Ref No: P WMA19/000/00/0407

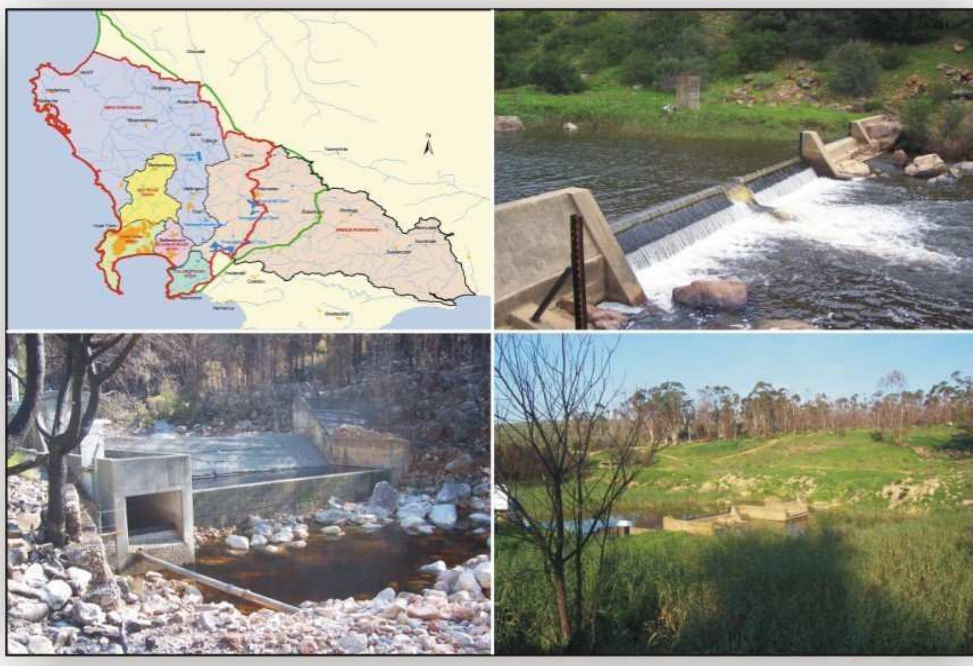
Department of Water Affairs and Forestry

Directorate: National Water Resource Planning

The Assessment of Water Availability in the Berg Catchment (WMA 19) by means of Water Resource Related Models

Report No. 6 : Water Quality

Volume 1 : A Literature Review of Water Quality Related Studies in the Berg WMA 1994 - 2006



FINAL **August 2007**

Submitted by:
Ninham Shand (Pty) Ltd
in Association with
Umvoto Africa (Pty) Ltd

NINHAM SHAND CONSULTING SERVICES

UMVOTO

DEPARTMENT OF
WATER AFFAIRS AND FORESTRY

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

REPORT No. 6
WATER QUALITY

Volume No. 1
A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006

Final

August 2007

Department of Water Affairs and Forestry
Directorate National Water Resource Planning

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

REPORT No. 6
WATER QUALITY

Volume No. 1
A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006

APPROVAL

DWAF REF NO.	:	P WMA19/000/00/0407
CONSULTANTS	:	Ninham Shand in association with Umvoto Africa
AUTHORS	:	J N Rossouw and G Enongene
REPORT STATUS	:	Final
DATE	:	August 2007

STUDY TEAM : Approved for Ninham Shand

....
G ENGLISH

....
A H M GöRGENS

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Directorate National Water Resource Planning
Approved for Department of Water Affairs and Forestry

....
I THOMPSON
CE : NWRP (South)

....
J A VAN ROOYEN
Director : NWRP

REFERENCE

This report is to be referred to in bibliographies as :

Department of Water Affairs and Forestry, South Africa. 2007. *The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models. Report No. 6 : Water Quality. Volume No. 1 : A Literature Review of Water Quality Related Studies in the Berg WMA, 1994-2006.*

Prepared by Ninham Shand (Pty) Ltd in association with Umvoto Africa on behalf of the Directorate : National Water Resource Planning. DWAF Ref No. P WMA19/000/00/0407.

REPORT No	REPORT TITLE	VOLUME No.	VOLUME TITLE
1	Final Summary Report		
2	Rainfall Data Preparation and MAP Surface		
3	The Assessment of Flow Gauging Stations		
4	Land Use and Water Requirements	Vol 1	Data in Support of Catchment Modelling
		Vol 2	Invasive Alien Plant Mapping
		Vol 3	Water Use and Water Requirements
5	Update of Catchment Hydrology	Vol 1	Berg River
		Vol 2	Upper Breede River
		Vol 3	Peripheral Rivers
6	Water Quality	Vol 1	A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006
		Vol 2	Updating of the ACRU Salinity Model for the Berg River
		Vol 3	Update Monthly FLOSAL Model to WQT
7	(Report No Not Used)		
8	System Analysis Status Report		
9	Groundwater Model	Vol 1	Overview of Methodology and Results
		Vol 2	Data Availability and Evaluation
		Vol 3	Regional Conceptual Model
		Vol 4	Regional Water Balance Model
		Vol 5	Cape Flats Aquifer Model
		Vol 6	Langebaan Road and Elandsfontein Aquifer System Model
		Vol 7	TMG Aquifer, Piketberg Model
		Vol 8	TMG Aquifer, Witzenberg – Nuy Model
		Vol 9	Breede River Alluvium Aquifer Model
10	Berg and Mhlathuze Assessment Studies (Refer to Report No.1)		
11	Applicability of the Sami Groundwater Model to the Berg WAAS Area		

ACKNOWLEDGEMENTS

Ninham Shand would like to extend its appreciation to the following individuals who provided comments and information for this report:

- Dr Liz Day of Freshwater Research Group, 6 Flamingo Crescent, Zeekoevlei, who provided us with a wide range of reports addressing different water quality issues within the Berg water management area.

- The Department of Water Affairs and Forestry Regional Office, Bellville, Cape Town, especially Gareth McKonkey, Tony Brutus, Larry Ferguson, Bertrand Van Zyl, who provided us with pointers for relevant water quality information.

- Mrs Linda Rossouw for her input in the microbial water quality.

- Dr Heather Malan, Project coordinator, Freshwater Research Unit, Department of Zoology, University of Cape Town.

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

REPORT No. 6 : WATER QUALITY

Volume No. 1 : A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006

EXECUTIVE SUMMARY

Water is one of the most fundamental and indispensable natural resources. It is fundamental to life and the quality of life, to the environment, food production, hygiene, industry, and power generation. The availability of affordable water can be a limiting factor for economic growth and social development, especially in a semi arid country like South Africa, where water is a relatively scarce resource that is distributed unevenly socio-economically, geographically and through time.

Water quality in the Berg WMA, varies not only between the individual river basins but also within individual river systems. The natural geology, agricultural practises and point source polluters all play a role in determining the quality of water in this WMA. Water quality management in the Berg WMA should aim to address the problems associated with water quality and to recommend steps that can be taken to improve the quality where problems currently exist.

Although the City's recreational waters are generally considered safe for contact recreation, water quality in many of the major watercourses is of concern. This could be attributed primarily to rapid urbanization and capacity constraints on both water services and waste management infrastructure and services. Closer co-operation at a strategic level between those responsible for all three sectors of the urban water cycle (water supply, wastewater, stormwater) in accordance with the principles of integrated urban water management is required to effect change in this regard.

Certain wastewater treatment works within the Berg Water Management Area are not treating their sewerage to the quality standards required under their authorisations. Co-operative governance between the Department of Water Affairs and Forestry and municipalities (local authorities) must be focussed on this problem, to ensure that the local authorities accept responsibility for the quality of effluent from all wastewater treatment works in their areas of jurisdiction.

Most of the rivers in the water management area rise from the Table Mountain Group mountain catchments which provide very good quality of water with total dissolved solids concentrations of less than 60 mg/l. The quality of water however, generally deteriorates further downstream as follows:

- Although the upper reaches of the Berg River has remained unpolluted, the water quality has deteriorated considerably downstream over time as a result of human activities.
- The water quality in the Berg River and the lower reaches of the tributaries have shown substantial declines which could be attributed to increased organic loading rates (wastewater discharges) to the river between Paarl and Wellington, agricultural return flows, urban and

industrial runoff and irrigation releases from Voëlvlei Dam during summer resulting in increases in conductivity during that period.

