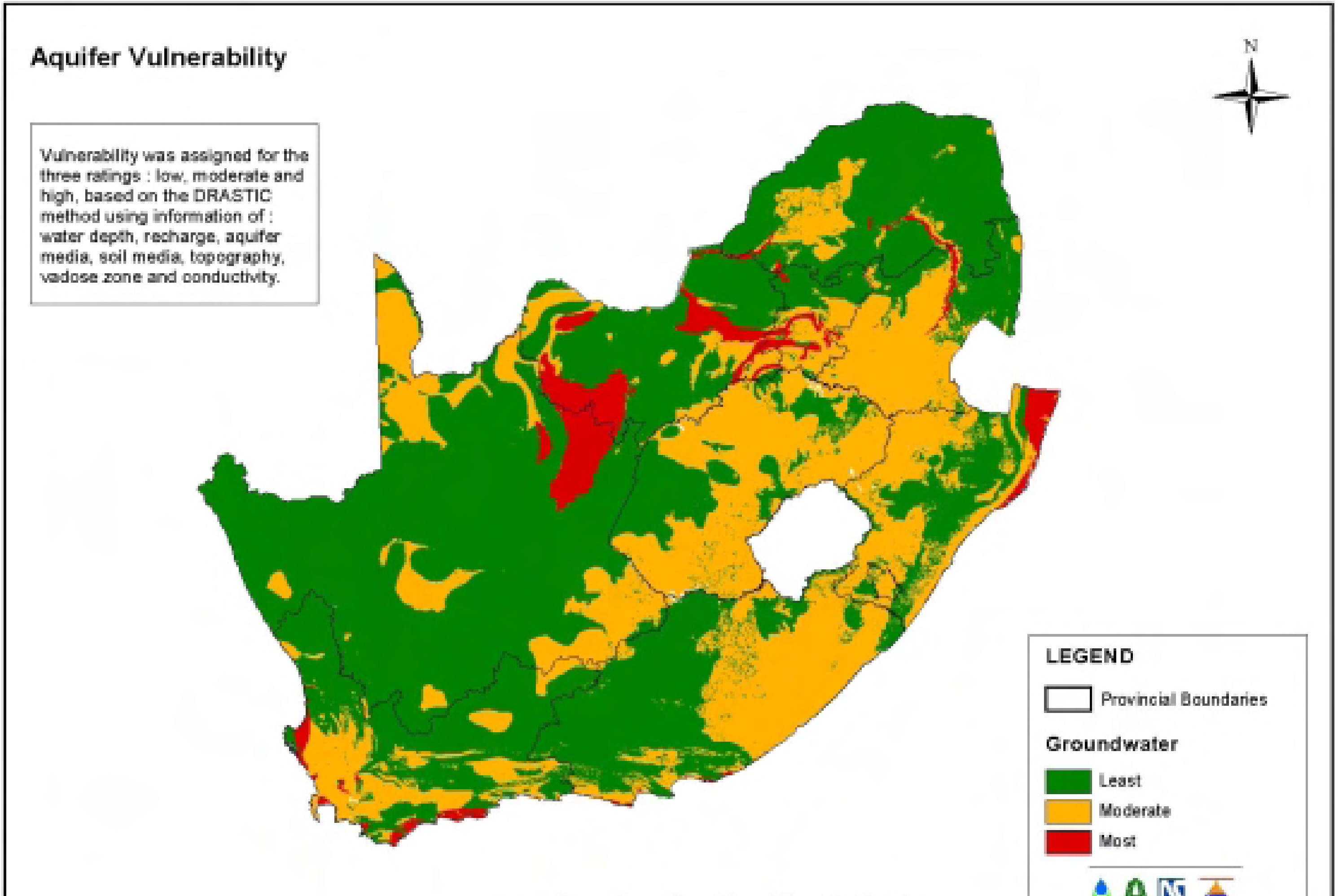

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
LEGEND
Provincial Boundaries
Groundwater
Least
Moderate
Most
100 0 100 200 300 400 Kilometers
(Parsons and Conrad, 1998)

FIGURE 3

TABLE 1: FACTORS USED BY DRASTIC

D	Depth to water
R	(net) Recharge
A	Aquifer media
S	Soil media
T	Topography (slope)
I	Impact of the vadose zone media
C	Conductivity (hydraulic) of the aquifer

Each factor was weighted according to its relative importance (Aller *et al.*, 1985). Using a set of tables, a rating is assigned based on prevailing conditions. A relative DRASTIC index (I) is derived using the following formula, with higher index values showing greater groundwater vulnerability:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \quad ..... \quad (7)$$

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,

$$\text{Index} = 5\,D_R + 5\,S_R + 4\,I_R \quad .... \quad (8)$$

It must be noted that (1) the value of the index is relative, (2) the factors used in the index were considered by the team to have the greatest influence in assessing the potential for microbial contamination at the surface entering underlying aquifers.

[1] A similar approach was used by Xu & Braune (1995) where they used the factors D, A and S, and used the weightings assigned by DRASTIC and not Pesticide DRASTIC.

3.3 Aquifer vulnerability map

Three DRASTIC groundwater coverages were used to produce an indication of vulnerability of groundwater contamination, namely, depth to groundwater, soil media and vadose.

Each grid element on the DRASTIC coverages was allocated a rating, that was multiplied by a weighting factor (Depth = 5, Soil = 5, Vadose = 4) to produce a score. These three coverages were intersected and their scores added to produce a relative index for each point on the resulting coverage. An additional assumption was applied that assigned a low vulnerability to all areas with a Depth score of less than or equal to 2. This was used to account for deep infiltration of groundwater (over 35 metres) where long residence time and filtration will reduce the degree of contamination.

The relative index (RI) obtained for each grid allowed for grouping into high, medium and low categories. However, setting the intervals for the three categories proved difficult because of sensitivity to the interval chosen. A large percentage of indices fell in the interval of 60 to 80. It was thus decided to use the interval of 70 to 85 to allow for equal distribution between high, medium and low vulnerability areas (see Figure 4), namely:

Low	Green	$RI < 70$	
Medium	Yellow	$70 < RI < 85$	
High	Red	$RI > 85$	.... (9)

To illustrate the sensitivity to the interval chosen the map was replotted using two further intervals of 60-90 and 65-90 (see Figure 5).

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider D, S and I. Comparison of Figures 3 and 4 shows remarkable similarity and confirms that the vulnerability *per se* is largely controlled by the three factors (D, S and I), which promotes confidence in the resultant microbial contamination vulnerability map.

A limitation of the study is the inability to validate results obtained. Little information is available regarding groundwater microbial contamination. Monitoring data, from selected areas, should be collected to assess the validity of the vulnerability assessment presented in this report.

3.4 Groundwater faecal contamination

Figure 2 (*Potential Surface Faecal Contamination)* and Figure 4 (*Aquifer vulnerability to Faecal Contamination)* maps were intersected to produce a combined *Risk of Faecal Contamination of Aquifers* map on a quaternary basis, see Figure 6.

A total rating score was calculated for each quaternary (e.g. two medium risk areas and one high risk area gives 2 + 2 + 3). This total was then divided by the total number of different risk areas present in each quaternary to produce an average risk value. Each quaternary catchment was shaded according to this average risk value.

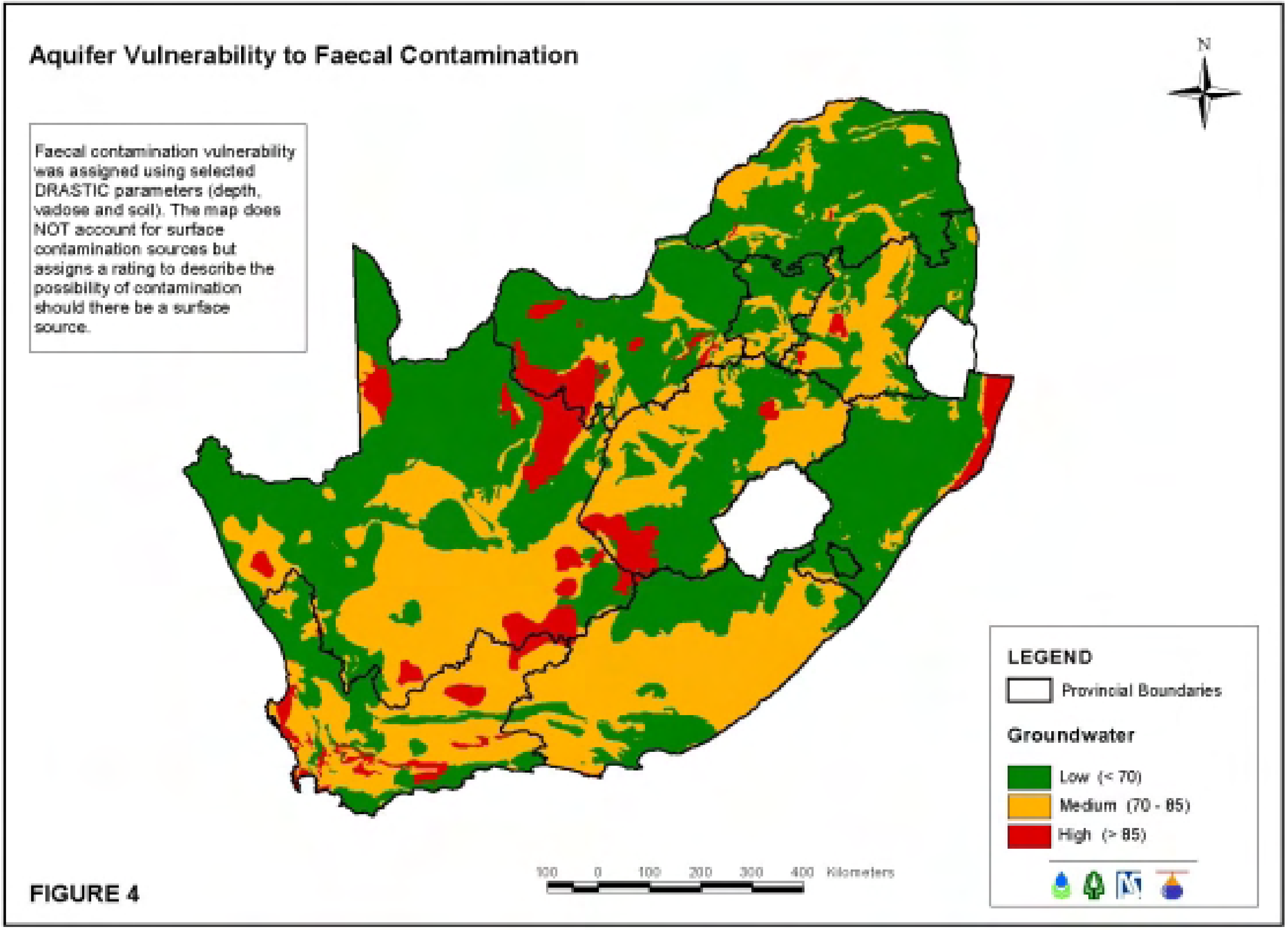

Aquifer Vulnerability to Faecal Contamination
N
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers

FIGURE 4

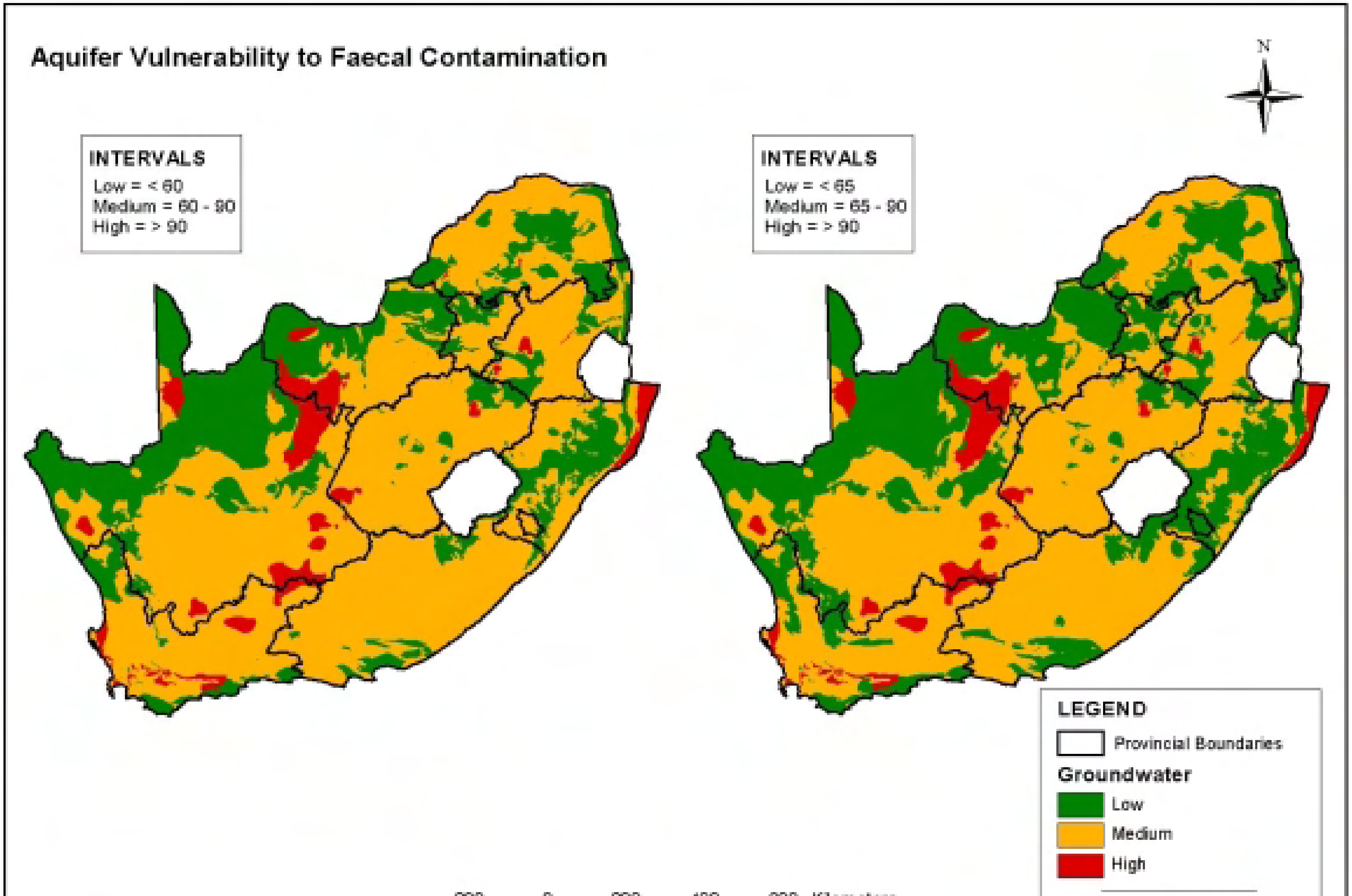

Aquifer Vulnerability to Faecal Contamination
N
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers

FIGURE 5

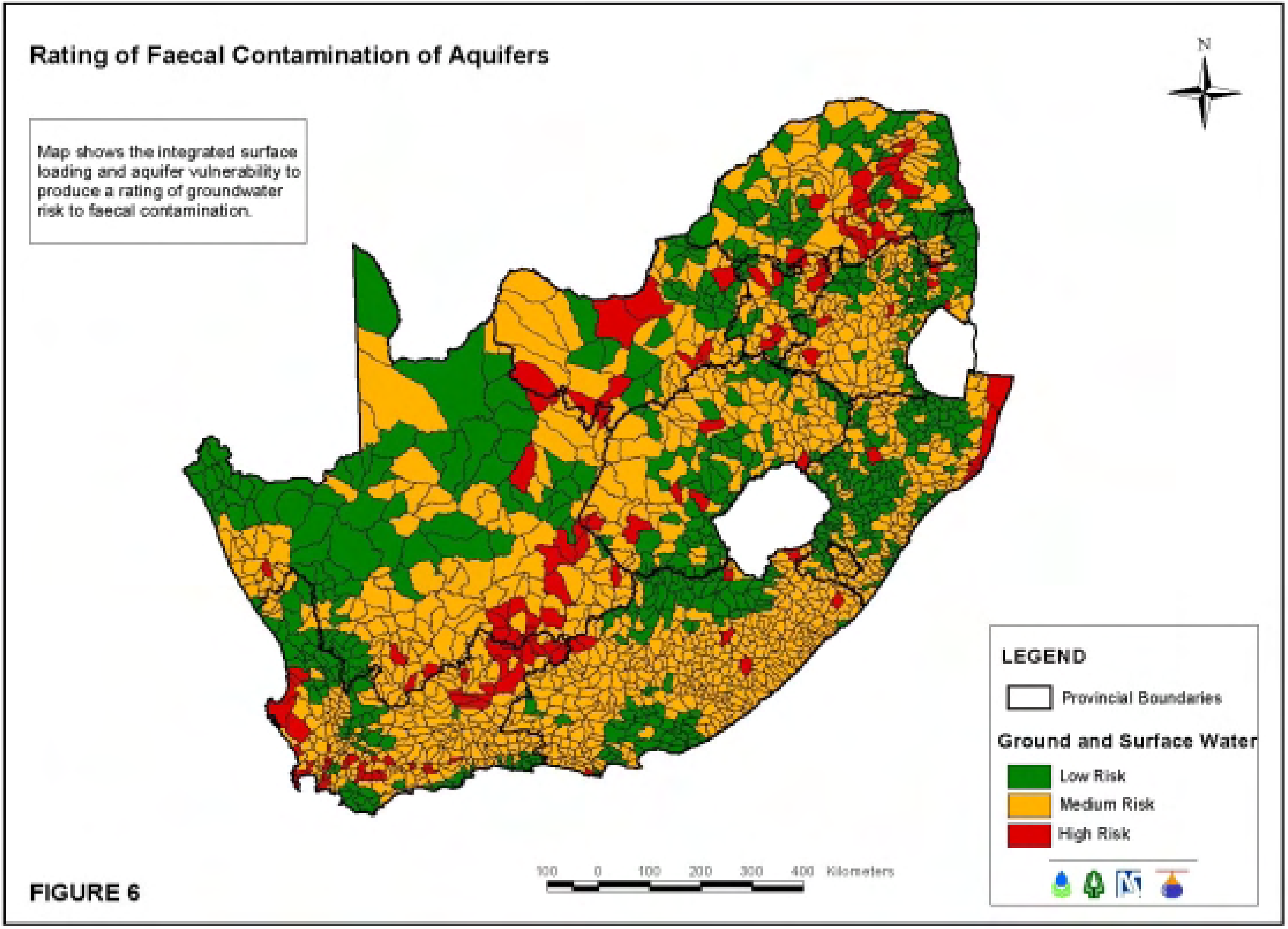

Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk
100 0 100 200 300 400 Kilometers