- In the Upper Middle Berg area, which corresponds largely to the southern portion of the Drakenstein Municipal Area, the water quality of the Berg River has been severely impacted as a result of agricultural activities (coupled with river modification, water abstraction and runoff of pollutants) and general urban development.
- In the Lower Middle Berg area, which corresponds mainly to the northern part of the Drakenstein Municipal Area (north of Hermon), the water quality has been severely affected by diversion weirs which resulted in disruption of flow patterns in the Klein Berg and Vier-en-Twintig Rivers, and as a result of agricultural activities (largely the building of flood-protection levees and the use of pesticides).

The middle reaches of the Berg River receive effluent from various wastewater treatment works as well as agricultural return flows and occasionally high salinity runoff from tributaries underlain by Malmesbury shales of marine origin. This has resulted in water quality problems in the lower Berg River. Industrial users (steel manufacturers) in the Saldanha area need to pre-treat this water before being able to utilise it in their industrial processes. Irrigators are limited to the types of crops they can cultivate, due to increased salinity levels.

Effluent return flows and stormwater washoff from Stellenbosch enters the Eerste River. This will have an impact on the costs associated with treating water if the Eerste River Diversion scheme is ever implemented.

Runoff in the lower reaches of the Diep River arising from the Malmesbury formation is also saline and wastewater is discharged into the river from two of the City of Cape Town's wastewater treatment works. The Rietvlei wetland, a highly valued ecosystem, receives treated effluent being discharged from wastewater treatment works and the potential impacts are of particular concern with respect to water quality.

The Lourens River, most of the Peninsula Rivers, the Cape Flats rivers and vleis have been impacted by urban runoff. The Kuils River and Salt River are also impacted by large, wastewater return flows that have changed these seasonal rivers into perennial rivers. These urban rivers cannot be rehabilitated but their condition must at least be maintained at levels that will not introduce social, health and aesthetic problems.

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

REPORT No. 6 : WATER QUALITY

Volume No. 1 : A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006

TABLE OF CONTENTS

Page No

LIST OF TABLES

LIST OF FIGURES

I:\HYDRO\400820 WC Modelling\40 - WaterQuality\WQ_Status\Status Report\Final Report\Berg WQ Literature Review Final Aug 2007.doc

GLOSSARY OF TERMS

Term	Definition
Acute effect values	Defined by the Department of Water Affairs and Forestry as: "the concentration of a constituent above which there is expected to be a significant probability of acute toxic effects to up to 5% of a species in the aquatic community. If such effects even for a short while occur at too high a frequency, they can quickly cause the death and disappearance of sensitive species or communities".
Aquifer	A saturated permeable geologic unit that can transmit significant (economically useful) quantities of water under ordinary hydraulic gradients. Specific geologic materials are not innately defined as aquifers and aquitards, but within the context of the stratigraphic sequence in the subsurface area of interest.)
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
Chronic effect values	Defined by the Department of Water Affairs and Forestry as: "the concentration of constituent above which there is expected to be a significant probability of measurable chronic effects to up to 5% of a species in the aquatic community. If such effects persist for some time, they can lead to the eventual death of individuals and the disappearance of sensitive species from aquatic ecosystem"
Contaminant	Any physical, chemical, biological, or radiological substance or matter in the water
Grey water	Any water that has been used in the home, such as water from the bath, shower, washing machine, and bathroom sink, but not from toilets and the kitchen sink, is referred to as "grey water". Grey water can be used for other applications around the home, such as garden irrigation
Groundwater	Water in the sub-surface, which is beneath the water table, and thus present within the saturated zone. In contrast, to water present in the unsaturated or vadose zone which is referred to as soil moisture
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.
Non-point source pollution	A contributory factor to water pollution that cannot be traced to a specific spot; for example, pollution that results from water runoff from urban areas, construction sites, agricultural sites, etc.
Point-source pollution	Pollution discharged through a pipe or some other discrete source from municipal wastewater treatment plants, factories, confined animal feedlots, or combined sewers
Pollution	Any substance, natural or synthetic, that degrades water quality to such a degree that water is not suitable for a particular use

Term	Definition
Quaternary catchment	The basic unit of catchment area 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
Reservoir	The lake formed behind a dam wall. In this report the colloquial term dam is generally used for reservoir
Resource quality	The quality of all the aspects of a water resource including: (a) the quantity, pattern, timing, water level and assurance of instream flow; (b) the water quality, including the physical, chemical and biological characteristics of the water; (c) the character and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of the aquatic biota
Resource quality objectives	Quantitative and verifiable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection
River system	A network of rivers ranging from streams to major rivers and, in some cases, including rivers draining naturally separate basins that have been inter-connected by man-made transfer schemes
Salinity	The concentration of dissolved salts in water. The most desirable drinking water contains 500 ppm or less of dissolved minerals
Sub-catchment	A sub-division of a catchment
Surface water	Bodies of water, snow, or ice on the surface of the earth (such as lakes, streams, ponds, wetlands, etc.)
Turbidity	A measure of water cloudiness caused by the amount of suspended matter in the water
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists
Water quality monitoring	An integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses

Term	Definition
Water-quality standard	A law or regulation that consists of the beneficial designated use or uses of a water body, the numerical and narrative water-quality criteria that are necessary to protect the use or uses of that particular water body, and an antidegradation statement

ABBREVIATIONS

Term	Definition
ℓ/c/d	litres per capita per day
BRBMP	Berg River Baseline Monitoring Programme
BRMP	Berg River Monitoring Programme
CCT	City of Cape Town
CMA	Catchment Management Agencies
CMS	Catchment Management Strategy
DEA&DP	Department of Environmental Affairs and Development Planning
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EEU	Environmental Evaluation Unit
GA	General Authorisation
GDP	Gross Domestic Product
IBTs	Inter-basin water transfer schemes
ISP	Internal Strategic Perspective
IWQM	Integrated Water Quality Model
IWRM	Integrated Water Resource Management
m^3/a	cubic metres per annum
m^3/s	cubic metres per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mg/ℓ	milligrams per litre
NEMA	National Environmental Management Act (Act 108 of 1998)
NEMP	National Eutrophication Monitoring Programme
NMMP	National Microbiological Monitoring Programme
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
RO	Regional Office (DWAF, Western Cape Regional Office)
RQO	Resource Quality Objectives
SoE	State of the Environment
TDS	Total dissolved solids

Term	Definition
TMS	Table Mountain Sandstone
TSS	Total suspended/settleable solids
TWQR	Target Water Quality Range
WCSA	Western Cape System Analysis
WCWSS	Western Cape Water Supply System
WDCS	Waste Discharge Charge System
WMA	Water Management Area
WRC	Water Research Commission
WRYM	Water Resources Yield Model
WUA	Water User Association
WWTW	Wastewater Treatment Works

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

South Africa is generally regarded as a semi arid country. In South Africa, the emphasis in water resource management has focused on water quantity with less attention being given to water quality. Water quality and quantity are related and should form part of an integrated water resource management. The national water quality management framework policy (DWAF, 2002a) is aligned with the National Water Act (Act No 36 of 1998), and an integrated water quality management (IWQM) model addresses water quality management related issues (Van Wyk *et al*., 2003). Water resources have been placed under increasing pressure as growing populations demand more water for a range of uses, while simultaneously polluting the existing sources. The quality of water determines its suitability for particular uses and further deterioration exacerbates an already existing problematic situation in the receiving catchments. The Department of Water Affairs and Forestry (DWAF) recognises that "in time, quality may become a more important factor than quantity as regards the availability of water in some areas in the interior" (DWAF, 1987).

DWAF in 1986 identified one of its major objectives to ensuring equitable provision of adequate quantities and qualities of water to all consumers at acceptable degrees of risk and affordability under changing conditions (DWAF, 1986). In mid 1991, initial concerns were raised as to the water quality in the Berg River in the Western Cape and this lead DWAF to initiate a water quality situation analysis study for the Berg River (DWAF, 1993).

In an attempt to understand the processes which influence the available water resources in the Western Cape, the Western Cape System Analysis (WCSA) (which includes the catchments of the Berg River, the upper Riviersonderend as far as Theewaterskloof Dam, the Palmiet River, the Steenbras, Diep and Eerste Rivers, and a small section of the upper Breede River Catchment) completed a series of studies in 1993 (refer to the general index of reports, DWAF, 1993). The studies included an assessment of water quality of rivers and impoundments and the suitability of surface water resources for a variety of uses in the Water Management Area (WMA).

The water quality issues that were identified during the studies as emerging problems in the Berg WMA, have since then received greater prominence at all relevant levels. As a result, a number of water quality related studies (refer to Section 1.5) were commissioned and completed for the WMA in the period 1994 to 2006, including a number of Water Research Commission (WRC) projects, ecological reserve determinations, studies for water resource development projects and investigations for different Local Municipalities within the WMA.

Also, a number of national and local water monitoring programmes such as the National Microbiological Monitoring Programme (NMMP), National Eutrophication Monitoring Programme (NEMP), and Berg River Monitoring Programme (BRMP), have also been implemented in the WMA.

1.2 THE NEED FOR THE STUDY

The concept of water availability, quantity and quality and the requirements of users as well as the sources of pollutants that leads to deterioration are interdependent and should be managed in an integrated manner. This holistic approach is essential in achieving water quality management objectives and plans and in identifying issues and concerns in the Berg WMA. The quality of surface water (streams, rivers, dams, reservoirs, weirs, estuaries) in the Berg WMA can however, not be considered an intrinsic property, but is rather determined by the uses of which the National Water Act recognises five user sectors: agricultural, domestic, industrial, recreational and ecological.

The responsibility for ensuring the protection of the water resources in the Berg WMA is a shared responsibility encompassing DWAF, Western Cape Department of Environmental Affairs and Development Planning (DEA&DP), Western Cape Department of Agriculture and by each of the local authorities (municipalities) within the Berg WMAs. The personal environmental ethic of people who live and work in the Berg WMA is crucial to the improvement of water quality. Such a stewardship ethic results in environmentally-sound personal practices and also creates the widespread expectation and insistence that all levels of government institute and enforce laws and regulations that are protective of water resources.

DWAF is in the forefront of protecting the nation’s water resources and in this regard initiated two major water resource management and planning undertakings in the area of Western Cape Water Supply System (WCWSS), *viz*:

- Compulsory licencing in terms of the National Water Act due to be piloted in the Berg WMA, in response to concerns that growing water user demands, as well as streamflow salinity increases, might place parts of the WCWSS in a water-stress condition during the foreseeable future; and

- A Reconciliation Strategy Study, which aims at reviewing the future water requirements and the options for meeting these demands. The Study will identify the most favourable augmentation options and will recommend a programme of feasibility studies and other investigations to improve the operation and planning of the system, and to ensure that the necessary infrastructure or other interventions are implemented timeously so as to reconcile the supplies with the future demands.

The Assessment of Water Availability in the Berg Catchment (WMA 19) by means of water resource related models forms part of the five studies commissioned nationally by DWAF to support, inter alia, allocable water quantification as a prerequisite for compulsory licencing.

The objectives of the study are to:

- Reconfigure the existing Water Resources Yield Model (WRYM) at a spatial resolution suitable for allocable water quantification to support compulsory licencing.
- Use reconfigured existing models or newly configured models for allocable water quantification for both surface water and groundwater, where applicable.
- Incorporate changes in concepts, models and approaches, as derived from pilot studies initiated by DWAF elsewhere, if these become available in time.

- Support the Reconciliation Study with model-based assessment of water resource augmentation options.

Ninham Shand (Pty) Ltd has been appointed by DWAF as the lead consultant and is responsible for the surface water components and the management of the study, while Umvoto Africa (Pty) Ltd is responsible for the groundwater components. The study comprises two phases: Phase 1 (Inception) and Phase 2 (Model configurations for assessment of current water availability and selected augmentation options).

This report has been compiled by Ninham Shand (Pty) Ltd and constitutes Task 18 of Phase 2 - Water Quality Literature Review of the Berg WMA.

1.3 OBJECTIVES AND TERMS OF REFERENCE

A number of water quality related studies have been undertaken in the Berg WMA since the completion of the WCSA in 1993. This study aims to compile a Water Quality Literature Review Report that summarises the pertinent findings of the water quality related studies in the Berg WMA for the period 1994 - 2006 and provide a scoping level assessment of how the situation has changed since the completion of the WCSA studies in 1993. The objective of the study is not to undertake a comprehensive analysis of water quality data that has been collected in WMA, but rather to synthesise recent studies and to identify knowledge, information and data gaps that could potentially impede water quality planning and licencing efforts in the Berg WMA.

Accordingly, the tasks performed in this study to achieve the above-mentioned objectives included the following:

- Collation of water quality related studies and monitoring reports that have been undertaken since the completion of the WCSA studies in 1993.
- Synthesis of key water quality findings of these studies into a water quality literature review report.
- Internal review and finalisation of the water quality literature review report.

This report attempts to explore the extent to which the water quality issues in the Berg WMA could be pinpointed so as to put in place practicable solutions, interventions measures and necessary programs (where possible), which would serve to improve the water quality and licensing efforts in the area. This is a complex task since there are various types of pollutants from diverse sources entering the WMA.

1.4 LEGISLATIVE REQUIREMENTS

Prosperity for South Africa depends upon sound management and utilisation of our many natural and other resources, with water playing a pivotal role. South Africa needs to manage its water resources optimally in order to further the aims and aspirations of its people.

1.4.1 The National Water Act

The National Water Act (Act No. 36 of 1998) is the principal legal instrument relating to water resource management in South Africa. The Act is now being implemented incrementally. Other recent legislation which supports the National Water Act (NWA) includes the Water Services Act (Act No. 108 of 1997) and the National Environmental Management Act (Act No. 107 of 1998).

1.4.2 The National Water Resource Strategy

Current government objectives for managing water resources in South Africa are set out in the National Water Resource Strategy (NWRS) (DWAF, 2004). The NWRS is the implementation strategy for the NWA and provides the framework within which the water resources of South Africa will be managed in the future. All authorities and institutions exercising powers or performing duties under the NWA must give effect to the NWRS. This strategy sets out policies, strategies, objectives, plans, guidelines, procedures and institutional arrangements for the protection, use, development, conservation, management and control of the country's water resources. These include:

- The national framework for managing water resources;
- The framework for preparation of catchment management strategies in a nationally consistent way;
- Information, in line with current legislation, regarding transparent and accountable public administration; and
- The identification of development opportunities and constraints with respect to water availability (quantity and quality).

1.4.3 The water quality standards

The discharge of effluent, mainly from wastewater treatment works into rivers within the Berg WMA, is of great concern. The effluent quality discharged into South African water resources is governed by two sets of regulations/ guidelines:

The first set are those specified under the general authorisation in terms of Section 39 of the NWA and apply to effluent discharges into water bodies (DWAF, 1996a). Different wastewater discharge standards for discharging wastewater into water courses and estuaries, which are referred to as Waste Discharge Standards Regulations, have been compiled by DWAF (DWAF, 2000a) and provide what would be a phased approach towards the improvement of effluent quality standards. These regulations, although yet to be promulgated, should be used for future policy and legislation in the planning of future wastewater treatment works (WWTW) developments (Day, 2004) and are expected to replace the general and special limits (refer to Table 4.2. Serious objections to these standards have however, been raised with concerns that the implementation is not practicable at any treatment works, given the financial challenges facing these operations by the municipalities.