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

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BERG WATER MANAGEMENT AREA

APPENDIX G.3

SEDIMENTATION DATA PER QUATERNARY CATCHMENT

Quarternary Catchment	Area	Yield	25 year sediment Volume
	km^2	tonnes/a	tonnes
G10A	172	1,000	27,400
G10B	126	1,000	27,400
G10C	328	6,000	164,400
G10D	688	20,000	548,000
G10E	394	10,000	274,000
G10F	539	17,000	465,800
G10G	186	1,000	27,400
G10H	675	23,000	630,200
G10J	868	29,000	794,600
G10K	1176	35,000	959,000
G10L	1755	45,000	1,233,000
G10M	2005	25,000	685,000
G21A	523	8,000	219,200
G21B	304	4,000	109,600
G21C	244	7,000	191,800
G21D	484	11,000	301,400
G21E	531	18,000	493,200
G21F	242	6,000	164,400
G22A	238	2,000	54,800
G22B	109	1,000	27,400
G22C	254	4,000	109,600
G22D	246	2,000	54,800
G22E	271	4,000	109,600
G22F	66	1,000	27,400
G22G	106	3,000	82,200
G22H	227	7,000	191,800
G22J	128	3,000	82,200
G22K	80	2,000	54,800
G40A	72	1,000	27,400
TOTALS	**13037**		**8,137,800**

APPENDIX G.4

GROUNDWATER 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 <u>Harvest Potential</u>

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 ℓ/s	0.7
1.5 - 3.0 ℓ/s	0.6
0.7 - 1.5 ℓ/s	0.5
0.3 - 0.7 ℓ/s	0.4
<0.3 ℓ/s	0.3

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

3.3 **Ground Water, Surface Water Interaction**

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

- ***Baseflow***

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

- ***Baseflow factor***

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

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

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

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

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

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

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

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

3.4 Existing Ground Water Use

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

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

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

- Municipal Use

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

- Rural Use

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

- Livestock use

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

- Irrigation Use

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

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

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

3.5 Ground Water Balance

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

The following scenarios were mapped, viz :-

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

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

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

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

3.6 Water Quality

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

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

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

Forestry (1996) for these two uses were combined into a single classification system as shown in Table 3.6.1

TABLE 3.6.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

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 GROUNDWATER 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 i.e., 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.

GROUNDWATER USE PER QUATERNARY CATCHMENT

QUARTER-NARY	AREA (km^2)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL ($x10^6$ m^3/a)	AVERAGE YIELD BOREHOLES (ℓ/s, 8hrs/day)	fGECi EXPLOITA-TION FACTOR	EXPLOITA-TION POTENTIAL (mm)	oGEPo EXPLOITA-TION POTENTIAL ($x10^6$ m^3/a)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (ℓ/s)	SUM OF BOREHOLE YIELDS ($x10^6$ m^3/a)	MUNICIPAL USE ($x10^6$ m^3/a)	RURAL USE ($x10^6$ m^3/a)	LIVESTOCK USE ($x10^6$ m^3/a)	IRRIGATION USE ($x10^6$ m^3/a)	TOTAL USE FACTOR	oGWSo TOTAL USE ($x10^6$ m^3/a)	TOTAL USE (mm/a)
G10A	172	170.6	29.35	3.42	0.7	119.4	20.54	28	95.76	1.01	0.0000	0.0000	0.0000	0.1735	1.0000	0.1735	1.0
G10B	126	188.9	23.81	2.78	0.6	113.4	14.28	2	5.55	0.06	0.0000	0.0000	0.0000	0.0197	1.0000	0.0197	0.2
G10C	328	52.7	17.28	1.66	0.6	31.6	10.37	109	181.37	1.91	0.0000	0.0000	0.0000	0.8675	1.0000	0.8675	2.6
G10D	688	46.0	31.65	1.25	0.5	23.0	15.82	134	167.57	1.76	0.0000	0.0000	0.0152	1.3384	1.0000	1.3536	2.0
G10E	394	65.3	25.72	3.61	0.7	45.7	18.01	20	72.17	0.76	0.0000	0.0000	0.0572	10.1310	0.6000	6.1129	15.5
G10F	539	24.9	13.42	1.95	0.6	14.9	8.05	69	134.66	1.42	0.0050	0.0000	0.0331	5.5853	0.6500	3.6552	6.8
G10G	186	59.3	11.03	4.81	0.7	41.5	7.72	3	14.44	0.15	0.0000	0.0000	0.0345	0.0000	1.0000	0.0345	0.2
G10H	675	26.4	17.83	3.01	0.7	18.5	12.48	11	33.13	0.35	0.2000	0.0000	0.0084	0.3229	1.0000	0.5313	0.8
G10J	868	25.8	22.38	1.09	0.5	12.9	11.19	69	75.32	0.79	0.0000	0.0000	0.0167	12.0809	0.6000	7.2586	8.4
G10K	1176	28.5	33.52	1.16	0.5	14.3	16.76	39	45.38	0.48	0.0000	0.0000	0.0981	2.2162	0.5000	1.1572	1.0
G10L	1755	21.1	37.06	1.43	0.5	10.6	18.53	452	646.22	6.79	0.1733	0.0000	0.1128	1.3542	0.5000	0.8202	0.5
G10M	2005	30.1	60.29	1.38	0.5	15.0	30.15	117	161.46	1.70	0.0600	0.0000	0.4113	0.8700	1.0000	1.3413	0.7
G21A	523	36.9	19.30	1.28	0.5	18.5	9.65	133	170.07	1.79	0.0000	0.0000	0.1946	0.0000	1.0000	0.1946	0.4
G21B	304	46.8	14.22	4.97	0.7	32.7	9.95	44	218.81	2.30	7.1600	0.0000	0.1010	0.0000	1.0000	7.2610	23.9
G21C	244	27.4	6.69	0.65	0.4	11.0	2.68	46	29.97	0.32	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
G21D	484	24.8	11.98	3.28	0.7	17.3	8.39	160	524.34	5.51	0.0000	0.0000	0.0588	0.0000	1.0000	0.0588	0.1
G21E	531	23.0	12.20	2.74	0.6	13.8	7.32	123	336.48	3.54	0.0200	0.0000	0.0229	11.5497	0.4500	7.2167	9.8
G21F	242	28.1	6.80	2.43	0.6	16.9	4.08	23	55.89	0.59	0.0000	0.0000	0.0174	2.0613	0.5000	1.0394	4.3
G22A	238	77.5	18.44	0.98	0.5	38.7	9.22	12	11.77	0.12	0.0000	0.0000	0.0099	0.0000	1.0000	0.0099	0.0
G22B	109	79.1	8.62	1.03	0.5	39.5	4.31	8	8.20	0.09	1.0000	0.0000	0.0242	0.0000	0.5000	0.5121	4.7
G22C	254	67.1	17.05	1.99	0.6	40.3	10.23	35	69.76	0.73	0.0000	0.0000	0.0669	2.4155	0.2000	0.4965	2.0
G22D	246	100.3	24.67	6.96	0.7	70.2	17.27	29	201.87	2.12	5.0000	0.0000	0.0494	1.1064	0.4500	2.7701	11.3
G22E	271	46.1	12.50	1.68	0.6	27.7	7.50	101	170.00	1.79	0.0000	0.0000	0.0157	19.1676	0.2000	8.8367	14.2
G22F	66	124.2	8.20	5.17	0.7	86.9	5.74	9	46.51	0.49	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
G22G	106	31.7	3.36	1.59	0.6	19.0	2.01	72	114.37	1.20	0.0000	0.0000	0.0000	0.3258	1.0000	0.3258	3.1
G22H	227	49.4	11.22	0.97	0.5	24.7	5.61	61	59.17	0.62	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
G22J	128	54.6	7.00	0.90	0.5	27.3	3.50	8	7.18	0.08	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
G22K	80	39.2	3.14	1.25	0.5	19.6	1.57	6	7.48	0.08	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
G30A	258	37.6	9.69	1.35	0.5	18.8	4.85	41	55.33	0.58	0.0000	0.0000	0.1440	1.7973	2.6500	5.1444	20.0
G40A	72	117.2	8.44	2.00	0.6	70.3	5.06	0	0.00	0.00	0.0000	0.0000	0.0000	0.0000	4.0000	0.0000	0.0
TOTALS	**13295**		**526.83**	**68.77**				**1964**	**3720.22**	**39.11**	**13.6183**	**0.0000**	**1.4921**	**73.3832**		**57.1913**	

GROUNDWATER CONTRIBUTION TO BASEFLOW PER QUATERNARY CATCHMENT

QUATERNARY	vMARi MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	oGBFi BASE FLOW SCHULTZ	BASE FLOW FACTOR	fGBDo CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUND WATER UTILISATION	IMPACT OFGROUND WATER ABSRTACTION ON SURFACE WATER	fGPQi PORTION POTABLE	$_oGWM_o$ MAX UTILISABLE GROUND WATER
	($x10^6$ m^3/a)	(mm/a)	(mm/a)	(mm/a)	($x10^6$ m^3/a)						($x10^6$ m^3/a)
G10A	183.65	62.14	142.40	373.11	10.69	0.36	0.36	UNDER-UTILISED	MODERATE	1.00	20.54
G10B	93.09	40.78	101.50	259.26	5.14	0.22	0.22	UNDER-UTILISED	LOW	0.85	12.14
G10C	147.61	15.26	58.60	141.62	5.00	0.29	0.29	UNDER-UTILISED	LOW	0.93	9.63
G10D	115.42	5.84	22.70	53.88	4.02	0.13	0.13	UNDER-UTILISED	LOW	0.54	8.56
G10E	67.74	5.78	23.90	55.43	2.28	0.09	0.09	UNDER-UTILISED	LOW	0.85	15.31
G10F	60.73	4.12	15.20	36.18	2.22	0.17	0.17	MODERATELY-UTILISED	LOW	0.50	4.03
G10G	124.27	16.44	84.90	207.40	3.06	0.28	0.28	UNDER-UTILISED	LOW	0.85	6.56
G10H	21.20	0.75	0.00	9.36	0.51	0.03	0.03	UNDER-UTILISED	LOW	0.50	6.24
G10J	34.92	0.93	0.00	12.11	0.81	0.04	0.04	HEAVILY-UTILISED	LOW	0.27	3.01
G10K	25.17	0.00	0.00	2.14	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.25	4.19
G10L	50.58	0.00	0.00	2.83	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.39	7.20
G10M	17.45	0.00	0.00	0.56	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.38	11.35
G21A	16.65	0.00	0.00	2.28	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.75	7.26
G21B	9.64	0.00	0.00	2.09	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.77	7.66
G21C	15.17	1.60	8.60	18.85	0.39	0.06	0.06	UNDER-UTILISED	LOW	0.78	2.08
G21D	23.43	1.37	7.00	14.84	0.66	0.06	0.06	UNDER-UTILISED	LOW	0.66	5.53
G21E	36.23	1.92	8.90	20.89	1.02	0.08	0.08	HEAVILY-UTILISED	LOW	0.58	4.25
G21F	13.11	1.61	7.30	16.84	0.39	0.06	0.06	UNDER-UTILISED	LOW	0.22	0.91
G22A	31.60	3.55	15.90	41.00	0.84	0.05	0.05	UNDER-UTILISED	LOW	1.00	9.22
G22B	32.55	6.63	33.40	87.90	0.72	0.08	0.08	UNDER-UTILISED	LOW	0.70	3.02
G22C	23.29	2.94	12.00	28.73	0.75	0.04	0.04	UNDER-UTILISED	LOW	0.85	8.65
G22D	40.89	4.04	19.30	50.13	0.99	0.04	0.04	UNDER-UTILISED	LOW	0.94	16.29
G22E	20.72	2.43	10.60	24.20	0.66	0.05	0.05	OVER-UTILISED	LOW	0.72	5.42
G22F	59.09	72.25	127.70	339.92	4.77	0.58	0.58	UNDER-UTILISED	MODERATE	0.85	4.88
G22G	16.41	4.51	20.50	47.49	0.48	0.14	0.14	UNDER-UTILISED	LOW	0.50	1.01
G22H	24.94	3.69	15.00	35.04	0.84	0.07	0.07	UNDER-UTILISED	LOW	0.80	4.49
G22J	60.29	36.32	66.70	173.16	4.65	0.66	0.66	UNDER-UTILISED	MODERATE	0.67	2.33
G22K	24.00	23.22	43.20	113.64	1.86	0.59	0.59	UNDER-UTILISED	MODERATE	0.55	0.86
G30A	4.76	0.00	0.00	0.07	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.28	1.33
G40A	39.45	44.22	79.70	213.83	3.18	0.38	0.38	UNDER-UTILISED	MODERATE	0.95	4.81
TOTAL	**1434.0500**				**55.92**						**198.74**

APPENDIX G.5 : WATER QUALITY INFORMATION

Quatenary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
G10A	G1H003Q01	95	212	Blue	Blue	Blue
G10B	G1H020Q01	62	89	Blue	Blue	Blue
G10C	G1H020Q01	62	89	Blue	Blue	Blue
G10D	G1H036Q01	148	233	Blue	Blue	Blue
G10E	G1H008Q01	139	321	Blue	Green	Green
G10F	G1H013Q01	164	264	Blue	Green	Green
G10G	G1H028Q01	29	64	Blue	Blue	Blue
G10H	G1H035Q01	1736	4214	Yellow	Purple	Purple
G10J	G1R003Q01	209	354	Blue	Green	Green
G10K	G1H031Q01	224	299	Blue	Green	Green
G10L	G1H023Q01	853	4495	Yellow	Purple	Purple
G10M	G1H023Q01	853	4495	Yellow	Purple	Purple
G21A	NO					
G21B	NO					
G21C	NO					
G21D	NO					
G21E	NO					
G21F	G202 DRL	1376	2749	Yellow	Red	Red
G22A	NO					
G22B	NO					
G22C	NO					
G22D	NO					
G22E	NO					
G22F	G2H005Q01	48	89	Blue	Blue	Blue
G22G	G2H020Q01	152	218	Blue	Blue	Blue
G22H	G2H015Q01	307	489	Green	Green	Green
G22J	G2H038Q01	302	3867	Green	Purple	Red
G22K	G2H039Q01	159	240	Blue	Blue	Blue

H40G	H4H018Q01	3809	5199	Purple	Purple	Purple
H40H	H4H024Q01	173	312	Blue	Green	Green
H40J	H4H019Q01	1538	2475	Yellow	Red	Red
H40K	H4H015Q01	40	72	Blue	Blue	Blue
H40L	H5H006Q01	296	539	Green	Green	Green
H50A	H5H004Q01	614	1697	Yellow	Yellow	Yellow
H50B	H5H005Q01	643	1100	Yellow	Yellow	Yellow
H60A	H6H012Q01	72	147	Blue	Blue	Blue
H60B	H6H012Q01	72	147	Blue	Blue	Blue
H60C	H6H012Q01	72	147	Blue	Blue	Blue
H60D	H6H012Q01	72	147	Blue	Blue	Blue
H60E	H6H005Q01	47	70	Blue	Blue	Blue
H60F	H6H009Q01	158	430	Blue	Green	Green
H60G	H6H009Q01	158	430	Blue	Green	Green
H60H	H6H009Q01	158	430	Blue	Green	Green
H60J	H6H009Q01	158	430	Blue	Green	Green
H60K	H6H009Q01	158	430	Blue	Green	Green
H60L	H6H009Q01	158	430	Blue	Green	Green
H70A	H7H006Q01	354	855	Green	Yellow	Yellow
H70B	H7H005Q01	36	56	Blue	Blue	Blue
H70C	H7H004Q01	399	701	Green	Yellow	Yellow
H70D	NO					
H70E	NO					
H70F	NO					
H70G	NO					
H70H	NO					
H70J	NO					
H70K	NO					
H80A	NO					
H80B	NO					
H80C	NO					
H80D	NO					
H80E	NO					
H80F	NO					
H90A	H9H004Q01	57	87	Blue	Blue	Blue
H90B	H9R001Q01	68	106	Blue	Blue	Blue
H90C	NO					
H90D	NO					
H90E	NO					

Quatenary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
G10A	G1H003Q01	95	212	Blue	Blue	Blue
G10B	G1H020Q01	62	89	Blue	Blue	Blue
G10C	G1H020Q01	62	89	Blue	Blue	Blue
G10D	G1H036Q01	148	233	Blue	Blue	Blue
G10E	G1H008Q01	139	321	Blue	Green	Green
G10F	G1H013Q01	164	264	Blue	Green	Green
G10G	G1H028Q01	29	64	Blue	Blue	Blue
G10H	G1H035Q01	1736	4214	Yellow	Purple	Purple
G10J	G1R003Q01	209	354	Blue	Green	Green
G10K	G1H031Q01	224	299	Blue	Green	Green
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G10M	G1H023Q01	853	4495	Yellow	Purple	Purple
G21A	NO					
G21B	NO					
G21C	NO					
G21D	NO					
G21E	NO					
G21F	G202 DRL	1376	2749	Yellow	Red	Red
G22A	NO					
G22B	NO					
G22C	NO					
G22D	NO					
G22E	NO					
G22F	G2H005Q01	48	89	Blue	Blue	Blue
G22G	G2H020Q01	152	218	Blue	Blue	Blue
G22H	G2H015Q01	307	489	Green	Green	Green
G22J	G2H038Q01	302	3867	Green	Purple	Red
G22K	G2H039Q01	159	240	Blue	Blue	Blue

APPENDIX H

WATER RESOURCES

APPENDIX H.1

DATA SOURCES

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

APPENDIX H.2

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
FilPMi	Irrigation efficiency Medium category irrigation (factor)	0,75
FilPHi	Irrigation efficiency High category irrigation (factor)	0,75
ORTLi	Rural losses (factor)	0,2

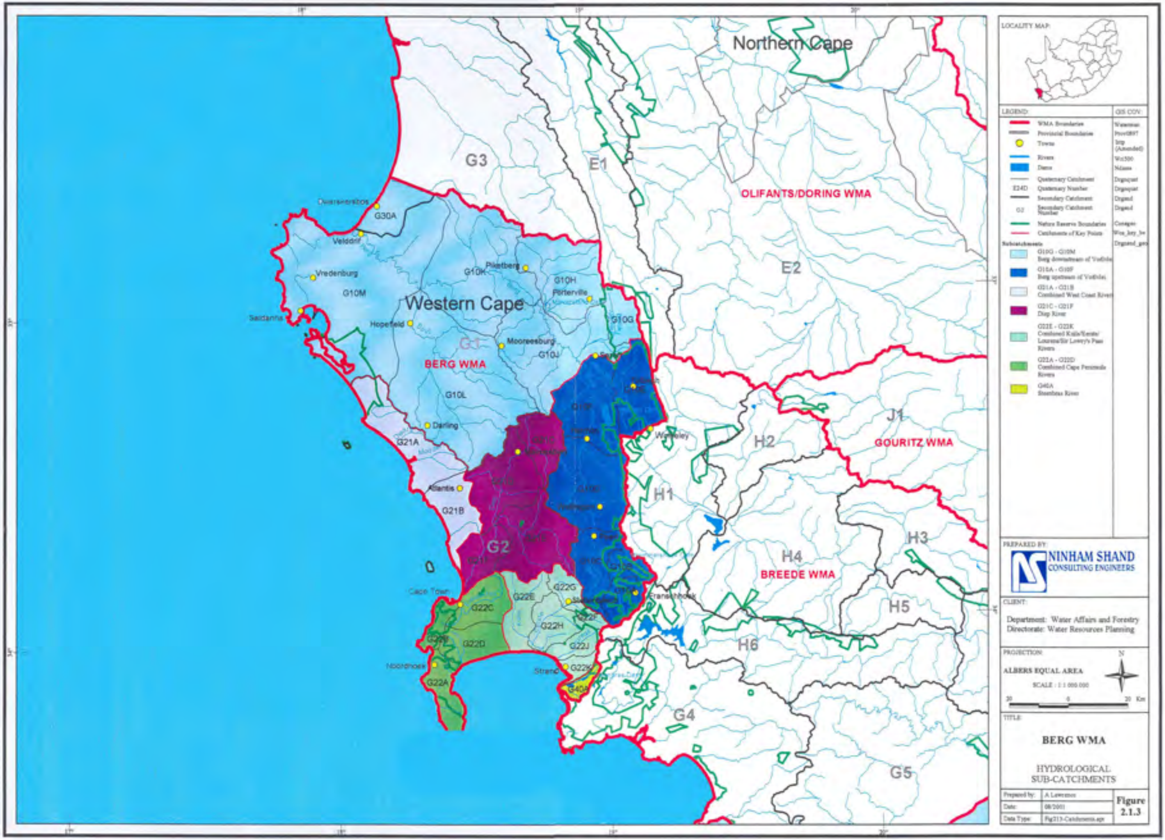
THE DATA AT QUATERNARY CATCHMENT RESOLUTION

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**

LIST OF FIGURES


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10F
G10E
G10D
G10C
G21A
G21B
G21C
G21D
G21E
G21F
G22C
G22D
G22E
G22G
G22H
G22J
G22K
G22A
G40A
Dwarskersbos
Velddrif
Piketberg
Vredenburg
Porterville
Saldanha
Hopefield
Moorreesburg
Saron
Tulbagh
Darling
Wolseley
Hermon
Malmesbury
Atlantis
Wellington
Paarl
Robben Island
Cape Town
Franschhoek
Stellenbosch
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
THE STUDY AREA
Prepared by:
A Lawrence
Date:
08/2001
Figure
2.1.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
Velddrif
Piketberg
Vredenburg
Porterville
Saldanha
Hopefield
Moorreesburg
Saron
Tulbagh
Darling
Hermon
Wolseley
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Endemic Areas
Local
Global
Elevation
0 - 400
401 - 800
801 - 1200
1201 - 1600
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
0
Km
TITLE:
BERG WMA
TOPOGRAPHY AND
RIVER CATCHMENTS
Prepared by:
A Lawrence
Date:
08/2001
Data Type:
Fig212-Topography.apr
Figure
2.1.2


Northern Cape
G3
E1
E2
OLIFANTS/DORING WMA
Western Cape
BERG WMA
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
GOURITZ WMA
BREEDE WMA
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Piketberg
G10K
G10H
Porterville
G10G
Hopefield
Moorreesburg
G10J
G10L
Darling
G21A
Atlantis
G21B
Wellington
Franschhoek
Cape Town
G22C
G22E
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G22H
G22J
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G22B
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Noordhoek
Strand
G40A
LOCALITY MAP:
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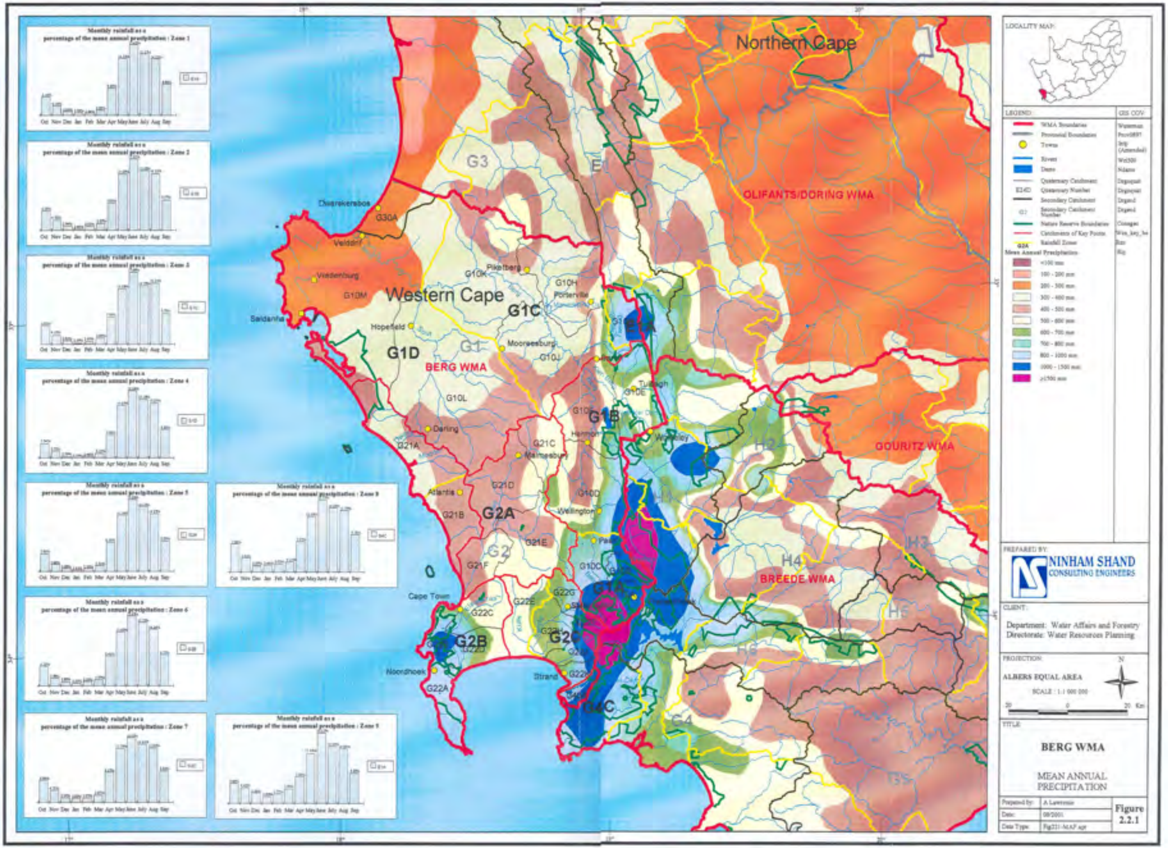
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Subcatchments
G10G - G10M Berg downstream of Voëlvlei
G10A - G10F Berg upstream of Voëlvlei
G21A - G21B Combined West Coast Rivers
G21C - G21F Diep River
G22E - G22K Combined Kuils/Eerste/Lourens/Sir Lowry's Pass Rivers
G22A - G22D Combined Cape Peninsula Rivers
G40A Steenbras River
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
HYDROLOGICAL SUB-CATCHMENTS
Prepared by: A Lawrence
Date: 08/2001
Figure 2.1.3


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G3
E1
E2
G1
G1C
G1D
G1B
G1A
E1A
G2
G2A
G2B
G2C
G4C
G4
H1
H2
H3
H4
H5
H6
G10K
G10M
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G10J
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G21B
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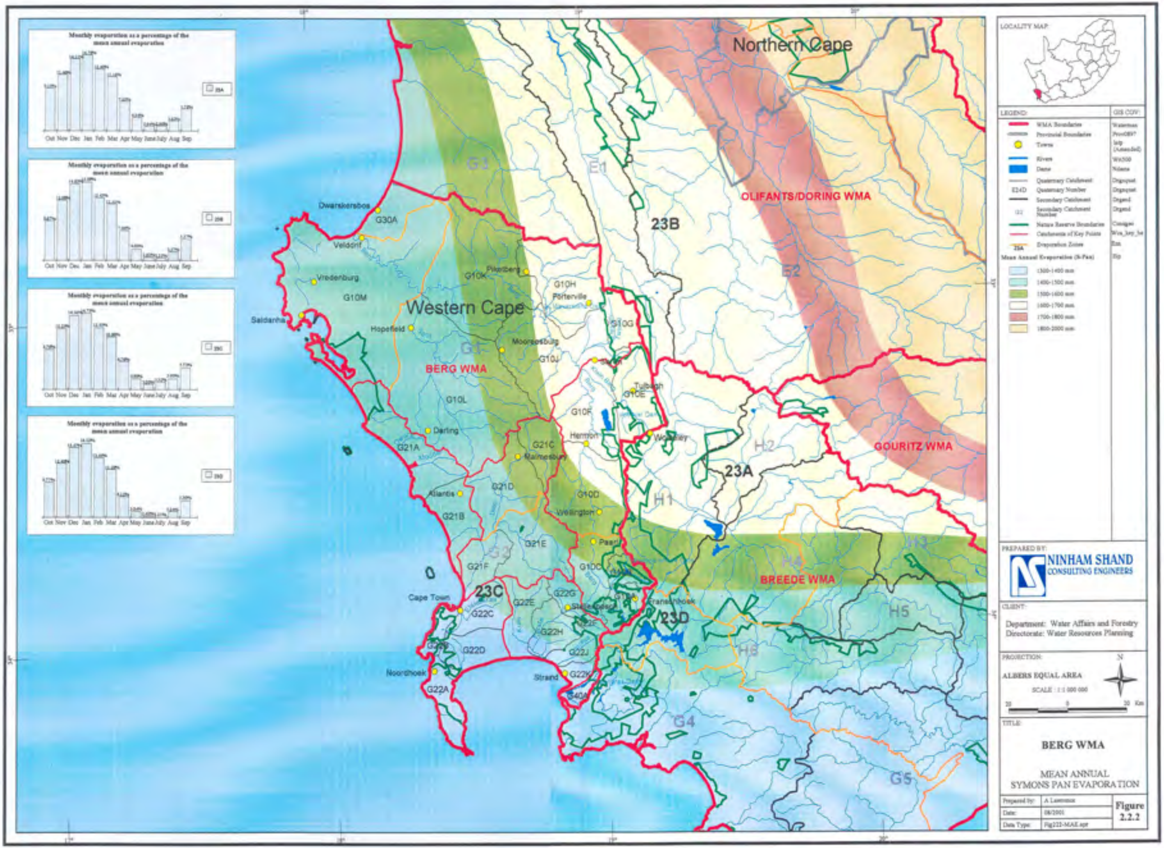
G21E
G21F
G22A
G22C
G22E
G22G
G30A
Doringbaai
Velddrif
Vredenburg
Saldanha
Piketberg
Porterville
Hopefield
Moorreesburg
Tulbagh
Wolseley
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Noordhoek
Strand
Monthly rainfall as a percentage of the mean annual precipitation : Zone 1
Monthly rainfall as a percentage of the mean annual precipitation : Zone 2
Monthly rainfall as a percentage of the mean annual precipitation : Zone 3
Monthly rainfall as a percentage of the mean annual precipitation : Zone 4
Monthly rainfall as a percentage of the mean annual precipitation : Zone 5
Monthly rainfall as a percentage of the mean annual precipitation : Zone 6
Monthly rainfall as a percentage of the mean annual precipitation : Zone 7
Monthly rainfall as a percentage of the mean annual precipitation : Zone 8
Monthly rainfall as a percentage of the mean annual precipitation : Zone 9
Oct Nov Dec Jan Feb Mar Apr May June July Aug Sep
LOCALITY MAP:
LEGEND:
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Rainfall Zones
Mean Annual Precipitation
<100 mm
100 - 200 mm
200 - 300 mm
300 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
800 - 1000 mm
1000 - 1500 mm
>1500 mm
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
20 0 20 Km
TITLE:
BERG WMA
MEAN ANNUAL PRECIPITATION
Prepared by: A Lawrence
Date: 08/2001
Figure 2.2.1


Monthly evaporation as a percentage of the mean annual evaporation
Oct Nov Dec Jan Feb Mar Apr May June July Aug Sep
Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
23A
23B
23C
23D
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
G30A
G10K
G10H
G10M
G10G
G10J
G10E
G10F
G10L
G21A
G21C
G21D
G21B
G10D
G21E
G21F
G10C
G22C
G22E
G22G
G22H
G22F
G22D
G22J
G22K
G22A
G40A
LOCALITY MAP
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Evaporation Zones
Mean Annual Evaporation (S-Pan)
1300-1400 mm
1400-1500 mm
1500-1600 mm
1600-1700 mm
1700-1800 mm
1800-2000 mm
GIS COV:
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
MEAN ANNUAL
SYMONS PAN EVAPORATION
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig222-MAE.apr
Figure 2.2.2

Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G1
G2
G3
G4
G5
E1
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
Saldanha
Piketberg
Porterville
Moorreesburg
Darling
Malmesbury
Hermon
Tulbagh
Wolseley
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
G10K
G10H
G10G
G10J
G10E
G10F
G10L
G21C
G21D
G10D
G21E
G21F
G10C
G22G
G22E
G22C
G22H
G22J
G22K
G22A
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Geology
Acid, intermediate or alkaline intrusives (Granite Outcrops)
Compact sedimentary strata (Malmesbury Shales)
Compact, dominantly arenaceous strata (Table Mountain Sandstone)
Porous unconsolidated to semi-consolidated sediment
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
GEOLOGY
Prepared by: A Lawrance
Date: 08/2001
Data Type: Fig231-Geology.apr
Figure 2.3.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
E1
E2
H1
H2
H3
H4
H5
H6
J1
G4
G5
Dwarskersbos
Saldanha
Piketberg
Porterville
Moorreesburg
Darling
Malmesbury
Hermon
Tulbagh
Wolseley
Wellington
Paarl
Cape Town
Noordhoek
Strand
G10K
G10H
G10G
G10J
G10L
G10F
G10E
G21C
G21D
G10D
G21E
G10C
G22G
G22E
G22H
G22J
G22K
LOCALITY MAP:
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G1 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Soils
Depth
Texture
Relief
Moderate to Deep
Clay Loam
Undulating
Moderate to Deep
Sandy Loam
Steep
Moderate to Deep
Sandy Soil
Flat
GIS COV:
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
20
0
20 Km
TITLE:
BERG WMA
SOILS
Prepared by: A Lawrance
Date: 08/2001
Data Type: Fig241-Soils.apr
Figure 2.4.1