- The second set is a series of guideline documents known as the South African Water Quality Guidelines which generally provide a Target Water Quality Range (TWQR) for different water quality constituents, including heavy metals, and estimates of 'acute effect values' and 'chronic effect values' recommended by DWAF (DWAF, 1996). The TWQR applies to the quality of water in rivers and provides the criteria for the correct measurements and evaluation of the water quality constituents. The TWQR are also used in the derivation of resource-directed measures and the source-directed measures aimed at the setting of clear objectives for a desired level of protection for a water resource, satisfy the water quality requirements of water users within reasonable limits and at controlling the generation of water pollutants sources, respectively (DWAF, 2000b). It should be noted that, although the DWAF TWQRs have no legal standing, they however, play a crucial role in setting the resource quality objectives for the water quality component of reserve determinations for rivers and streams (DWAF, 1999).

1.4.4 Catchment Management Strategies

South Africa has been divided into nineteen (19) water management areas. The delegation of water resource management from central government to catchment level will be achieved by establishing Catchment Management Agencies (CMAs) at WMA level. Each CMA will progressively develop a Catchment Management Strategy (CMS) for the protection, use, development, conservation, management and control of water resources within its WMA.

DWAF's eventual aim is to hand over certain water resource management functions to CMAs. Until such time as the CMAs are established and are fully operational, the Regional Offices (ROs) of DWAF will have to continue managing the water resources in their areas of jurisdiction.

This water quality review assessment was also informed by the national guidelines for the protection of the aquatic ecosystem (DWAF 1996c) and those for the use of water for agricultural irrigation (DWAF, 1996b) which was desirable due to the extensive use of river water for the irrigation of agricultural crops in the Berg River WMA.

1.5 ASSESSMENT PROCESS AND SOURCES OF INFORMATION

This water quality literature review report represents a summary of the pertinent findings of the existing water quality studies, best professional judgement and compliance with the South African Water Quality Guidelines (Second Edition) (DWAF, 1996a, 1996b, 1996c, 1996d) and the relevant water quality and effluent discharge standards.

The assessment process relied on information from a number of studies which have focused on different aspects of water quality, including modelling of the parameters in the Berg WMA. Information was accessed from various sources contained in numerous reports, particularly from DWAF, local authorities (directorates of scientific services), various water quality assessment reports and publications from fresh water specialists, ecological/reserve studies, environmental consultancies, independent consultants, relevant groups and individuals.

Information from several existing water quality studies (Dallas, 1995; Dallas and Day, 1995; Day and Dallas; 1996; Dallas *et al*, 1998; Snaddon, 1998 and Snaddon and Davies, 2000) and water chemistry databases for the Berg River was accessed for the Water Chemistry component of the Initialisation Report 2004 (Day, 2004) as part of the Berg River Baseline Monitoring Programme (BRBMP).

A synopsis of the main focus of reports for water quality studies that have been undertaken in the Berg WMA and from which some of the information presented in this water quality literature review report has been largely drawn is provided below:

- **Department of Water Affairs and Forestry, South Africa (2004): Berg Water Management Area: Internal Strategic Perspective**. Prepared by Ninham Shand (Pty) Ltd in association with Jakoet & Associates, Umvoto Africa and Tlou & Matji, on behalf of the Directorate: National Water Resource Planning. DWAF Report No. PWMA19/000/00/0304. The study was aimed at providing a framework for DWAF's management of the water resources in the Berg WMA and to ensure consistency when processing applications for new water licenses.

- **Berg River Baseline Monitoring Programme Initialisation Report - Water Chemistry (2004): Volume 1: Introduction to the Berg River Catchment, the Groundwater Environment and the Riverine Environment and The First Annual Report (edited by Dallas, H and Ractliffe, G. (2004))**. The water quality component of the study as compiled by Dr Liz Day of Freshwater Consulting Group was aimed at accessing and compiling an electronic database of all historical raw data pertaining to the Berg River upstream of the estuary. The interpretation of trends in the water quality was based on the above data and relevant information was presented in a summarised form using tables and GIS maps.

- **Investigation of Microbiological Pollution of the Berg River within Paarl, Drakenstein Municipality from Informal and High-Density Areas (2004)**. The Drakenstein Municipality appointed Lyners Consulting Engineers in association with Ninham Shand Consulting Services to develop an intervention plan supported by all role players to address pollution from under-serviced and high-density settlements in the Paarl area in order to mitigate the impacts of water quality in the Middle Berg River.

- **Water Quality Situation Assessment of Berg River System in Drakenstein Municipal Area (2004)**. Final Report prepared for the Environmental Evaluation Unit (EEU) of University of Cape Town (UCT) by Dean Ollis on behalf of Amathemba Environmental Management Consulting cc. The study was aimed at obtaining relevant data and reporting on the state of water quality of the Berg River and its tributaries within the Drakenstein Municipal Area. This study was also incorporated into the 2004 State of Environment (SoE) Report for Drakenstein Municipality.

- **Department of Water Affairs and Forestry, South Africa (2002)**: **Berg Water Management Area: Water Resources Situation Assessment, Main Report Volume 1**. Prepared by Ninham Shand (Pty) Ltd in association with Jakoet & Associates, Umvoto Africa and Tlou & Matji, on behalf of the Directorate: Water Resource Planning. DWAF Report No. P19000/00/0101. The study was aimed at undertaking a water resources situation assessment for the purpose of gathering information and using it to reconcile the water requirements of the users and the availability. The information produced was for the establishment of the National Water Resource Strategy (NWRS).

- **Snaddon, C D and Davies, B R (2000)**: An assessment of the ecological effects of inter-basin water transfer schemes (IBTs) in dryland environments. Reports to the South African Water Research Commission (WRC), TT665/1/00 and Snaddon, C.D. (1998): Some of the ecological effects of a small inter-basin water transfer on the receiving reaches of the Upper Berg River, Western Cape. Unpublished M.Sc. Thesis, University of Cape Town. These studies reported the results of a three-year water quality monitoring programme between 1994 and 1997, on the Upper Berg River Dam. The programmed was aimed at elucidating the effects of the Riviersonderend/Berg River inter-basin transfer scheme on the macro-invertebrate fauna and water quality of the Berg River.

- **Dallas H F, Day, J A and Day, E G. (1998)**. The effects of water quality variables on riverine biotas. Report to the Water Research Commission. WRC No 626/1/98. The study reported the results of a two-year water quality and macro-invertebrate monitoring programme for the Berg River upstream and downstream of the Berg River.

- **Day, J A and Dallas, H F. (1996)**. Skuifraam IFR Workshop: Water quality of the Berg River. Paper presented to the Berg River IFR Refinement Worksession, Skuifraam Feasibility Study (DWAF). Starter Document for Worksession of 31 January, 1 and 2 February 1996. The study used existing water chemistry data collected by Dallas and Day in 1992 and 1995, and by DWAF from the Berg River gauging stations to assess the water quality of the Berg River IFR. The report summarised spatial and temporal variations in major water quality variables in the Berg River and made broad predictions as to the potential impact on the water quality by changes in flow, and future threats as a result of the implementation of the Berg River Dam.

There are several databases housing water quality data from sampling sites in the Berg WMA that were accessed and analysed by various studies. The databases included:

- **DWAF water quality database**, which is composed of data for numerous physical and chemical parameters collected at the various DWAF gauging weirs as far back as 1965, throughout the Berg River catchment and its major tributaries.

- **DWAF hydrological records for the Berg River** that were accessed by Mr Gerald Howard, the then hydrologist of the BRBMP. The daily flow data in some cases dated as far back as 1949, based on existing disaggregations of monthly data were made available to the water quality study specialist for collation and reporting. This database is also available on DWAF's website: http://www.dwaf.gov.za.

- **The City of Cape Town Scientific Services water quality databases** collected from the long-term monitoring stations at water quality reservoirs, including the Theewaterskloof, Wemmershoek and Voëlvlei water bodies.

- **The South African River Health Programme's database** known as the Rivers Database (Ewart-Smith, *et al*, 2003) and houses *inter alia*, raw data from Dallas (1995) and Brown (1993). The database incorporates biological, physical, chemical and other data collected during, or of relevance to the National River Health Programme.

- **The Biobase database**, owned by the Water Research Commission of South Africa and housed in the Freshwater Research Unit, University of Cape Town is a database of physico-chemical and biological variables collected from a number of South African rivers (Dallas and Janssens, 1999 and Dallas *et al*, 1999).