Northern Cape
Western Cape
BERG WMA
OLIFANTS/DORING WMA
GOURITZ WMA
BREEDE WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
Piketberg
G10K
G10H
Porterville
Moorreesburg
G10J
G10L
G10F
G10E
Tulbagh
Darling
Hermon
G21A
G21C
Malmesbury
Wolseley
G21D
Atlantis
G10D
G21B
Wellington
G21E
G21F
Cape Town
G22C
G22E
G22H
G22D
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Natural Vegetation
Karoo and Karroid
Sclerophyllous Bush
Temperate and Transitional
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
NATURAL VEGETATION
Prepared by: A Lawrence
Date: 08/2001
Figure 2.5.2.1

Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10E
G10F
G21C
G21A
G21D
G10D
G21B
G21E
G21F
G10C
G22C
G22E
G22G
G22H
G22D
G22J
G22K
Dwarskersbos
Velddrif
Vredenburg
Piketberg
Porterville
Saldanha
Hopefield
Moorreesburg
Tulbagh
Darling
Hermon
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Default Ecological Management Classes
Class A : Unmodified, Natural
Class B : Largely Natural
Class C : Moderately modified
Class D : Largely Modified
Not Assessed
Note:
The ecological management class that is shown only applies to the river reach at the outlet of the quaternary catchment.
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Prepared by: A Lawrence
Figure 2.6.3.1

BERG WMA

PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES

Figure 2.6.3.2

Northern Cape
OLIFANTS/DORING WMA
Western Cape
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
Piketberg
G10K
G10H
Porterville
G10G
Moorreesburg
G10J
Tulbagh
G10E
G10L
G10F
Darling
G21A
Hermon
G21C
Malmesbury
Wolseley
Atlantis
G21D
G10D
Wellington
G21B
G21E
Paarl
G21F
G10C
Cape Town
G22G
G22E
G22C
Stellenbosch
G22H
G22D
G22J
Noordhoek
Strand
G22A
G40A
LOCALITY MAP:
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Suggested Future Ecological Management Class
Class B : Largely Natural
Class C : Moderately Modified
Class D : Largely Modified
Not Assessed
Note:
The ecological management class that is shown only applies to the river reach at the outlet of the quaternary catchment.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASS
Prepared by: A Lawrence
Date: 08/2001
Figure 2.6.3.3


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G3
E1
E2
G1
G2
H1
H2
H3
H4
H5
H6
J1
G4
G5
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Saron
Tulbagh
Wolseley
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Franschhoek
Stellenbosch
Noordhoek
Strand
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10F
G10E
G10D
G10C
G21A
G21C
G21D
G21B
G21E
G21F
G22G
G22E
G22C
G22F
G22H
G22D
G22J
G22K
G22A
G40A
LOCALITY MAP
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Population
Rural
Urban
Population Quantity
100 000
500 000
1 000 000
2 700 000
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
POPULATION DISTRIBUTION
Prepared by:
A Lawrence
Date:
08/2001
Data Type:
Figure 3.2.4.1

LOCALITY MAP:

LEGEND:

Legend	GIS COV:
WMA Boundaries	Watermas
Provincial Boundaries	Prov0897
Towns	Info (Amended)
Rivers	Wr500
Dams	Ndams
Quaternary Catchment	Orgnquat
E24D Quaternary Number	Orgnquat
Secondary Catchment	Orgsecd
Secondary Catchment Number	Orgsecd
Nature Reserve Boundaries	Consspec
Magisterial District Boundaries	Mag96
Catchments of Key Points	Wm_key_bs
District Councils	SADC
Breede River	
Cape Metro	
Overberg	
West Coast	
Winelands	

PREPARED BY:

NINHAM SHAND CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE : 1:1 000 000

20 0 20 Km

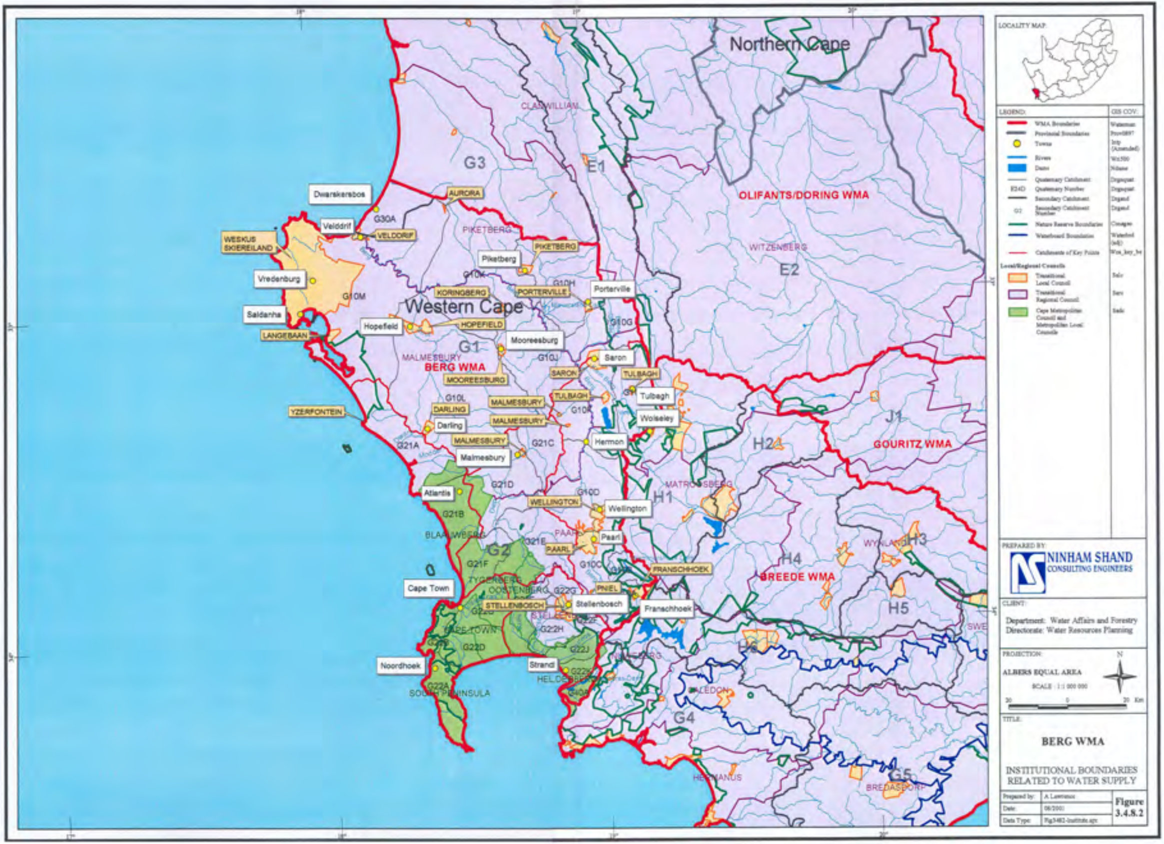
N

TITLE:

BERG WMA

DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS

Prepared by:	A Lawrence	**Figure 3.4.8.1**
Date:	08/2001	
Data Type:	Fig3481-Districts.apr	



Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
Velddrif
VELDDRIF
AURORA
WESKUS SKIEREILAND
Vredenburg
Saldanha
LANGEBAAN
Piketberg
PIKETBERG
KORINGBERG
PORTERVILLE
Porterville
Hopefield
HOPEFIELD
Moorreesburg
MOORREESBURG
Saron
SARON
TULBAGH
Tulbagh
Wolseley
YZERFONTEIN
DARLING
Darling
MALMESBURY
Malmesbury
Hermon
Atlantis
WELLINGTON
Wellington
Paarl
PAARL
FRANSCHHOEK
Franschhoek
PNIEL
STELLENBOSCH
Stellenbosch
Cape Town
Noordhoek
Strand
CLANWILLIAM
WITZENBERG
MATROOSBERG
SOUTH PENINSULA
HERMANUS
BREDASDORP
LOCALITY MAP
LEGEND
GIS COV.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Prepared by: A Lawrence
Date: 08/2001
Figure 3.4.8.2

LOCALITY MAP:

LEGEND: / GIS COV:

- WMA Boundaries — Watermas
- Provincial Boundaries — Prov0897
- Towns — Stp (Amended)
- Rivers — Wrc500
- Dams — Ndams
- Quaternary Catchment — Dgnquat
- E24D Quaternary Number — Dgnquat
- Secondary Catchment — Dgsecd
- G2 Secondary Catchment Number — Dgsecd
- Nature Reserve Boundaries — Consgen
- Catchments of Key Points — Wrs_key_bo
- Industries
- Powerstation

Land Use — WSAM

Dryland Sugarcane, Afforestation, Irrigation

Total Land Use (km²)

80

200

380

PREPARED BY:

NINHAM SHAND CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE : 1:1 000 000

20 0 20 Km

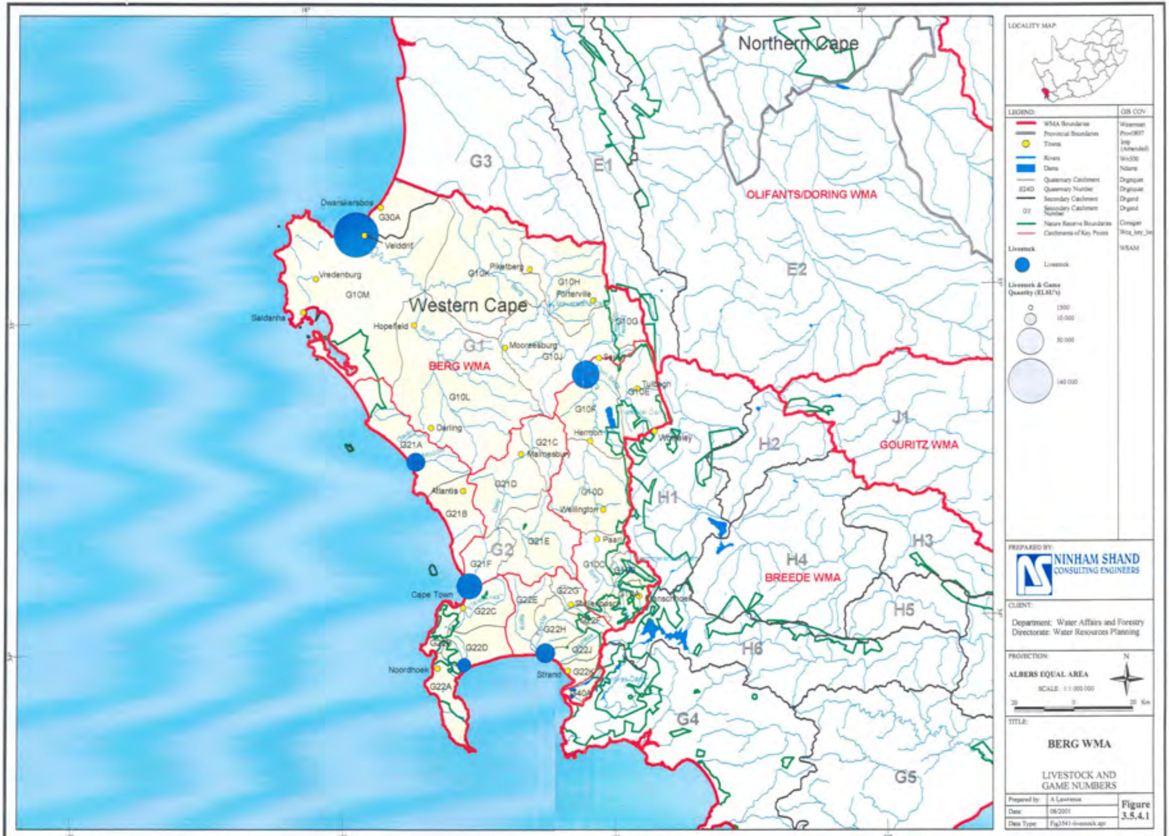
N

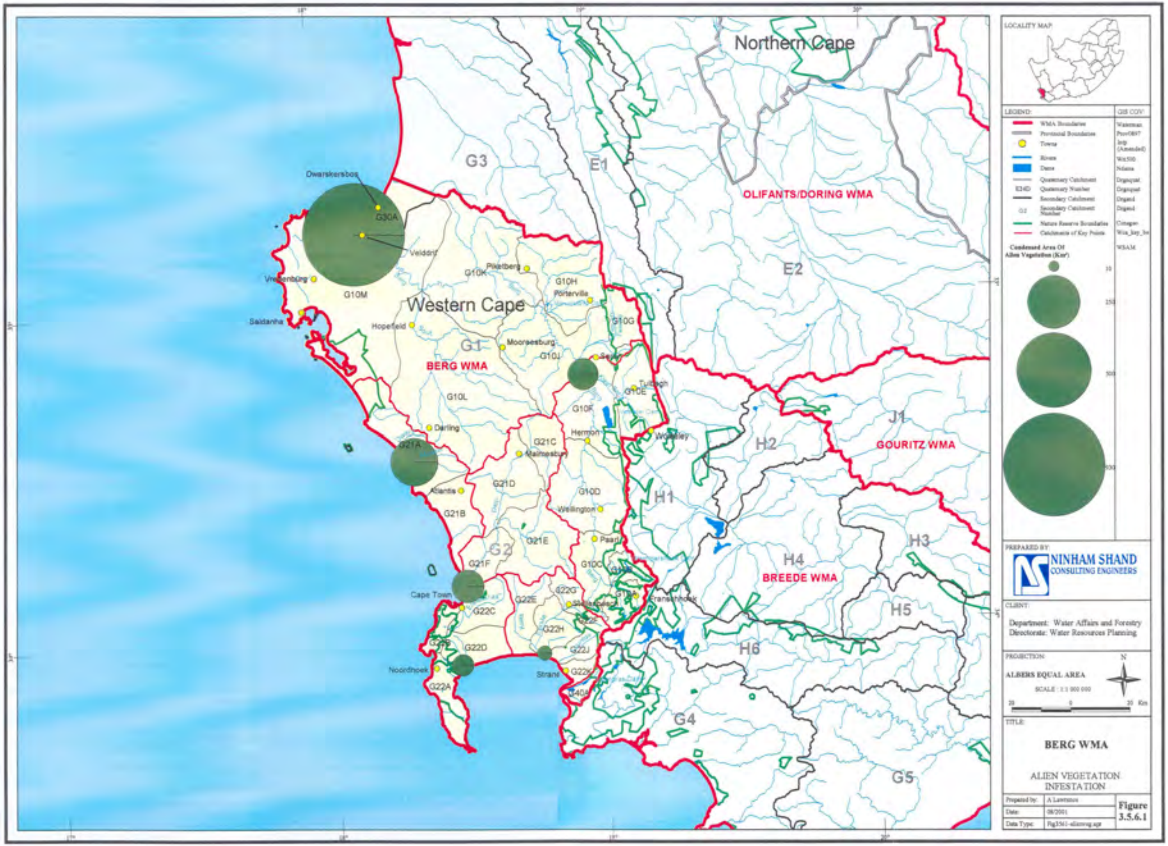
TITLE:

BERG WMA

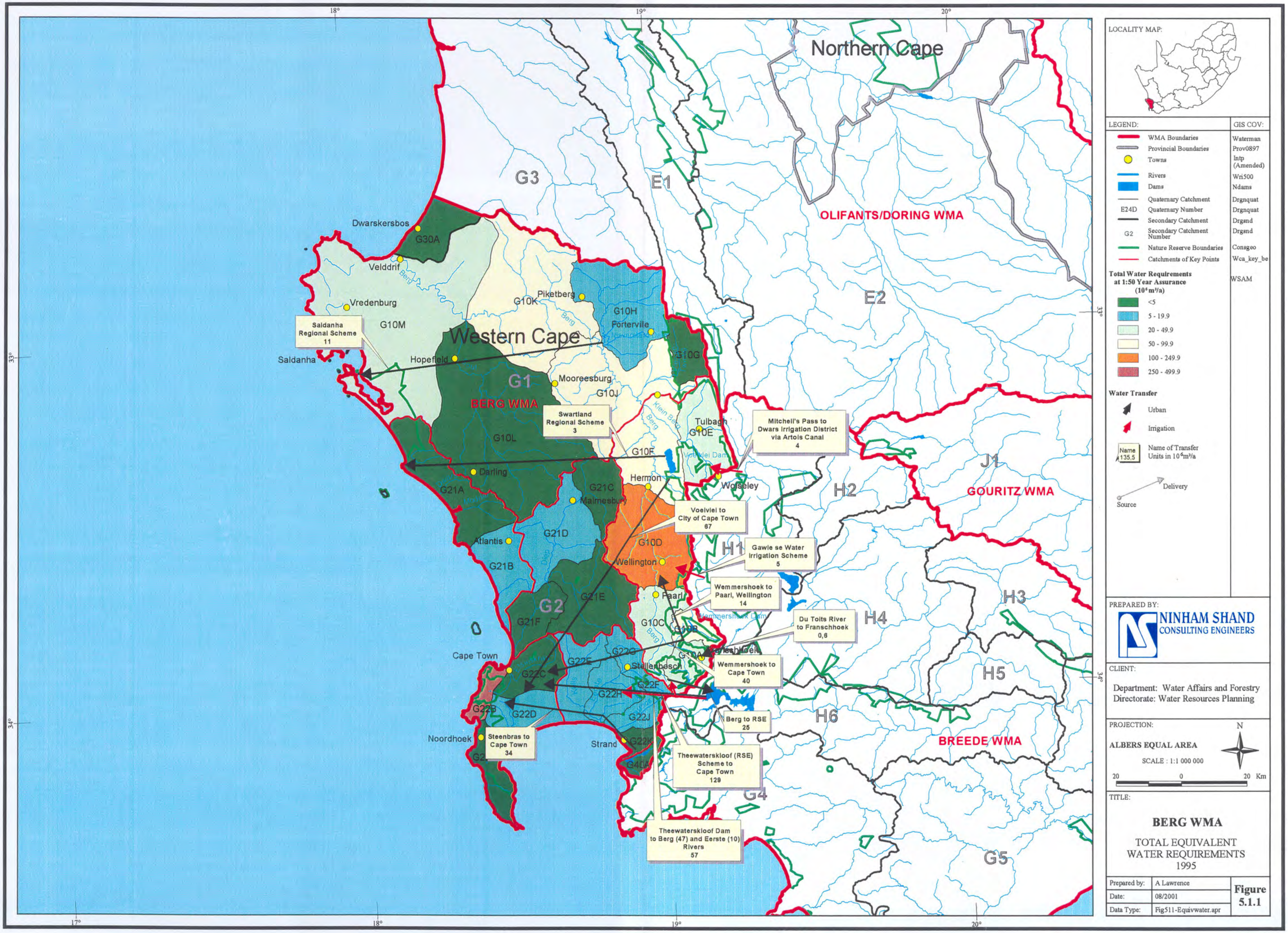
LAND USE

Prepared by:	A Lawrence	Figure 3.5.1.1
Date:	08/2001	
Data Type:	Fig3511-landuse.apr	