Information from the above sources has been synthesised and incorporated into this water quality literature review report for the period 1994 to July 2006. This period effectively coincides with the completion of the WCSA studies (in 1993), which is also the period covered by this literature review.

1.6 ASSUMPTIONS AND LIMITATIONS

Given the geographic size of the Berg WMA, the enormous amount of water quality data available and the limited amount of water quality data that has been consolidated, evaluated and synthesised into reports or publications, the water quality assessment summarised in this report is somewhat limited in depth. As with many WMAs nationwide, limited reporting precludes characterising detailed levels of pollutants and essential water quality parameters in most water bodies in the Berg WMA and prevents determining the extent and segment of impairment in most waters.

The lack of consolidated reports underscores the need for improved and expanded ambient water quality monitoring and reporting in priority watersheds within the Berg WMA. This is in order to more completely evaluate and further consolidate and synthesise existing water quality data in databases from DWAF, local municipalities, educational institutions and in the industry.

In undertaking this investigation and compiling this water quality literature review report, the following has been assumed or limits the study unless otherwise indicated:

- One of the major limitations of this study is that the information used in this report relied on data collected and analysed by different research groups and laboratories using different analytical techniques and methods with varying degrees of precision and accuracy. It is therefore inevitable that a substantial but unquantifiable degree of variability could have been introduced to the data.
- It was assumed in some cases that no major changes in water quality have occurred since the last available studies on the water resources were carried out;
- This is a desktop study and relied solely on information contained in existing water quality reports within the Berg WMA. The study did not require site visits and no new water quality data was collected. Also, existing water quality data such as data from DWAF and local authorities' long-term databases of water quality data from 1994 to 2006 was not accessed and analysed as part of the investigation. This was due to the scope of the work and financial constraints.
- Given the assumptions and limitations outlined above, it is important to recognise that the information presented in this report could not be validated and the findings and recommendations presented are based entirely on existing reports.

1.7 STRUCTURE OF THE REPORT

Chapter 1 of the report gives an overview, the need and the objectives of this study, legislative requirements as well as the water quality standards. The assumptions and limitations of the study are also discussed. The assessment process and sources of information which comprises of the water quality studies and databases accessed for the study are also highlighted in this section. The section concludes with a synopsis of the structure of the report.

Chapter 2 provides a brief description of the biophysical and social environment of the Berg WMA. Also included in this section is a brief overview of the WCWSS and the sub-areas of the Berg WMA and the catchments.

Chapter 3 discusses the water quality monitoring initiatives within the Berg WMA, typical water quality parameters monitored and issues and concerns associated with monitoring water quality parameters within the WMA.

Chapter 4 discusses the water quality assessment of the Berg WMA with particular emphasis on the water quality situation of each of the sub-areas. Particular water quality influences as well the major pollutants affecting water quality within the Berg WMA and the sources have been highlighted. Particular influences of water quality from the informal settlements and lessons learnt from previous studies have also been discussed. The chapter concludes with a summary of the water quality situation prior to 1993 and between 1994 and 2006, the period covered by this study.

Chapter 5 discusses water quality and water resource management and management actions to deal with the water quality management issues. The section also touches on the information management with regard to water quality data and reports. The section concludes with a brief discussion of pollution control measures, hazardous spills and the public health and safety with respect to water quality issues.

Chapter 6 discusses the conclusions of the study and recommendations.

CHAPTER 2: DESCRIPTION OF THE STUDY AREA

2.1 OVERVIEW

The Berg River and its tributaries, *viz*. Franschhoek, Wemmer, Dwars, Kompagnies, Klein Berg, Vier-en-Twintig, Kuilsrivier and Salt River, constitute one of the most important sources of water supply in the Berg WMA and the Western Cape Province. Those tributaries rising on the eastern side of the river tend to be perennial while those draining from the western side are semi-perennial. The Berg River rises in the Drakenstein and Franschhoek Mountains and flows in a north-westerly direction discharging into the sea at St Helena Bay. The length of the river itself is approximately 285 km with a width of the catchment of about 1 to 5 km near it origins to about 30 to 40 km at the coast.

The Berg WMA is the smallest WMA in South Africa and falls entirely in the Western Cape Province (**Figure 2-1**), in the south-western corner of the country. The WMA borders the Atlantic Ocean to the south and west, the Breede WMA to the east and the Olifants/Doring WMA to the north-east and is characterised by diverse topographical, climatic and land-use features.

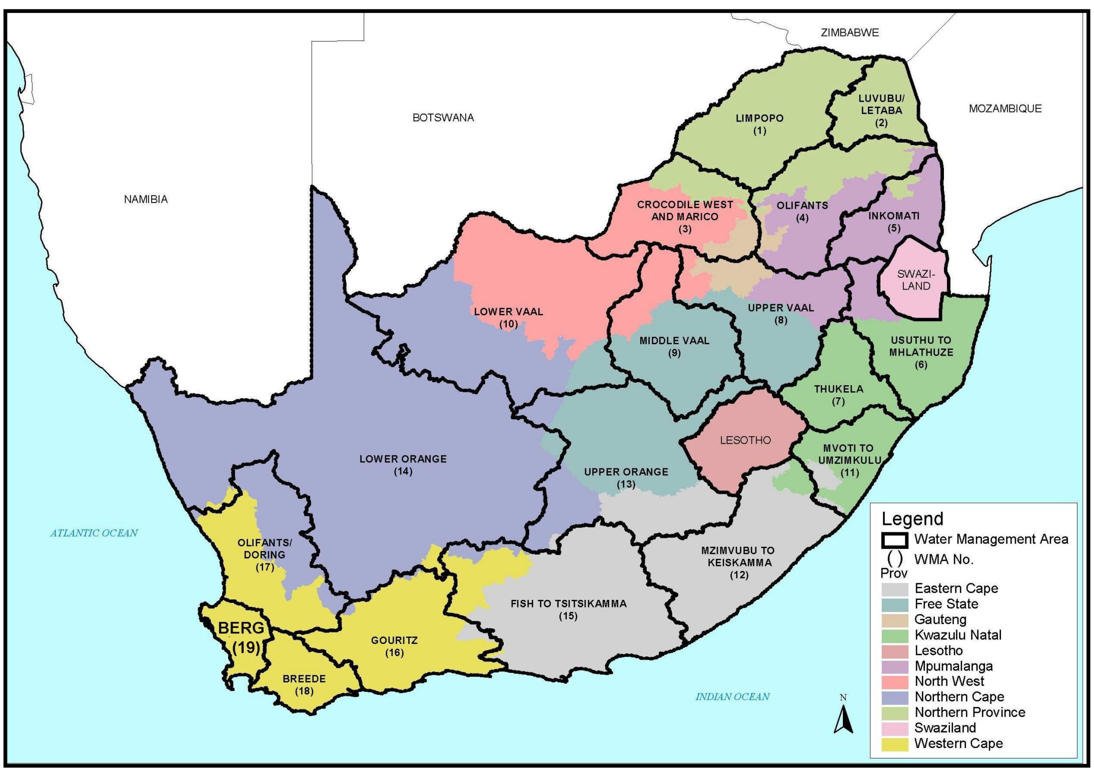


Figure 2-1 Location of the Berg Water Management Area in South Africa

2.2 BIOPHYSICAL AND SOCIAL ENVIRONMENT

Water quality within the Berg River area catchment has been greatly influenced by physical, biological and chemical characteristics. River systems do not maintain pristine conditions along their entire length, but vary from the headwaters near the source to the estuarine near the mouth. Consequently, the quality of water varies with changing concentrations of the various constituents towards downstream. In other to undertake a comprehensive assessment of the water quality within the Berg WMA, it is imperative to include a description of the biophysical and the social characteristics of the affected environment.

2.2.1 Geography

The Berg WMA falls entirely within the Western Cape Province and is situated in the south-western corner of South Africa (**Figure 2-1**).

2.2.2 Topography, rainfall and land-use

The topography varies considerably, with consequential impact on the climate of the region. Rainfall is highest in the southern mountain ranges where the mean annual precipitation is as high as 3 000 mm per annum, whilst the north-western part of the WMA immediately inland of the coast, receives as little as 300 mm per annum. There is intensive irrigation in the Upper Berg River and Lower Berg River sub-areas and in parts of the Greater Cape Town sub-area.