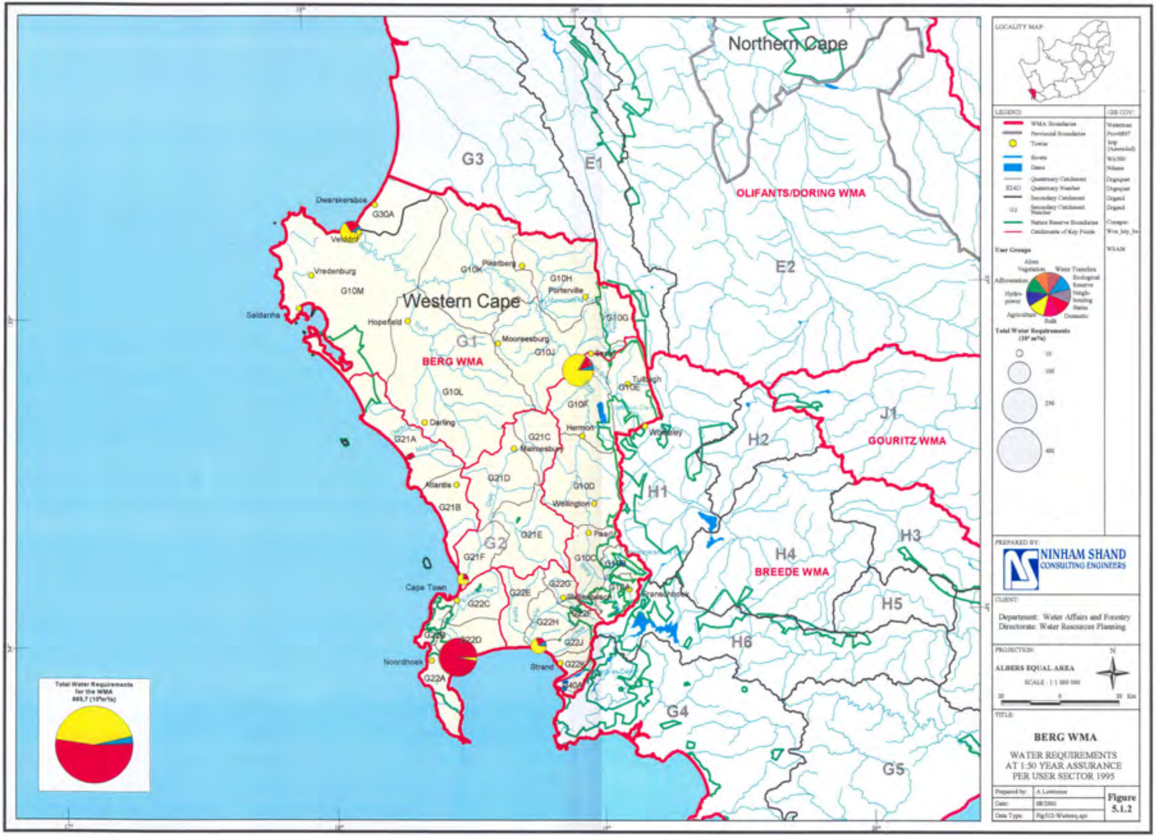

Northern Cape
G3
E1
OLIFANTS/DORING WMA
E2
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Piketberg
G10K
G10H
Porterville
Western Cape
Saldanha
Hopefield
G10G
G1
Moorreesburg
G10J
BERG WMA
Tulbagh
G10E
G10L
G10F
J1
GOURITZ WMA
Darling
Hermon
Wolseley
H2
G21A
G21C
Malmesbury
G21D
H1
Atlantis
G10D
Wellington
G21B
G21E
Paarl
H3
G2
H4
G21F
BREEDE WMA
Cape Town
G22G
G22E
Stellenbosch
G22C
H5
G22H
H6
G22D
G22J
Noordhoek
Strand
G22A
G4
G5
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Livestock
Livestock
Livestock & Game Quantity (ELSU's)
1500
10 000
50 000
140 000
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
LIVESTOCK AND
GAME NUMBERS
Prepared by:
A Lawrence
Date:
08/2001
Figure
3.5.4.1


Northern Cape
G3
E1
OLIFANTS/DORING WMA
E2
Dwarskersbos
G30A
Velddrif
Piketberg
G10K
G10H
Porterville
Vredenburg
G10M
Western Cape
G10G
Saldanha
Hopefield
G1
Moorreesburg
G10J
BERG WMA
Saron
Tulbagh
G10E
G10L
G10F
J1
GOURITZ WMA
H2
Darling
Hermon
Wolseley
G21A
G21C
Malmesbury
G21D
G10D
H1
Atlantis
G21B
Wellington
G21E
Paarl
H3
G2
H4
G21F
G10C
BREEDE WMA
Cape Town
G22G
Franschhoek
H5
G22C
G22E
Stellenbosch
G22H
H6
G22D
G22J
Noordhoek
Strand
G22K
G22A
G40A
G4
G5
LOCALITY MAP
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Condensed Area Of Alien Vegetation (Km²)
10
250
500
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
ALIEN VEGETATION INFESTATION
Prepared by: A Lawrence
Date: 08/2001
Figure 3.5.6.1

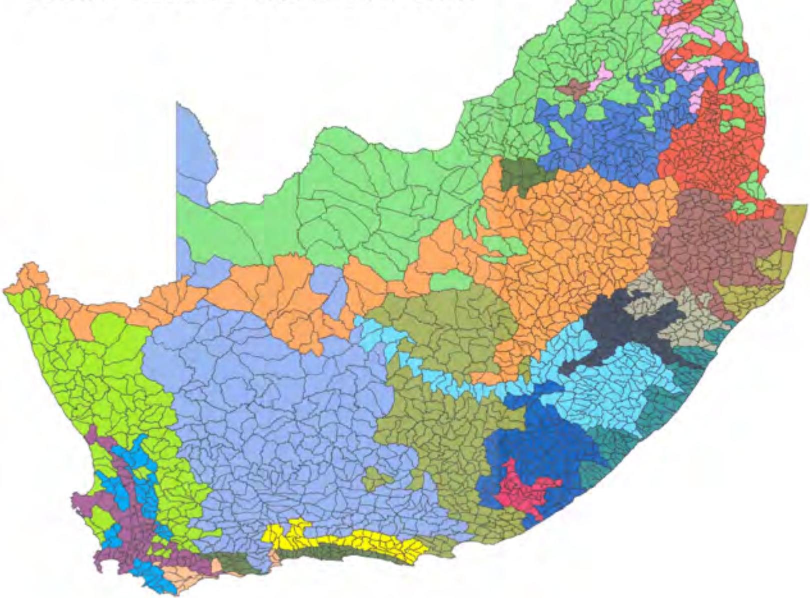
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries — Waterman
Provincial Boundaries — Prov0897
Towns — Intp (Amended)
Rivers — Wri500
Dams — Ndams
Quaternary Catchment — Drgnquat
E24D Quaternary Number — Drgnquat
Secondary Catchment — Drgsnd
G2 Secondary Catchment Number — Drgsnd
Nature Reserve Boundaries — Consgeo
Catchments of Key Points — Wca_key_be
Potable Water Scheme Supply Area
Irrigation Scheme Supply Area
Potable Water Infrastructure
Bulk Supply Pipes
Boreholes
Water Treatment Works
Pump Stations
Bulk Storage Reservoirs
Irrigation Infrastructure
Pipeline / Canal
Pump Stations
Bulk Infrastructure
Pipeline / Canal / Tunnel
Pump Stations
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
20 0 20 Km
N
TITLE:
BERG WMA
WATER RELATED INFRASTRUCTURE
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig411-Infra.apr
Figure 4.1.1
Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
Besaansklip Reservoir
G10M
Saldanha
Hopefield
Piketberg
G10K
Misverstand Pump Station
Misverstand Weir
G10H
Porterville
G10G
Mooreesburg
G10J
Saron
Diversion Weirs
Swartland Pump Station
Tulbagh
Canal to Voëlvlei
G10E
Diversion Weir
G10L
G10F
Wolseley
Darling
Artois Canal
Hermon
Voëlvlei Pump Station
G21A
G21C
Malmesbury
Gawie se Water Transfer
Silverstroom Wellfield
Atlantis
G21D
G10D
Witsands Wellfield
G21B
Wellington
Wellington Reservoir
Glen Garry Reservoir
Tygerberg Reservoir
G21E
Paarl
Paarl Reservoir
Plattekloof Reservoir
G21F
G10C
G10B
Cape Town
G22G
Molteno Reservoir
G22E
G22C
Stellenbosch
G10A
Franschhoek
Newlands Reservoir
G22F
G22H
G22B
G22D
G22J
Blackheath Reservoir
Strand
G22K
Lourens River Boreholes
Riviersonderend Berg River Scheme Tunnels
Noordhoek
G22A
Kildare & Garlandale Pump Stations
G40A
17°
18°
19°
20°
33°
34°



Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
BREEDE WMA
BERG WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
G10M
G10K
G10H
G10G
G10J
G10L
G10E
G10F
G10D
G10C
G10B
G10A
G21A
G21B
G21C
G21D
G21E
G21F
G22A
G22B
G22C
G22D
G22E
G22F
G22G
G22H
G22J
G22K
G30A
G40A
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Mooreesburg
Tulbagh
Hermon
Wolseley
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Noordhoek
Strand
Saldanha Regional Scheme 11
Swartland Regional Scheme 3
Mitchell's Pass to Dwars Irrigation District via Artois Canal 4
Voelvlei to City of Cape Town 67
Gawie se Water Irrigation Scheme 5
Wemmershoek to Paarl, Wellington 14
Du Toits River to Franschhoek 0,6
Wemmershoek to Cape Town 40
Berg to RSE 25
Steenbras to Cape Town 34
Theewaterskloof (RSE) Scheme to Cape Town 129
Theewaterskloof Dam to Berg (47) and Eerste (10) Rivers 57
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries — Waterman
Provincial Boundaries — Prov0897
Towns — Intp (Amended)
Rivers — Wri500
Dams — Ndams
Quaternary Catchment — Drgnquat
E24D Quaternary Number — Drgnquat
Secondary Catchment — Drgend
G2 Secondary Catchment Number — Drgend
Nature Reserve Boundaries — Consgeo
Catchments of Key Points — Wca_key_be
Total Water Requirements at 1:50 Year Assurance ($10^6 m^3/a$) — WSAM
<5
5 - 19.9
20 - 49.9
50 - 99.9
100 - 249.9
250 - 499.9
Water Transfer
Urban
Irrigation
Name 135.5 — Name of Transfer Units in $10^6 m^3/a$
Delivery
Source
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
20 0 20 Km
N
TITLE:
BERG WMA
TOTAL EQUIVALENT WATER REQUIREMENTS 1995
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig511-Equivwater.apr
Figure 5.1.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
Piketberg
G10K
G10H
Porterville
G10G
Moorreesburg
G10J
G10L
G10F
Tulbagh
G10E
Darling
Hermon
Wolseley
G21A
G21C
Malmesbury
G21D
Atlantis
G10D
G21B
Wellington
Paarl
G21E
G21F
G10C
Cape Town
G22C
G22E
G22G
Franschhoek
G22H
G22D
G22J
Noordhoek
G22A
Strand
G22K
G40A
Total Water Requirements for the WMA
LOCALITY MAP:
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
GIS COV:
WSAM
User Groups
Alien Vegetation
Water Transfers
Ecological Reserve
Afforestation
Hydro-power
Neighbouring States
Agriculture
Bulk
Domestic
Total Water Requirements
10
100
250
400
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
WATER REQUIREMENTS
AT 1:50 YEAR ASSURANCE
PER USER SECTOR 1995
Prepared by:
Date:
Data Type:
Figure
5.1.2

DESKTOP RESERVE PARAMETER REGIONS



PREPARED BY:

NINHAM SHAND
CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

SCALE: N.T.S

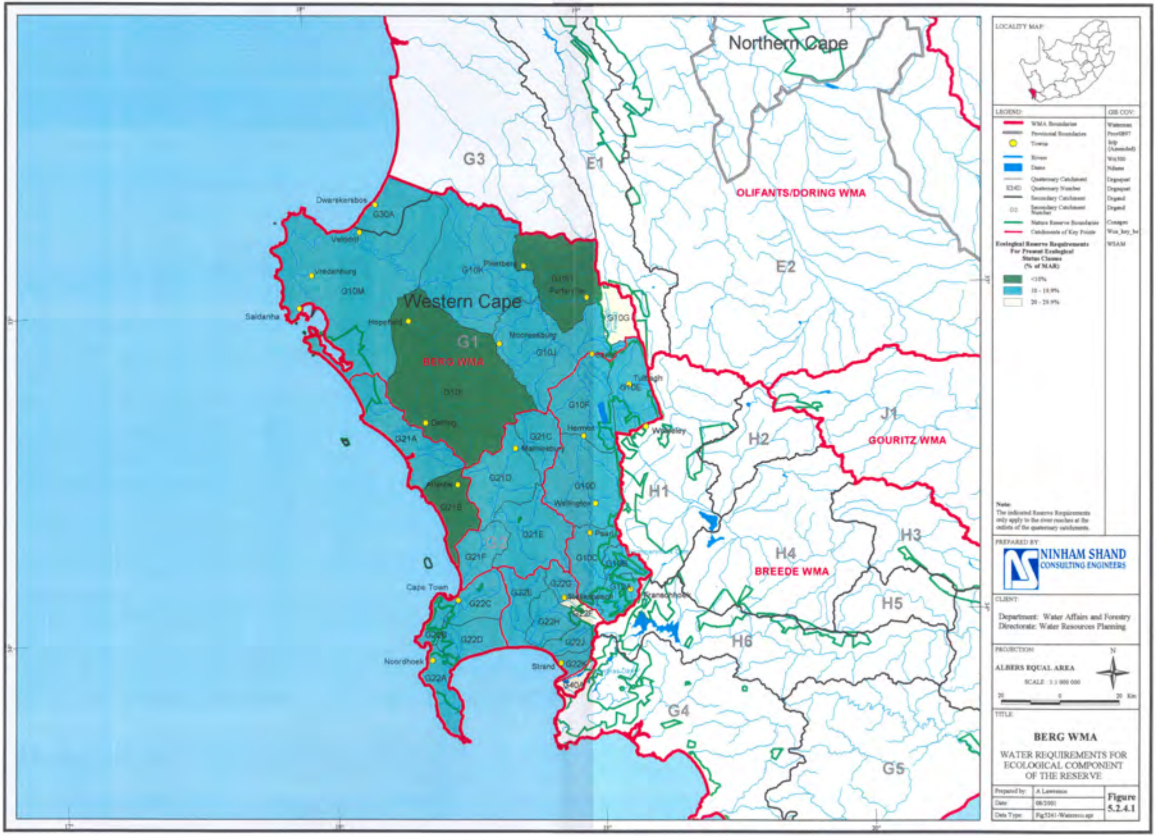
N

TITLE:

BERG WMA

DESKTOP RESERVE
PARAMETER REGIONS

Prepared by:	A Lawrence	**Figure 5.2.1.1**
Date:	08/2001	
Data Type:	Fig5211-Model.apr	

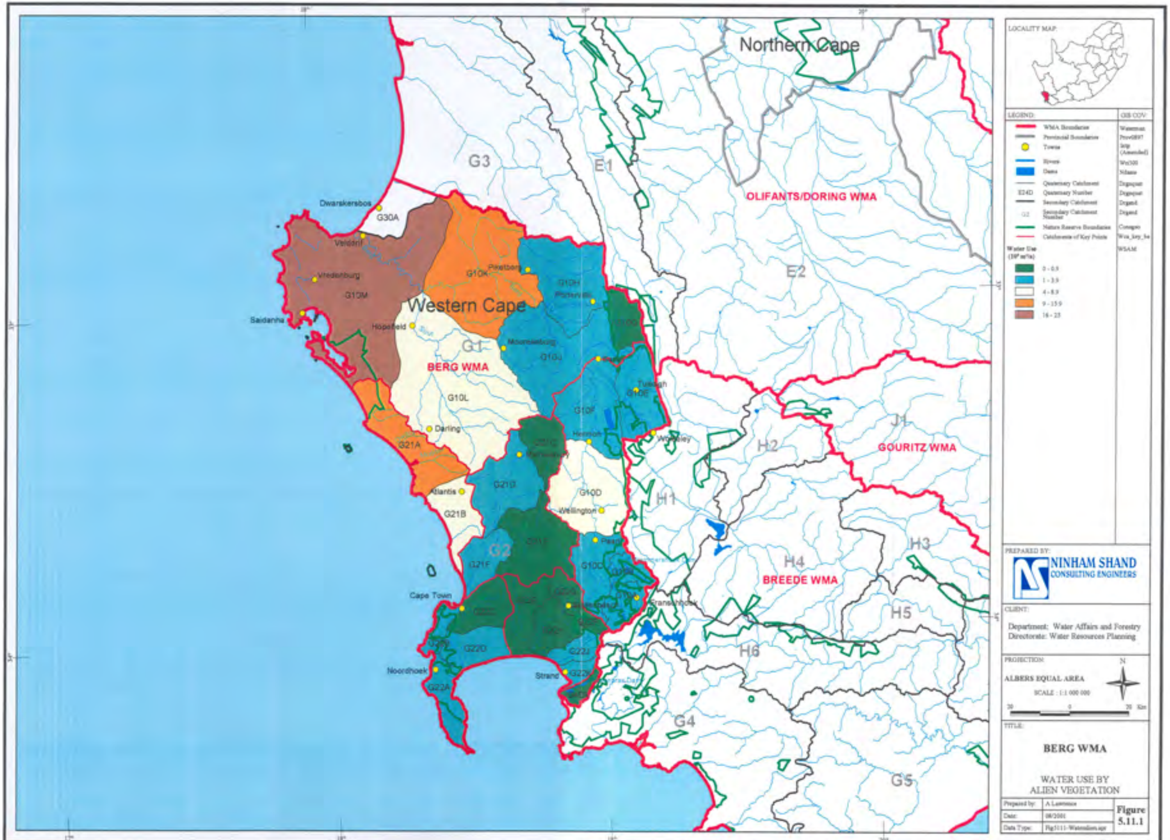

Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
G10K
Piketberg
G10L
Porterville
G10G
Moorreesburg
G10J
Tulbagh
G10E
G10F
Darling
G21A
Hermon
G21C
Malmesbury
Wolseley
G21D
Atlantis
G10D
G21B
Wellington
G21E
Paarl
G21F
G10C
Cape Town
G22C
G22G
Stellenbosch
Franschhoek
G22F
G22H
G22D
G22J
Noordhoek
Strand
G22A
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
WSAM
Ecological Reserve Requirements For Present Ecological Status Classes (% of MAR)
<10%
10 - 19.9%
20 - 29.9%
Note:
The indicated Reserve Requirements only apply to the river reaches at the outlets of the quaternary catchments.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
20 0 20 Km
TITLE:
BERG WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig5241-Watereco.apr
Figure 5.2.4.1

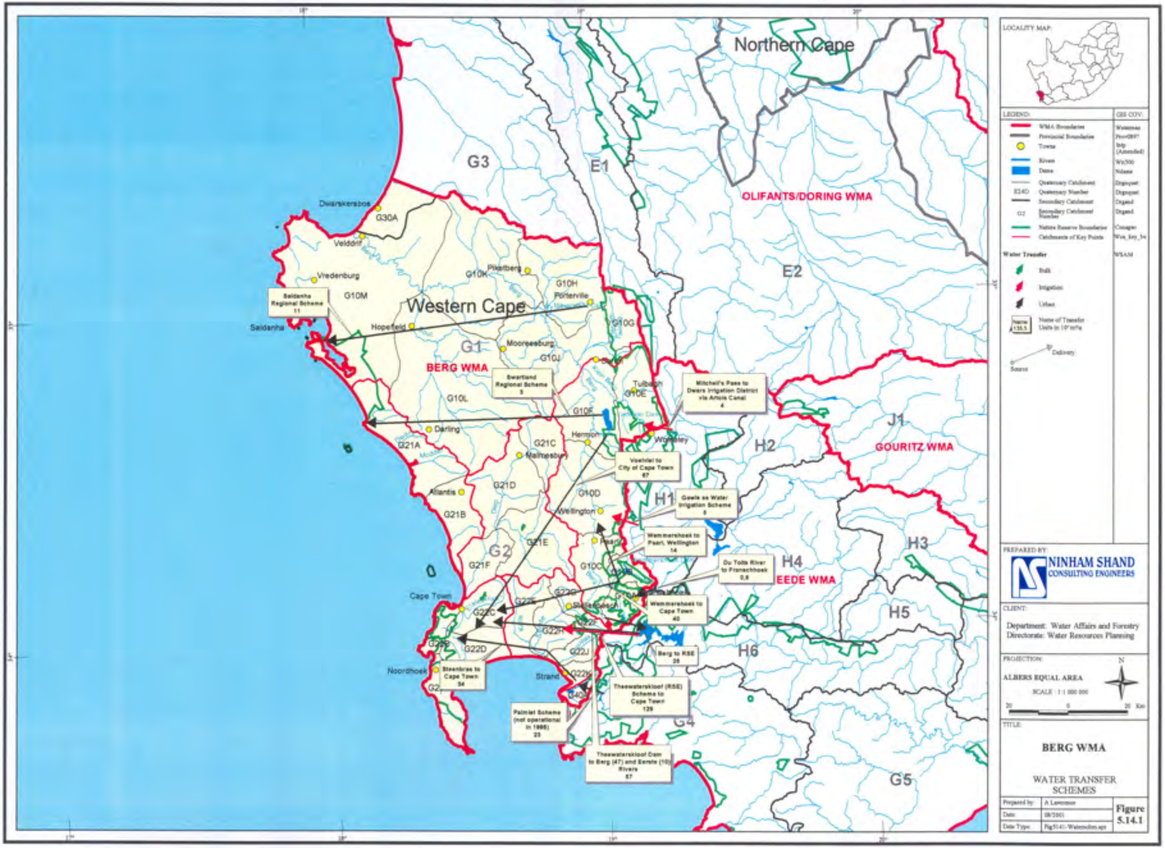

Northern Cape
G3
E1
OLIFANTS/DORING WMA
E2
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Piketberg
G10H
Porterville
Western Cape
Hopefield
G1
Moorreesburg
G10J
BERG WMA
G10L
Tulbagh
G10E
G10F
Darling
Hermon
Wolseley
H2
J1
GOURITZ WMA
G21A
G21C
G21D
G10D
Wellington
H1
G21B
G21E
Paarl
G2
G21F
G10C
H3
H4
BREEDE WMA
Cape Town
G22E
G22G
Franschhoek
H5
G22H
H6
Noordhoek
Strand
G4
G5
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Urban & Rural Total Water Requirements
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
URBAN & RURAL DOMESTIC WATER REQUIREMENTS IN 1995
Prepared by:
Date:
Data Type:
Figure 5.3.1.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10J
G10F
G10E
G10D
Dwarskersbos
Piketberg
Saldanha
Moorreesburg
Tulbagh
Hermon
Wolseley
Wellington
Cape Town
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Requirements
0 - 9.9
10 - 19.9
20 - 49.9
50 - 79.9
80 - 129.9
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
IRRIGATION WATER REQUIREMENTS 1995
Prepared by: A Lawrence
Date: 08/2001
Figure 5.6.2.1

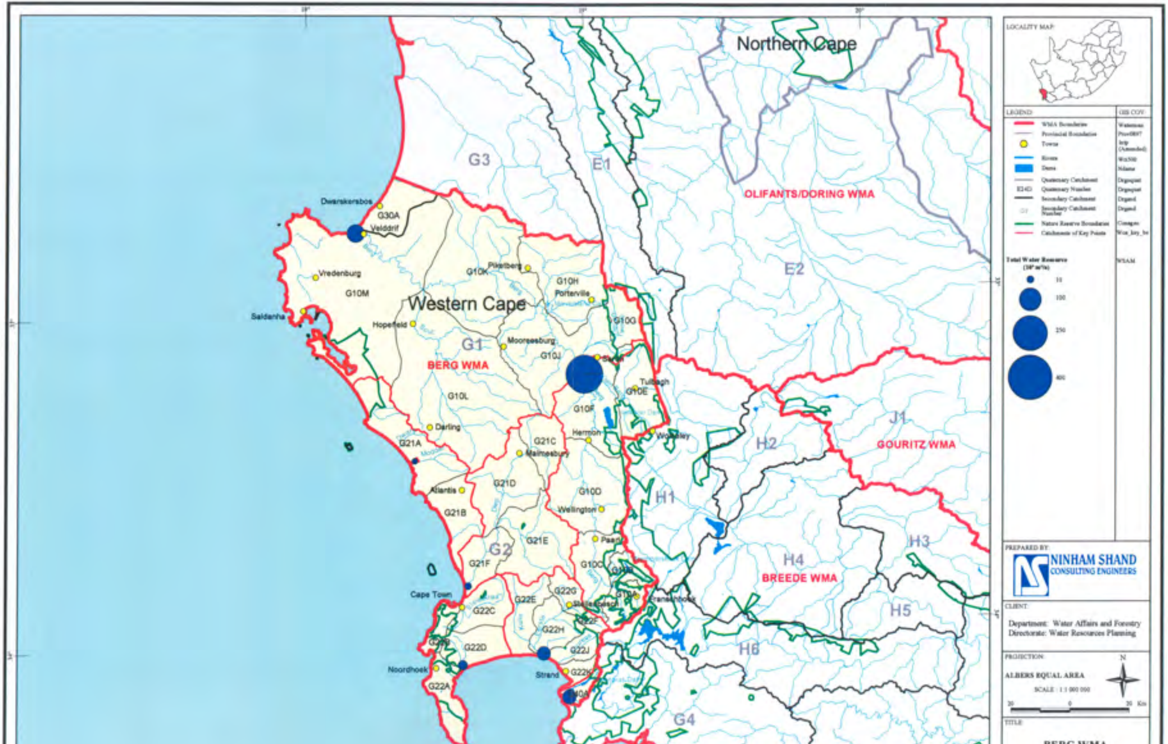
Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
J1
H1
H2
H3
H4
H5
H6
G4
G5
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10E
G10F
G10D
G10C
G10B
G10A
G21A
G21B
G21C
G21D
G21E
G21F
G22A
G22B
G22C
G22D
G22E
G22F
G22G
G22H
G22J
G22K
G40A
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Saron
Tulbagh
Hermon
Wolseley
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Use By Afforestation (mm/a)
0 - 2
2.1 - 6
6.1 - 14
WSAM
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
20 0 20 Km
TITLE:
BERG WMA
WATER USE BY AFFORESTATION IN 1995
Prepared by: A Lawrence
Date: 08/2001

Figure 5.9.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10M
G10H
G10J
G10L
G10F
G10D
G10C
G21A
G21B
G21D
G21F
G22D
G22J
G22A
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Hermon
Wolseley
Darling
Atlantis
Wellington
Paarl
Cape Town
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Use (10^6 m³/a)
0 - 0.9
1 - 3.9
4 - 8.9
9 - 15.9
16 - 23
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
WATER USE BY
ALIEN VEGETATION
Prepared by: A Lawrence
Date: 08/2001
Figure 5.11.1



Northern Cape
OLIFANTS/DORING WMA
Western Cape
BERG WMA
GOURITZ WMA
Saldanha Regional Scheme 11
Swartland Regional Scheme 5
Mitchell's Pass to Dwars Irrigation District via Artois Canal 4
Voelvlei to City of Cape Town 67
Gawie se Water Irrigation Scheme 5
Wemmershoek to Paarl, Wellington 14
Du Toits River to Franschhoek 0,8
Wemmershoek to Cape Town 40
Berg to RSE 25
Theewaterskloof (RSE) Scheme to Cape Town 128
Steenbras to Cape Town 34
Palmiet Scheme (not operational in 1995) 23
Theewaterskloof Dam to Berg (47) and Eerste (10) Rivers 57
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Wolseley
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Stellenbosch
Cape Town
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Transfer
Bulk
Irrigation
Urban
Name of Transfer Units in 10⁶ m³/a
Delivery
Source
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
WATER TRANSFER SCHEMES
Prepared by: A Lawrence
Date: 08/2001
Figure 5.14.1

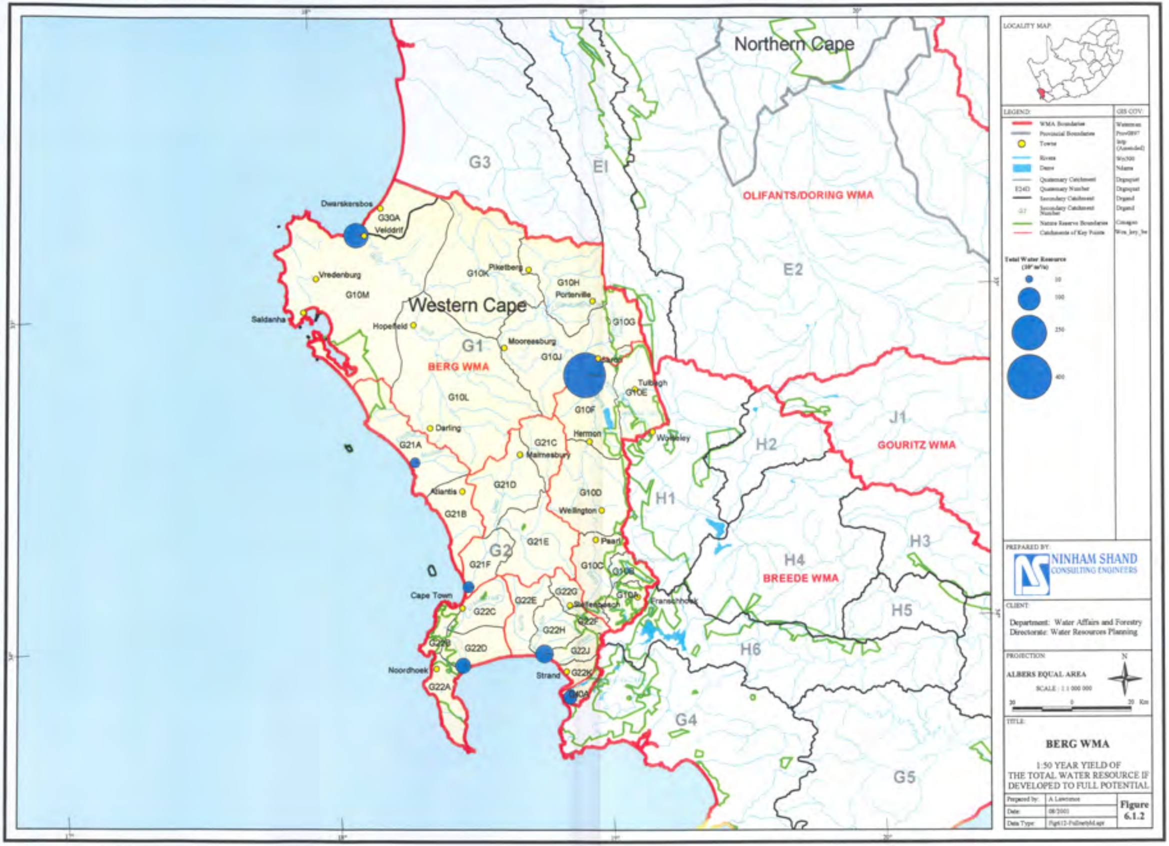


BERG WMA

1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE
AS DEVELOPED IN 1995

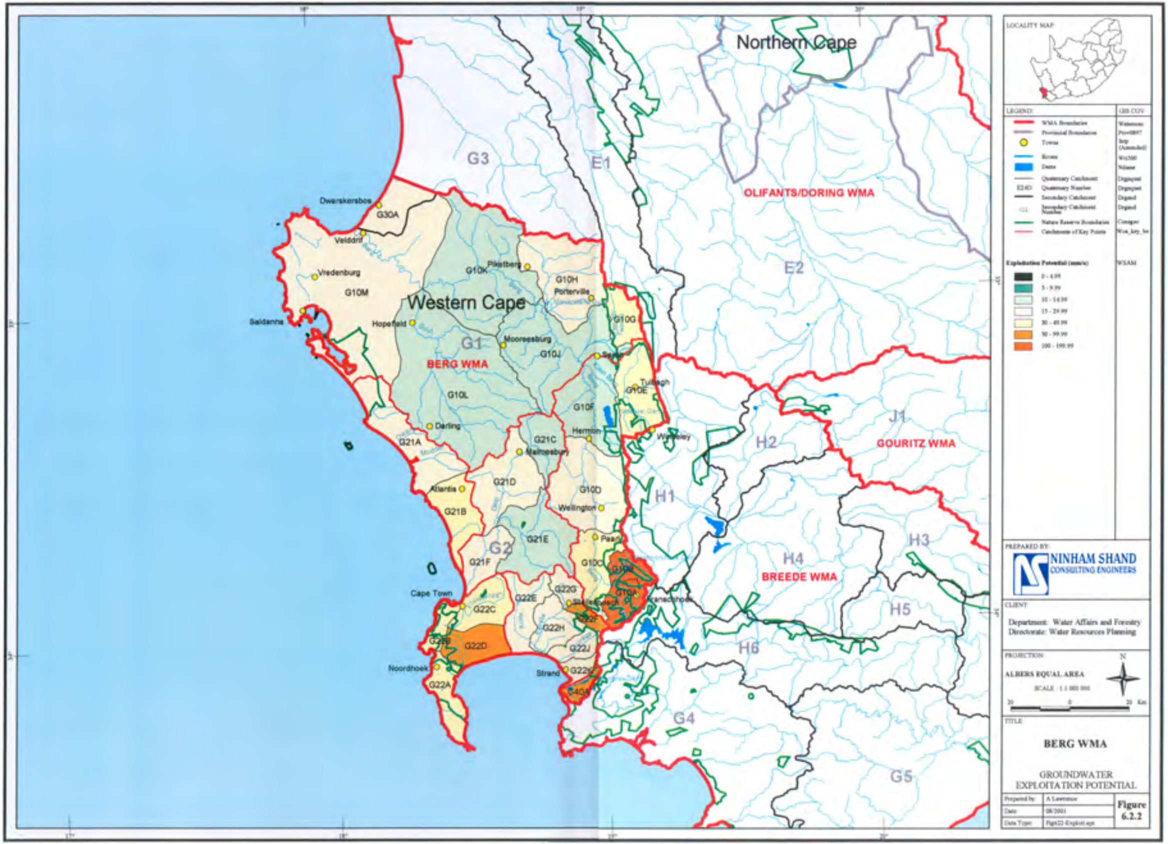
Prepared by:	A Lawrence
Date:	08/2001
Data Type:	Fig611-Natyield.apr