2.2.3 Economic activity

The Berg WMA is the economic hub of the Western Cape, with the dominant commercial and industrial activities taking place in Cape Town and the developing West Coast (Saldanha/ Vredenburg in the Lower Berg sub-area). Approximately 12% of the Gross Domestic Project (GDP) of South Africa originates from within this WMA, mainly in the Greater Cape Town sub area.

2.2.4 Population

Of the total Berg WMA population, estimated at 3 247 000 in 1995, 95% reside in urban areas, with 87% concentrated in the Greater Cape Town sub-area.

2.3 THE WESTERN CAPE WATER SUPPLY SYSTEM

The Western Cape Water Supply System (WCWSS) is one of the most important factors in the water environment of the Berg WMA. The Berg WMA is predominantly supplied with water via the WCWSS (**Figure 2-2**). The WCWSS serves the City of Cape Town (CCT), other water service providers and water users associations (irrigators) in the catchments of the Berg and Eerste, Lourens, Steenbras and Palmiet Rivers, domestic and industrial users on the West Coast and other irrigators and urban users in the Riviersonderend catchment of the Breede WMA. The scheme is operated in an integrated manner in order to reduce spillage and make optimum use of the limited available yield in the region.

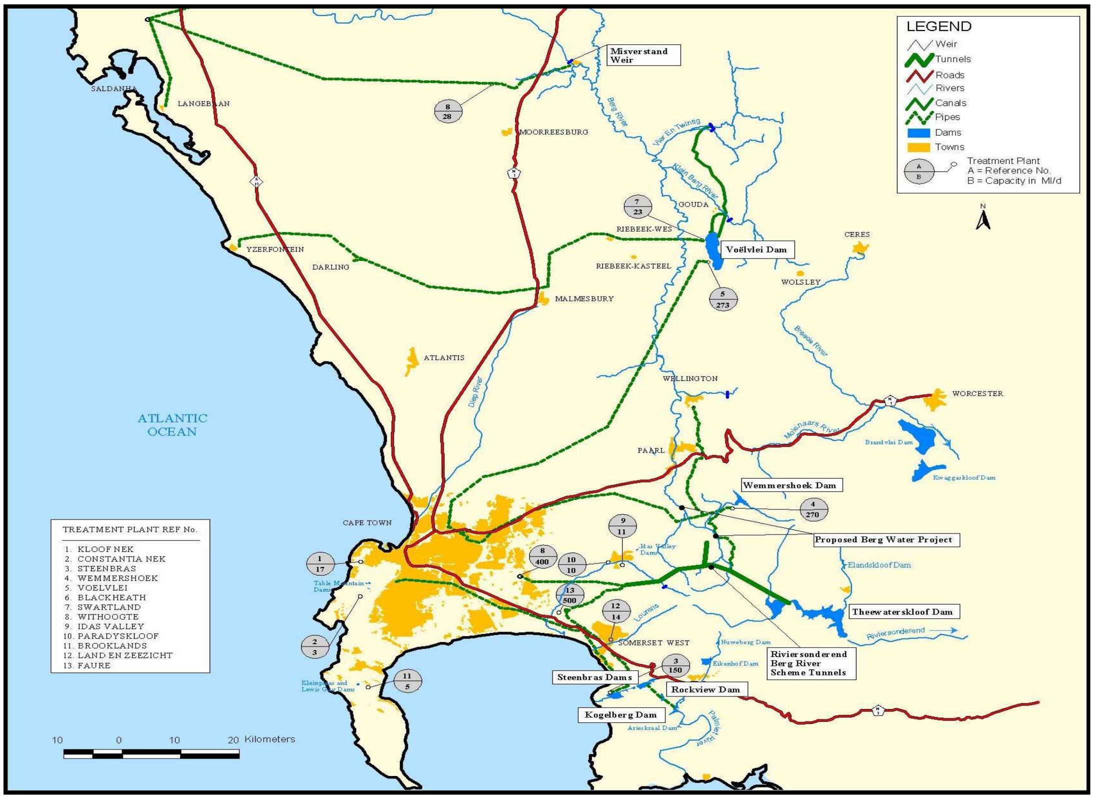


Figure 2-2 Western Cape Water Supply System

Existing storage dams and the future Berg Water Project form part of this integrated system, operated in such a manner that spills from the storage dams are minimised. The Berg Water Project, comprising the Berg River Dam (formerly known as Skuifraam Dam) and Supplement Scheme, a run-of-river pumping scheme, will be completed by 2007. The WCWSS is co-operatively managed by the CCT and the DWAF Regional Office. The majority of towns in the Berg WMA are either wholly or partially supplied by this integrated scheme.

A committee comprising DWAF and all major stakeholders reviews the system storage and projected demands annually on 1 November and decides whether or not restrictions need to be recommended for the following year. Other operational challenges include the need for close co-operation with authorities such as Eskom, varying water quality, and the operation of the Riviersonderend–Berg River Tunnel system which provides the means of transferring water from the Breede WMA into the Berg WMA.

The WCWSS is operated in an integrated manner and as such, this assessment of the water quality status within the Berg WMA will be best assessed at a regional level, rather than at a detailed level such as at the level of quaternary catchments. Consequently, for the purposes of this study, the Berg WMA has been divided into three sub-areas: Upper Berg, Lower Berg and Greater Cape Town as depicted in **Table 2-1** and **Figure 2-3**). These sub-areas correspond with the so-called areas of interest used in the National Water Resource Strategy (NWRS).

Table 2-1 Sub-areas of the Berg WMA and catchments

Sub-area	Brief description
Upper Berg	The sub-area extends from the source of the Berg River in the Franschhoek Mountains and includes the Berg River catchment down to Misverstand Weir, south of Piketberg and consists of 8 quaternary catchments (G10A – G10H).
Lower Berg	The sub-area encompasses the downstream reaches of the Berg River catchment together with the endorheic areas along the west coast, including the Diep River catchment in the southern part of the sub-area. The sub-area consists of 10 quaternary catchments (G10K, G10M, G21A-G21F and G30A.
Greater Cape Town	The sub-area encompasses the remainder of the Berg WMA and consists of 11 quaternary catchments (G22A-G22K and G40A). This sub-area includes the urban rivers in the Cape Town Metropolitan area, the Kuils, Eerste, Lourens and Sir Lowry's Pass Rivers, as well as the Steenbras River

The sub-division is in order to illustrate the broad overview of the water resources situation in the WMA and to facilitate the applicability and better use of information for strategic management and planning purposes, and for assessing the reconciliation of water availability, quality and requirements. The so-called areas of interest are depicted in **Figure 2-3**).

This study makes use of these sub-divisions and will thus report on the water quality status of surface waters (rivers, dams, estuaries and reservoirs) in these so-called areas of interest in the WMA, based on a review of existing literature.

Figure 2-3 The so-called areas of interest in the Berg WMA as depicted in the NWRS

CHAPTER 3: WATER QUALITY MONITORING IN THE BERG WMA

3.1 OVERVIEW

To meet the requirement for integrated information DWAF reviews and revises where necessary, all data-acquisition, monitoring and information systems. This puts a strong responsibility on DWAF.

The Water Services Act requires the Minister of Water Affairs and Forestry to establish national monitoring systems for water resources to collect appropriate data and information. DWAF operates several monitoring systems that collect some of the required data and information and addresses the shortcomings of the arrangements by amalgamating all existing and planned monitoring and assessment systems into a structured and coherent monitoring, assessment and information system.

The design and implementation of effective water quality monitoring networks and repository databases to ensure adequate quantification of the balance between sustainable water use and protection for surface freshwater bodies and groundwater would be important in the Berg WMA. An important component of this initiative would be to develop collaborative relationships between DWAF and other organisations involved in other water-related monitoring activities and information systems in the Berg WMA. Nonetheless, a National Monitoring Strategy is currently being developed by the DWAF and would be very useful in providing water quality information for the WMA.

3.2 MONITORING INITIATIVES IN THE BERG WMA

The resources currently available for water quality monitoring (surface and ground-water) are generally inadequate throughout all existing systems across South Africa. Some notable issues of concern in the Berg WMA relate to inadequate groundwater monitoring, groundwater/surface water interaction and a need to implement estuarine flow gauging.

Effluent from industrial consumers is generally discharged into the sewage system and treated at the wastewater treatment works and is therefore not considered as a pollution threat. However, industrial effluent which ends up in the stormwater system presents a real and serious threat. Containment of chemicals in storage and during transportation presents a definite risk to the stormwater system and hence the environment at large. The Water Pollution Control Inspectorate and Tradewaste Laboratory are equipped to monitor industrial effluents and provide assistance with containment during pollution incidents.

3.2.1 The City of Cape Town Scientific Services

The Scientific Services Department of the Cape Metropolitan Council has been involved in monitoring water quality within its Metropolitan area for over three decades (i.e. since about 30 years ago). There are twenty sewage treatment works within the municipality with a combined design capacity of about 500 mega litres per day which the City of Cape Town currently operates. The Scientific Services Department conducts extensive water quality monitoring and collects samples from 145 sampling points throughout the Metropolitan area to analyse a number of water quality parameters. This is achieved with a number of monitoring programmes which includes the urban river water quality monitoring programme primarily aimed at establishing the impact of treated effluent on the urban rivers, leaks in sewers and overflowing sewage pumping stations, runoff and rainfall events. These are collectively monitored as sewage and storm water systems. Certificates of analysis are being issued for each scheduled sampling run by the Scientific Services Department to other Departments such as roads, stormwater and sewage.

3.2.2 River Health Programme

Two monitoring initiatives in the Berg WMA which focused mainly on the Berg River Catchment were recently completed. These programmes both provided vital information for reviewing water quality in the Berg WMA and are briefly discussed:

a) State-of-Rivers Report: Berg River System - 2004

The study was undertaken by DWAF and Cape Nature Conservation during 2003 and completed in 2004 (River Health Programme, 2004) as part of the national River Health Programme (RHP) to produce a State-of-Rivers Report for the Berg River System.

The State-of-Rivers Report for the Berg River System (River Health Programme, 2004) recommended actions that should be implemented in different areas of the Berg River Catchment in other to improve on the water quality largely according to its suitability for aquatic biota.

b) State-of-Rivers Report: Greater Cape Town's Rivers - 2005

The study was undertaken by DWAF and was completed in 2005. The study constitutes part of the national River Health Programme (RHP) operational since 1994. The study covers the major catchments within the greater Cape Town, *viz*: Steenbras, Sir Lowry's Pass, Lourens, Eerste/Kuils, Sand, Zeekoe, Silvermine, Hout Bay, Salt, Diep and Sout. The report indicated that only a few of the upper reaches of rivers in the Greater Cape Town area are still in a natural or good ecological state with significant stretches of the rivers having poor water quality.

3.2.3 Berg River Baseline Monitoring Programme

The Berg River Baseline Monitoring Programme (BRBMP) was initiated in 2003 "to describe the natural and present state, including the natural variability, of those chemical, physical and biological characteristics of the river and its hydraulically linked systems (i.e. estuary, floodplains and groundwater) that are most likely to be affected by changes imposed after the construction of the Berg River Dam" (Dallas and Ractliffe, 2004).

The BRBMP has culminated in the production of two reports: The Initialisation Report (Ractliffe and Dallas, 2004) and the First Annual Report (Dallas and Ractliffe, 2004). The former comprises of three volumes - Volume 1 deals with the groundwater and riverine environment of the Berg River Catchment; Volume 2 deals with the estuary and floodplain, and Volume 3 deals with the social and cultural aspects relating to the Berg River.

The water chemistry component (compiled by Dr Liz Day) of Volume 1 of the Initialisation Report (Ractliffe and Dallas, 2004) provides a synthesis of the existing water quality monitoring data and studies that have taken place over the last 50 years, and outlines the most important characteristics and trends (in the water quality) in the Berg River. The study reported that one of the major problems that the groundwater/surface water monitoring for the BRBMP would encounter is the assessment of impacts of the quantity and quality of the irrigation return flows into the river.

3.2.4 Drakenstein Municipality Berg River Monitoring Programmes

Drakenstein Municipality operates within its municipal boundaries a programme to monitor water quality in the Berg River. This programme was established in 1999 and collects samples monthly at nine (9) sites along the length of the Berg River starting at the southern municipal border and ending at the northern municipal border at Lady Loch Bridge (refer to **Table 3-1**).

The water samples from these sampling points are analysed for a number of chemical and microbiological constituents. The programme provides good information on the water quality status of the Berg River and how it changes over time along its entire length.

Table 3-1 Berg River monitoring locations for Drakenstein Municipality

Point number	Location
B3	Berg River Resort (Southern Paarl)
B3	Cecilia's drift
B4	Pump station Berg River Boulevard
P1	Market street bridge
P2	Lady Grey Street bridge
P3	Long street bridge
P4	Upstream of final effluent at sewage works
SW ABW	Northern municipal border
B5	Lady Loch bridge

There are seven additional monitoring points, which are all situated on the tributaries or stormwater canals draining into the Berg River from the eastern side of Paarl/Wellington. The points are as follows:

- Palmiet/Hugo River at Distillery Road,
- Dal Josafat stormwater canal at Vosmaar Road,
- Groenheuwel Canal at the entrance to the Paarl WWTW,
- Stream between C and D dams,
- Moonlight Road canal,
- Oliver Tambo Villa canal, and
- Newton canal.

3.3 TYPICAL WATER QUALITY PARAMETERS MONITORED

Several water quality parameters should normally be sampled, and the data recorded and stored in databases by trained personnel. Water quality parameters measured could be divided into different categories depicted in **Table 3-2**, which include *inter alia*: pH, dissolved oxygen, biological oxygen demand (BOD), temperature, conductivity, turbidity, fecal coliform.

Also, typical water quality parameters monitored in previous studies and reported in WRC Report No 598/1/1, 2001) were divided into different categories as shown in Table **3-2**..

Table 3-2 Typical water quality parameters monitored

Category	Parameters
Physical	Electrical conductivity (EC), turbidity, temperature, suspended sediment, suspended solids (SS), colour
Inorganic major ions	Calcium, magnesium, sodium, potassium, alkalinity, bicarbonate, sulphate, chloride, fluoride, silica, pH
Trace metals	Zinc, arsenic, lead, nickel, iron, manganese, mercury, antimony, cobalt, chromium, cadmium, copper, silver, barium, boron
Organic	Pesticides, cyanide compounds, total organic carbon (TOC), hydrocarbons, dissolved organic carbon (DOC), carbonaceous oxygen demand (COD), dissolved oxygen (DO)
Nutrients	Ammonium ($NH4^+$), nitrate (NO_3), total Kjeldahl nitrogen (TKN), soluble phosphate (sol-PO_4), ortho-phosphate (ortho-PO_4), total phosphorous (total-P), biochemical oxygen demand (BOD)
Microbiological	Faecal coliforms, faecal streptococci, coliphages, total coliforms Escherichia coli (*E. coli*)
Litter	Plastic, glass, paper

Source: (WRC Report no 598/1/1, 2001)

3.4 ISSUES AND CONCERNS OF WATER QUALITY MONITORING IN BERG WMA

The following specific observations, issues and concerns for surface water quality monitoring were identified for the Berg WMA:

- A base-line monitoring programme of the Berg River is currently in progress to establish the existing biota in the river (Day, personal communication). This will be used to evaluate the extent of potential impacts of Reserve releases from the Berg River Dam and other potential schemes.
- Monitoring of wetlands and estuaries is insufficient.
- Monitoring of the interaction between surface and groundwater is insufficient.
- There is a need for monitoring of Reserve releases to ensure compliance with the applicable authorisation requirements.
- There are a number of major players in the gathering of hydrological information, notably DWAF, CCT, Department of Agriculture, and CSIR. A co-ordinating committee has already been established.