Figure 6.1.1

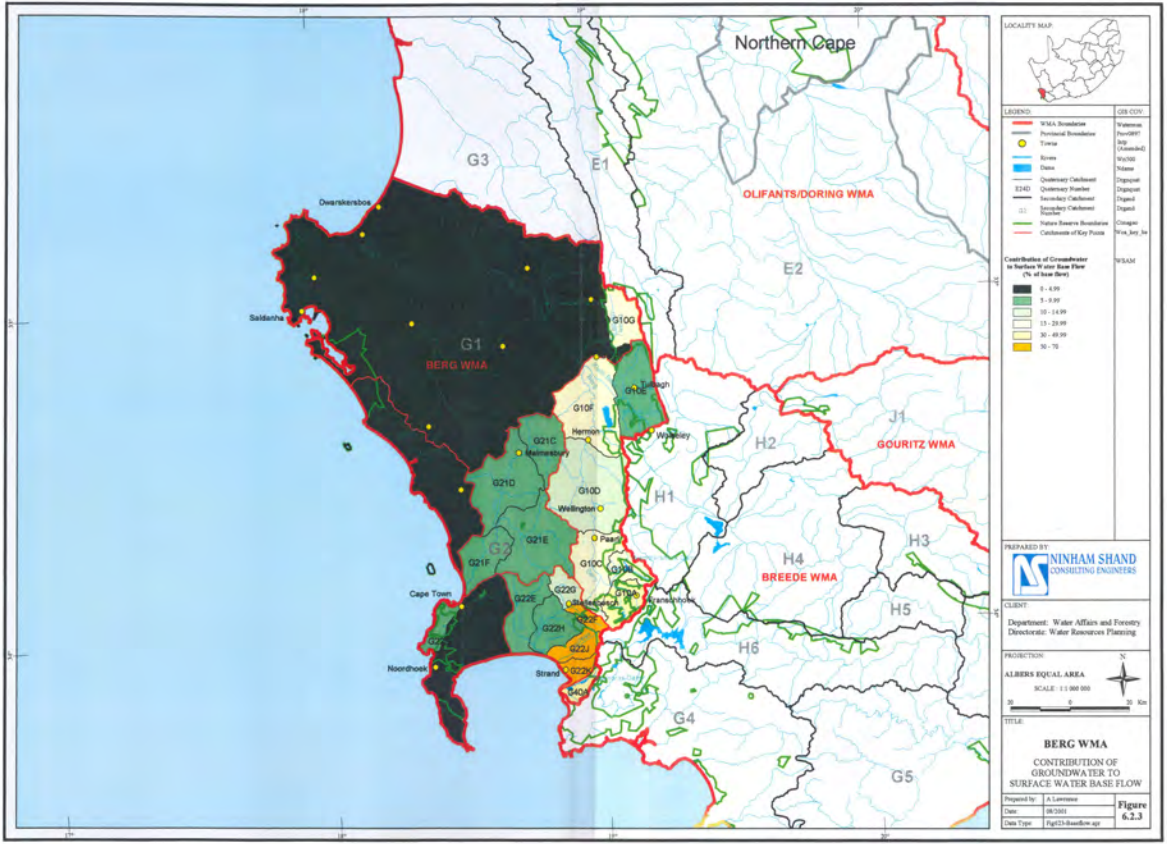


Northern Cape
G3
E1
OLIFANTS/DORING WMA
E2
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Piketberg
G10K
G10H
Porterville
Western Cape
Saldanha
Hopefield
G10G
G1
Moorreesburg
G10J
BERG WMA
Tulbagh
G10E
G10L
G10F
J1
GOURITZ WMA
Darling
Hermon
Wolseley
G21A
G21C
Malmesbury
H2
Atlantis
G21D
G10D
H1
Wellington
G21B
Paarl
H3
G2
G21E
H4
G21F
G10C
BREEDE WMA
Cape Town
G22G
G10A
G22E
Franschhoek
G22C
Stellenbosch
H5
G22F
G22H
G22B
G22D
H6
G22J
Noordhoek
Strand
G22K
G22A
G4
G5
LOCALITY MAP
LEGEND:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
GIS COV:
Total Water Resource
10
100
250
400
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE IF
DEVELOPED TO FULL POTENTIAL
Prepared by: A Lawrence
Figure 6.1.2

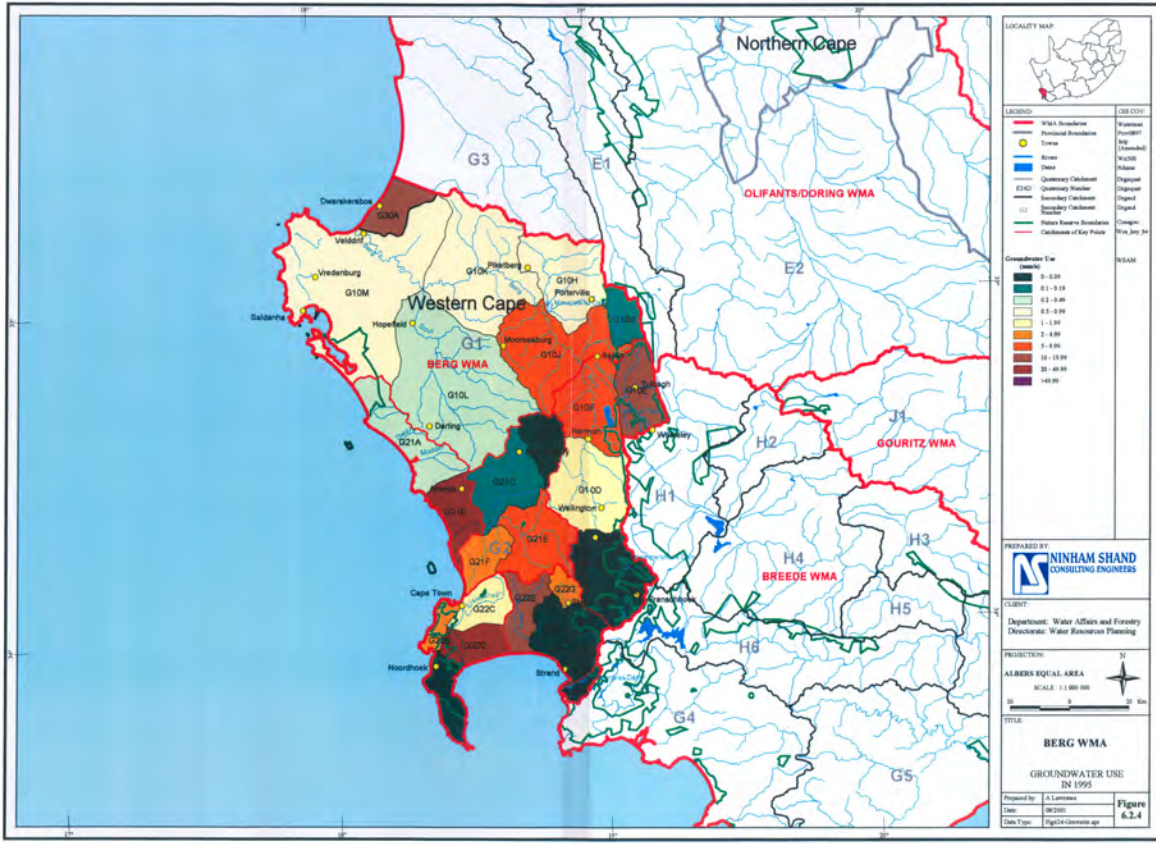
Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
G30A
G10M
G10K
G10H
G10G
G10J
G10L
G10E
G10F
G10D
G10C
G10B
G10A
G21A
G21B
G21C
G21D
G21E
G21F
G22A
G22B
G22C
G22D
G22E
G22F
G22G
G22H
G22J
G22K
G40A
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Wolseley
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
LOCALITY MAP
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D
Quaternary Number
Secondary Catchment
Harvest Potential (mm/a)
WSAM
0 - 4.99
5 - 9.99
10 - 14.99
15 - 29.99
30 - 49.99
50 - 99.99
100 - 199.99
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
GROUNDWATER
HARVEST POTENTIAL
Prepared by:
A Lawrence
Date:
08/2001
Data Type:
Figure
6.2.1



Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
Piketberg
G10K
G10H
Porterville
G10G
Moorreesburg
G10J
Tulbagh
G10E
G10L
G10F
Darling
Hermon
Wolseley
G21A
G21C
Malmesbury
Atlantis
G21D
G10D
G21B
Wellington
Paarl
G21E
G21F
G10C
Cape Town
G22C
G22E
G22G
G10A
G22H
G22D
G22J
Noordhoek
Strand
G22A
LOCALITY MAP
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Exploitation Potential (mm/a)
0 - 4.99
5 - 9.99
10 - 14.99
15 - 29.99
30 - 49.99
50 - 99.99
100 - 199.99
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
GROUNDWATER
EXPLOITATION POTENTIAL
Prepared by:
A Lawrence
Date:
08/2001
Figure 6.2.2



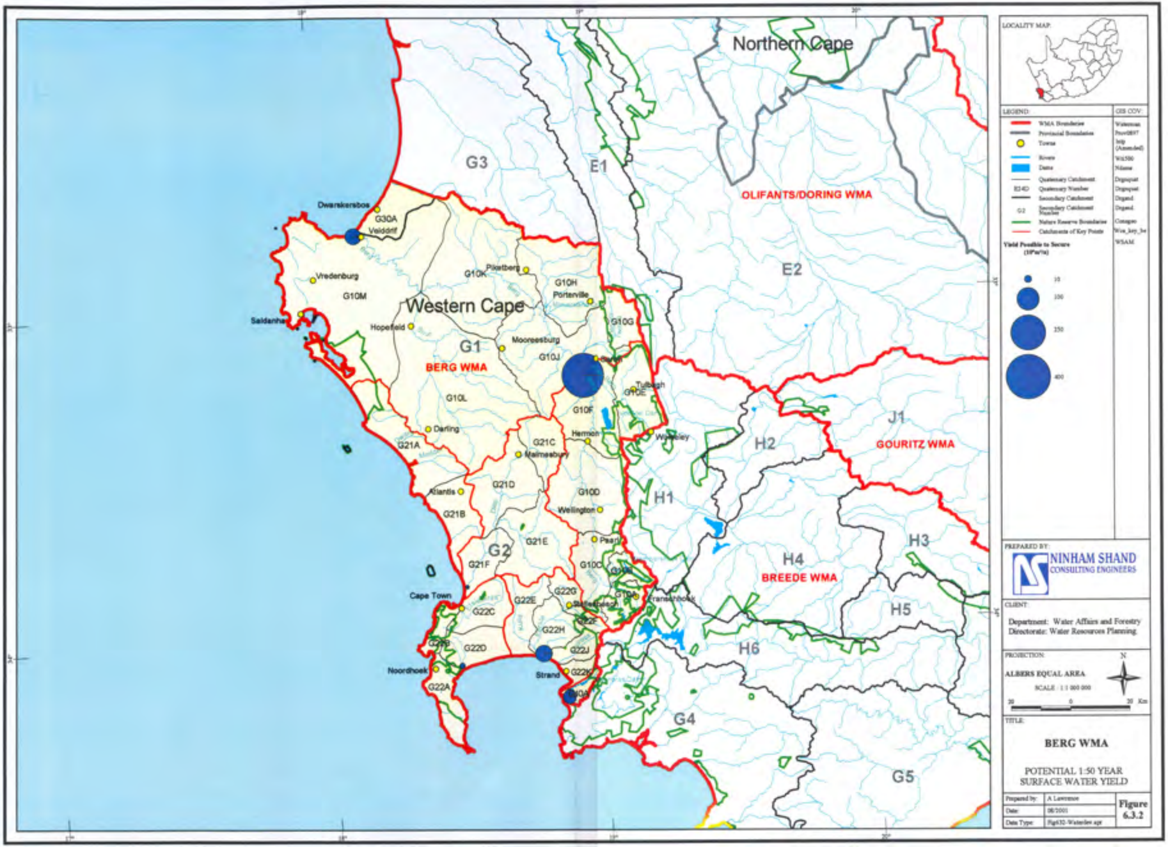
Northern Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
G10G
G10F
G10E
G10D
G10C
G10A
G21C
G21D
G21E
G21F
G22E
G22G
G22H
G22F
G22J
G22K
G40A
Dwarskersbos
Saldanha
Tulbagh
Hermon
Malmesbury
Wellington
Paarl
Stellenbosch
Franschhoek
Cape Town
Noordhoek
Strand
LOCALITY MAP
LEGEND:
GIS COV.
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Contribution of Groundwater to Surface Water Base Flow (% of base flow)
WSAM
0 - 4.99
5 - 9.99
10 - 14.99
15 - 29.99
30 - 49.99
50 - 70
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
CONTRIBUTION OF GROUNDWATER TO SURFACE WATER BASE FLOW
Prepared by: A Lawrence
Date: 08/2001
Figure 6.2.3

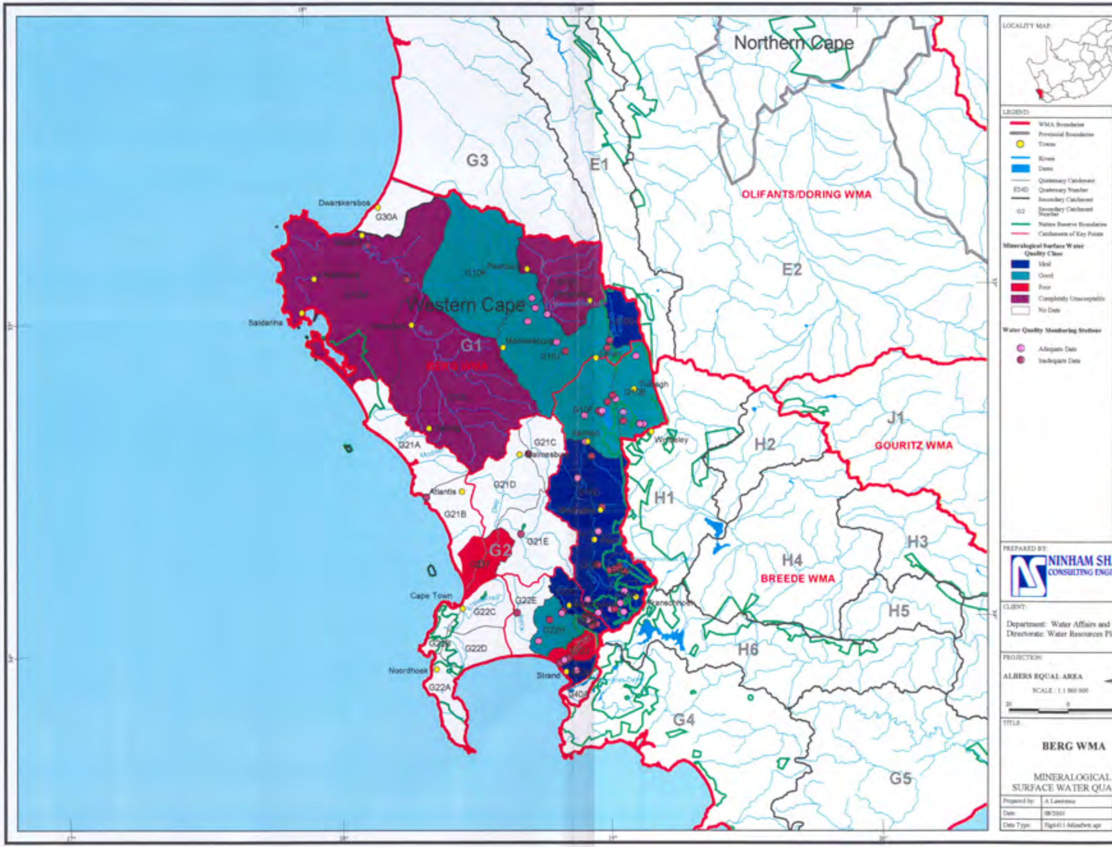


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10H
G10M
G10J
G10F
G10L
G10D
G21A
G21C
G21D
G21E
G21F
G22C
G22G
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Darling
Wellington
Cape Town
Noordhoek
Strand
Worcester
LOCALITY MAP
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Groundwater Use (mm/a)
0 - 0.09
0.1 - 0.19
0.2 - 0.49
0.5 - 0.99
1 - 1.99
2 - 4.99
5 - 9.99
10 - 19.99
20 - 49.99
>49.99
WSAM
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
GROUNDWATER USE IN 1995
Prepared by:
Date:
Data Type:
Figure 6.2.4


Northern Cape
Western Cape
G3
E1
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
H1
H2
H3
H4
H5
H6
BREEDE WMA
G4
G5
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10F
G10E
G21A
G21C
G21D
G10D
G21B
G21E
G21F
G10C
G10B
G10A
G22C
G22E
G22G
G22F
G22H
G22B
G22D
G22J
G22K
G22A
G40A
Dwarskersbos
Velddrif
Vredenburg
Piketberg
Porterville
Saldanha
Hopefield
Moorreesburg
Tulbagh
Darling
Hermon
Wolseley
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Stellenbosch
Franschhoek
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G1 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Remaining Exploitation Potential (mm/a)
<0
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
WSAM
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
20 0 20 Km
TITLE:
BERG WMA
REMAINING GROUNDWATER EXPLOITATION POTENTIAL IN 1995
Prepared by: A Lawrence
Date: 08/2001
Figure 6.2.5


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Wolseley
Hermon
Darling
Malmesbury
Atlantis
Wellington
Paarl
Franschhoek
Cape Town
Stellenbosch
Noordhoek
Strand
G30A
G10M
G10K
G10H
G10G
G10J
G10L
G10E
G10F
G21A
G21C
G21D
G10D
G21B
G21E
G21F
G10C
G22C
G22E
G22G
G22H
G22D
G22J
G22A
G40A
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
MAR (mm)
WSAM
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE
BERG WMA
MEAN ANNUAL NATURALISED SURFACE RUNOFF
Prepared by
A Lawrence
Date
Figure 6.3.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
G1
G2
G3
G4
G5
E1
E2
H1
H2
H3
H4
H5
H6
J1
G30A
G10K
G10H
G10M
G10G
G10J
G10L
G10F
G10E
G10D
G10C
G10A
G21A
G21B
G21C
G21D
G21E
G21F
G22A
G22B
G22C
G22D
G22E
G22F
G22G
G22H
G22J
G22K
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Piketberg
Porterville
Hopefield
Moorreesburg
Tulbagh
Wolseley
Hermon
Malmesbury
Darling
Atlantis
Wellington
Paarl
Franschhoek
Stellenbosch
Cape Town
Noordhoek
Strand
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Yield Possible to Secure
10
100
250
400
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
POTENTIAL 1:50 YEAR SURFACE WATER YIELD
Prepared by: A Lawrence
Date: 08/2001
Figure 6.3.2



PREPARED BY:

NINHAM SHAND CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE : 1:1 000 000

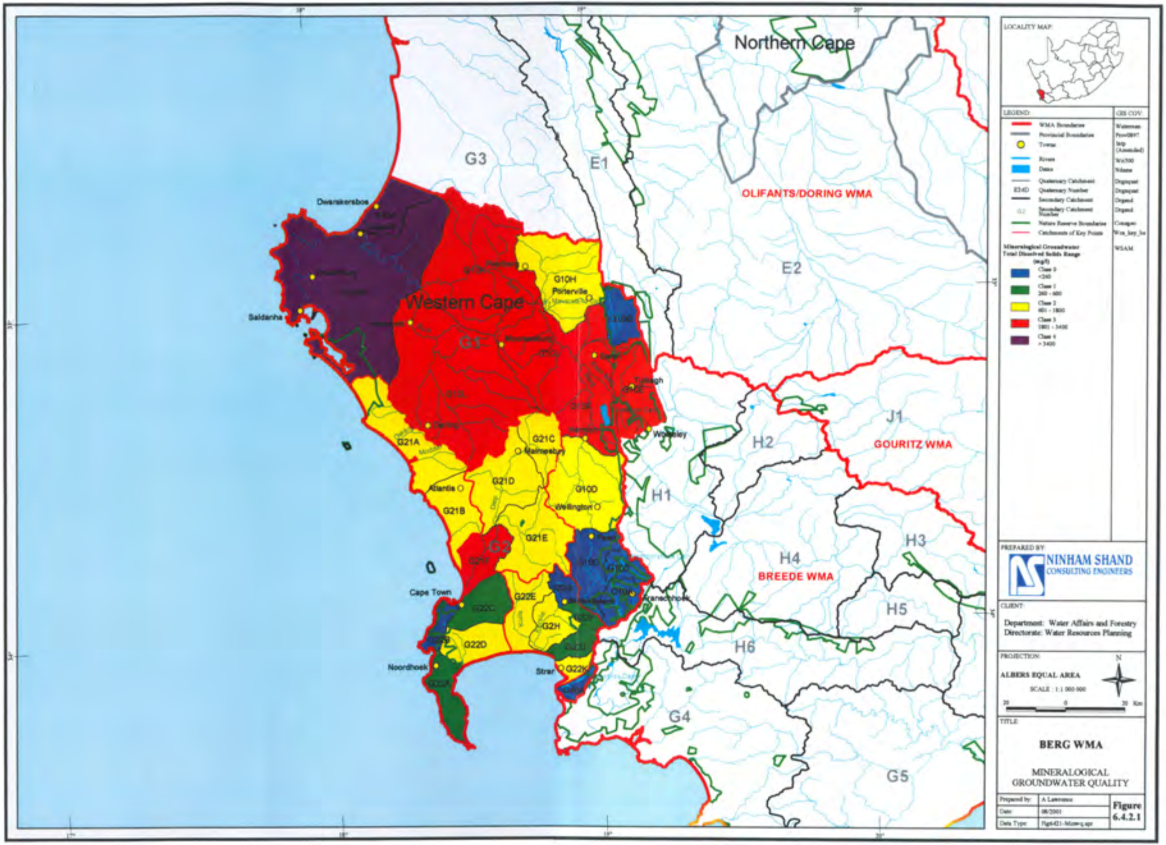
TITLE:

BERG WMA

MINERALOGICAL SURFACE WATER QUALITY

Prepared by:	A Lawrence
Date:	08/2001
Data Type:	Fig6411-Minsfwtr.apr

Figure 6.4.1.1


Northern Cape
OLIFANTS/DORING WMA
Western Cape
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
H1
H2
H3
H4
H5
H6
J1
G4
G5
Dwarskersbos
Saldanha
Piketberg
Porterville
Wellington
Malmesbury
Atlantis
Darling
Cape Town
Noordhoek
Tulbagh
Wolseley
Paarl
Franschhoek
Strand
G10H
G21A
G21B
G21C
G21D
G21E
G22C
G22D
G22E
G22K
G10D
G2H
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Mineralogical Groundwater Total Dissolved Solids Range (mg/l)
Class 0 <260
Class 1 260 - 600
Class 2 601 - 1800
Class 3 1801 - 3400
Class 4 > 3400
WSAM
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
20
0
20 Km
TITLE:
BERG WMA
MINERALOGICAL GROUNDWATER QUALITY
Date: 08/2001
Figure 6.4.2.1

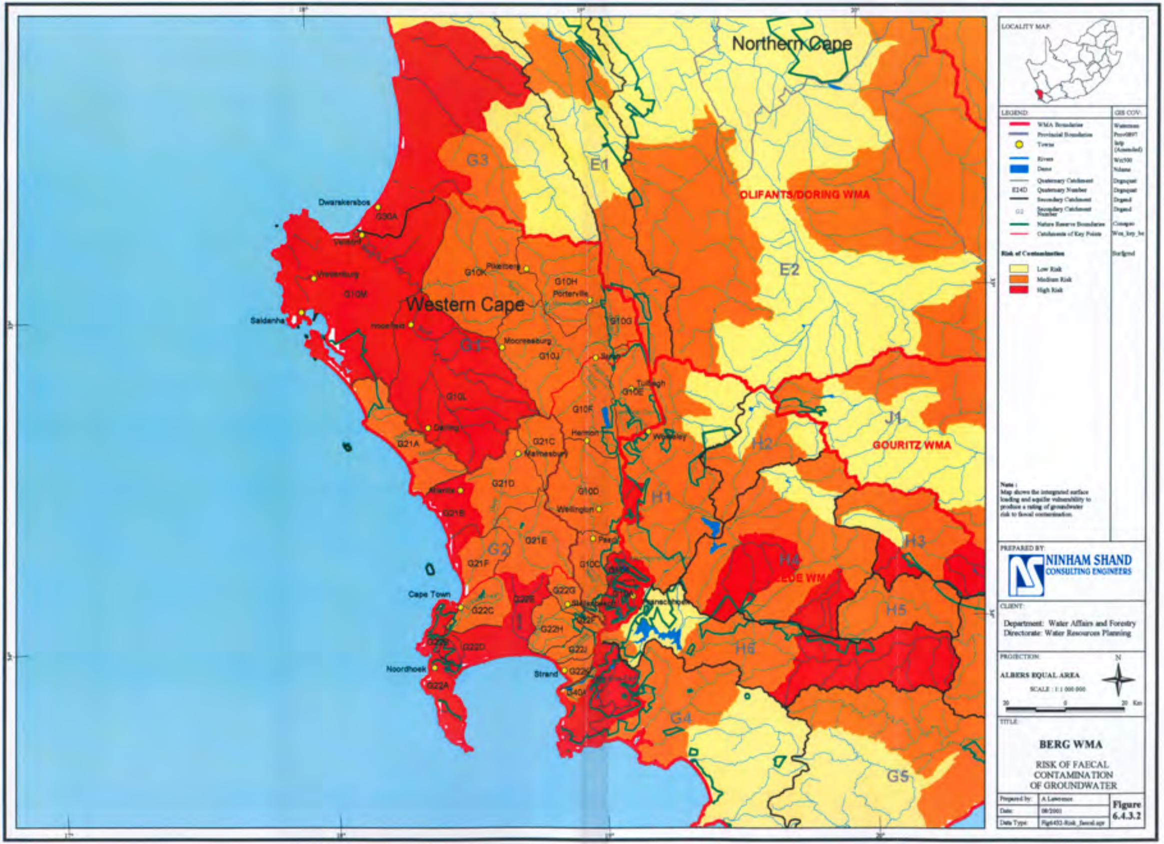

Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
Saldanha
Vredenburg
Hopefield
Piketberg
Moorreesburg
Darling
Atlantis
Wellington
Cape Town
Noordhoek
Strand
Franschhoek
G10M
G21D
G10D
G21E
G21F
G22J
G22K
LOCALITY MAP
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Potable Groundwater (%)
<30 %
30 - 50 %
50 - 70 %
70 - 90 %
> 90 %
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BERG WMA
PERCENTAGE OF
POTABLE GROUNDWATER
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.2.2

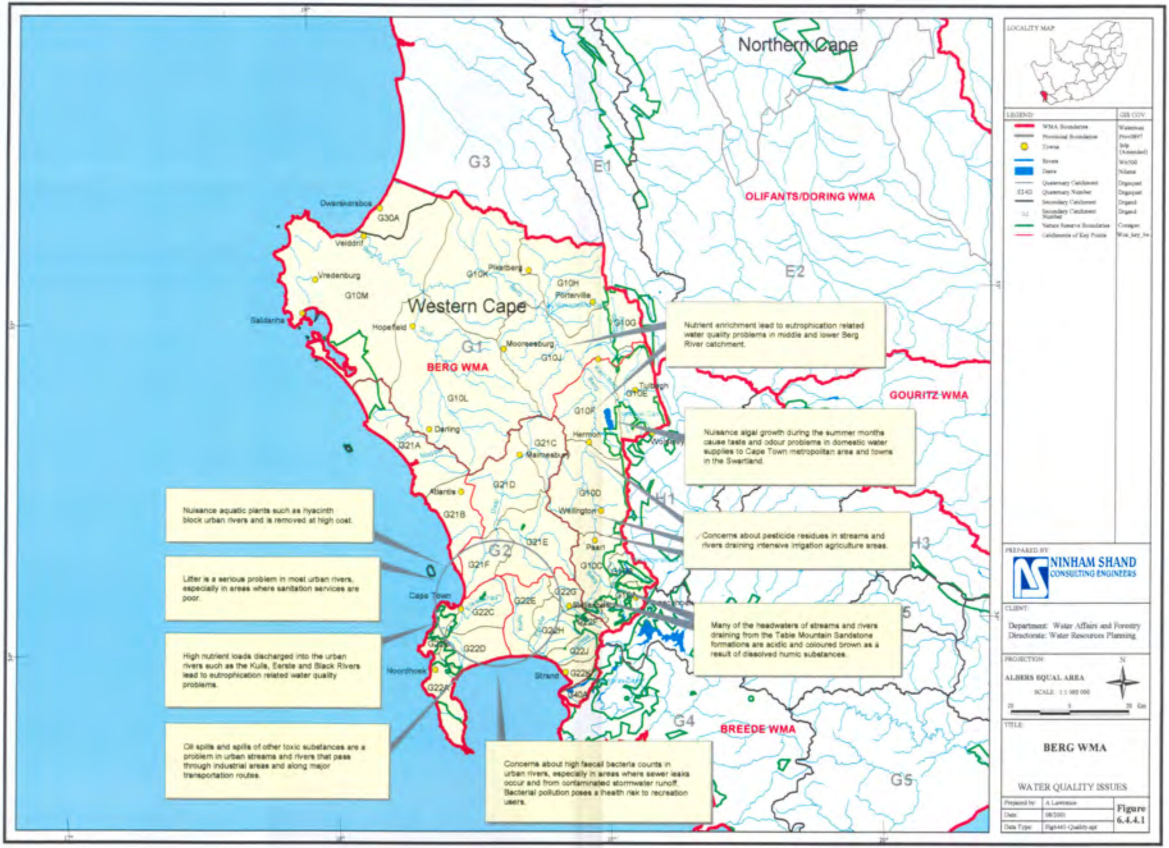
TITLE:

BERG WMA

POTENTIAL SURFACE FAECAL CONTAMINATION

Prepared by:	A Lawrence	**Figure 6.4.3.1**
Date:	08/2001	


Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
Saldanha
Hopefield
Piketberg
G10K
G10H
Porterville
G10G
Moorreesburg
G10J
G10L
Tulbagh
G10E
G10F
Darling
G21A
Hermon
Wellington
G21C
Malmesbury
G21D
G10D
Atlantis
G21B
G21E
Paarl
G21F
G10C
Cape Town
G22C
G22G
G22E
Stellenbosch
G22F
G22H
G22D
G22J
Noordhoek
G22A
Strand
G40A
GOURITZ WMA
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Risk of Contamination
Low Risk
Medium Risk
High Risk
Note :
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE:
BERG WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.3.2



Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
G1
G2
G3
G4
G5
E1
E2
H1
Dwarskersbos
Velddrif
Vredenburg
Saldanha
Hopefield
Piketberg
Porterville
Moorreesburg
Tulbagh
Hermon
Wolseley
Darling
Malmesbury
Atlantis
Wellington
Paarl
Cape Town
Noordhoek
Strand
G30A
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G21C
G21D
G10D
G21B
G21E
G21F
G10C
G22C
G22E
G22G
G22H
G22D
G22J
G22K
G22A
G40A
Nutrient enrichment lead to eutrophication related water quality problems in middle and lower Berg River catchment.
Nuisance algal growth during the summer months cause taste and odour problems in domestic water supplies to Cape Town metropolitan area and towns in the Swartland.
Concerns about pesticide residues in streams and rivers draining intensive irrigation agriculture areas.
Many of the headwaters of streams and rivers draining from the Table Mountain Sandstone formations are acidic and coloured brown as a result of dissolved humic substances.
Nuisance aquatic plants such as hyacinth block urban rivers and is removed at high cost.
Litter is a serious problem in most urban rivers, especially in areas where sanitation services are poor.
High nutrient loads discharged into the urban rivers such as the Kuils, Eerste and Black Rivers lead to eutrophication related water quality problems.
Oil spills and spills of other toxic substances are a problem in urban streams and rivers that pass through industrial areas and along major transportation routes.
Concerns about high faecal bacteria counts in urban rivers, especially in areas where sewer leaks occur and from contaminated stormwater runoff. Bacterial pollution poses a health risk to recreation users.
LOCALITY MAP
LEGEND:
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
BERG WMA
WATER QUALITY ISSUES
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.4.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
G3
E1
E2
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
J1
Dwarskersbos
G30A
Velddrif
Vredenburg
G10M
G10K
Piketberg
G10H
Porterville
Saldanha
Hopefield
Moorreesburg
G10J
G10G
Saron
Tulbagh
G10E
G10L
G10F
Darling
Hermon
Wolseley
G21A
G21C
Malmesbury
G21D
Atlantis
G10D
Wellington
G21B
G21E
Paarl
G21F
G10C
G10B
G10A
Cape Town
G22G
G22E
G22C
Stellenbosch
Franschhoek
G22F
G22H
G22B
G22D
G22J
Noordhoek
Strand
G22K
G22A
G40A
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
G2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
25 Year Sediment Accumulation Potential (% MAR)
0% - 0.49%
0.5% - 0.99%
1% - 1.99%
2% - 4.99%
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
20
0
20 Km
TITLE:
BERG WMA
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Prepared by: A Lawrence
Date: 08/2001
Figure 6.5.1

PREPARED BY:

NINHAM SHAND
CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

GEOGRAPHIC PROJECTION

N

TITLE:

BERG WMA

YIELD BALANCE OVERVIEW

Prepared by:	A Lawrence	Figure 7.2.1
Date:	08/2001	
Data Type:	Fig721-Overview.apr	