- Global warming is predicted to have a very serious impact on the Western Cape, with a possible 30% reduction in mean annual rainfall (MAR). This must be monitored, predicted, and steps taken to mitigate reduced flows.
- A number of rainstations with long-term records operated by the Weather Bureau have been closed, adversely affecting the ability to calibrate rainfall runoff models, which apparently is a national issue.
- There is no water quality monitoring of the Steenbras River, other than in the dam itself. The effect of dilution in the Upper Steenbras Dam, of the Palmiet River IBT (23 million m^3/a) is not well established.

CHAPTER 4: WATER QUALITY ASSESSMENT IN THE BERG WMA

4.1 OVERVIEW

Surface water quality in the Berg WMA is affected by many factors including sediment and erosion, diffuse discharges from irrigated farmland (both fertilisers and salinity through leaching), domestic and urban runoff, industrial waste, and sewage discharges. Of these sources of pollution, industrial waste and sewage discharges are the easiest to licence and control, but this does not mean that they are problem-free. DWAF has found that the situation with regard to sewage discharges often far exceeds the standards and conditions demanded by licences. There is a problem of compliance with regard to local authorities and private operators responsible for waste management systems. Diffuse discharges only compound the problem by reducing the assimilative capacity until the water becomes unfit for use, very expensive to purify, and a danger to human health.

Industrial wastewater discharge, diffuse agricultural discharges, wastewater treatment works, location and management of solid waste disposal sites, siting of new developments, informal settlements and impacts of sanitation systems, are all elements that impact on water quality in the Berg WMA and are considered with great concern in this review report. Despite the attention that has been given to water quality in the Berg WMA (DWAF, 2004), it has still not taken its rightful place in the integrated management of water resources. However, DWAF is moving towards Integrated Water Resource Management (IWRM) and the integration of water quantity and water quality issues. Managers have now been given crosscutting responsibilities that will ensure a far more integrated approach in future.

4.2 PRINCIPAL WATER QUALITY INFLUENCES ON THE BERG WMA

The water quality of the Berg River catchment is influenced to a large degree by the geology of the basin (DWAF, 1993a and b). In the mountains and upland areas of the basin the geology comprises Table Mountain Sandstone (TMS) (Bath, 1993a,b). 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.

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 Rivers) 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, Sand Spruit and Moorreesburg Spruit. 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 (refer to **Figure 2-3**) (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.

4.2.1 Mineralogical water quality in the Berg WMA

The mineralogical water quality of the surface water bodies is described in terms of total dissolved salts (TDS). 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 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.

4.2.2 Microbiological water quality in the Berg WMA

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

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 the 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 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.

4.3 POLLUTANTS AFFECTING WATER QUALITY IN THE BERG WMA

The term "pollutant" is a general term that, in the case of contaminants to the water resources in the Berg WMA, could include nutrients, partially oxidised organic waste/ material and other constituents. Some of these can be more easily controlled than others. The inherent effect of the pollutants would depend on the type of pollutant, its concentration and the length of exposure to the river communities.

The pollutants can be summarised according to their physico-chemical nature and can be broken down into three components:

- toxic substances, comprising of organic and inorganic pollutants, which include heavy metals and trace organics, decrease in concentration with increase in flow volumes by precipitation and adsorption;
- nutrients, which also includes nitrogen and phosphorous, and ammonia which results in an increase in toxicity and a reduction dissolved oxygen further downstream; and
- system variables, those constituents which vary due to the local and/or regional climatic, geochemical and hydrological characteristics. The variables comprise of pH, water temperature, dissolved oxygen, total dissolved solids (TDS) and total suspended/settleable solids (TSS).

4.3.1 Point source and non-point source pollutants

In addition to the various components of pollutants, there are two general categories of pathways through which pollutants can enter water resources in the Berg WMA. These two pathways are called "**point source**" and "**non-point source**" and are briefly described below:

a) Point source pollution

Point source pollution in the Berg WMA primarily originates from industrial facilities and municipal sewage treatment works (i.e. industrial and municipal effluents), where the discharge of wastewater or treated effluent can be pinpointed to a discrete pipe or ditch. Point source pollutants are subject to regulation and the wastewater discharge is expected to comply with DWAF's general standard effluent limits which could also be stipulated in the permits requirements.

b) Non-point source pollution

Non-point source pollutants in the Berg WMA on the other hand, comprises primarily of all other sources of pollutions, which are characterised as area-wide. These non-point source pollution causes diffuse discharges of pollutants to land and/or water and have been reported to contribute to degradation of water quality (Henderson *et al*, 1998). Non-point sources include *inter alia*:

urban, residential and agricultural runoff, below-quality effluent from sewerage works, raw sewage spills from some pump stations, polluted runoff from informal settlements and urban runoff, septic systems, and leaking fuel storage tanks.

Some activities, such as mining activities and developments could include both point and non-point sources. Greater success has been achieved in stemming point source pollutants than non-point source pollutants. Consequently, water quality trends for the specific types of pollutants must be described separately in order to accurately describe the trends and existing conditions. The trends described in this literature review report are peculiar to the Berg WMA and include *inter alia* the amount of organic waste discharged into the water resources of the WMA from municipal wastewater treatment facilities, soluble nutrients from these facilities, microbiological pollution from informal settlements, dams' construction activities, and pollutant sources attributable to agricultural activities (irrigation, return flows, etc).

Various studies undertaken by the Water Research Commission of South Africa in 2001 identified pollutants of concern and their major sources in urban areas (summarised in **Table 4-1**). Some of these pollutants sources have also emerged as potential sources of pollutants and concern in the Berg WMA.

Table 4-1 Pollutants and their major sources in urban areas

Pollutant sources	Pollutant of concerns
Domestic wastes, overloaded sanitation systems, night soil dumping, surcharging sewers, absence of sewerage services, human and animal excreta.	Nutrients, faecal bacteria, viruses, organic matter
Vehicle emissions, industrial emissions, spills, atmospheric deposition, pavements, roads	Heavy metals, hydrocarbons, oils, toxins, SO_2, CO, nitrous oxides (NO_x), lubricants
Litter, inadequate services, solid waste dumping	Plastic, paper, glass, organic compounds
Erosion, construction, vegetation, removal	Suspended soils
Urban pesticides spraying, fertilisers, herbicides and lightening	N-compounds
Vegetation, pollen and atmospheric deposition	P-, N-, and organic compounds
Wind, rain and groundwater	Dust, chlorides, S-compounds, leachates
Washing of clothes, vehicles, etc.	Dissolved solids, chlorides, phosphates
Burning of litter, wood and coal (deposition)	Dissolved solids, sulphate, carbon, particulate matter

Source: (WRC Report no 598/1/1, 2001)

4.3.2 Pollution from informal settlements

Pollution from densely populated and poorly serviced informal settlements and "squatter camps" is probably one of South Africa's most significant but rather complex water quality problems (DWAF, 2001). Informal settlements contribute to non-point sources of pollution or broad and diffuse pollution resulting from land runoff, precipitation, atmospheric deposition, drainage and seepage (Chanler, 1994 as quoted in Henderson *et al*., 1998). The problems in these settlements are rooted from socio-economic, political and institutional conditions and the situation in the Berg WMA is not different from any other areas in the country.

The primary sources of water quality pollution from informal settlements in the Berg WMA area were found to be pollutants from the following sources:

- surcharging sewers;
- pit latrines;
- low-flush systems;
- septic tanks;
- night soil buckets; and
- refuse dumping.

Some major findings of water quality pollution from informal settlements as reported (Drakenstein Municipality, 2004) included:

- The water quality of stormflow runoff from unserviced settlements in some instances compared with raw sewage and dry weather flows with settled sewage for some pollutants.
- The areas with “shacks” tend to be the greatest sources of pollution with increasing pollution found in areas with higher population densities and lower living standards.
- The extent of pollution and water quality runoff is affected by the following factors: local climate, hydrology, topography, geomorphology, geology and soil conditions, extent of impervious areas, urban geography, existing stormwater reticulation systems, land use and available land area.
- In the South Western Cape, higher pollutant concentrations were encountered during the drier months which could be attributed to base flows. It was, however, found that total pollutant loads, especially TDS, were three times higher than average for Khayelitsha during winter stormflow conditions.
- It was reported that no “first flush” effect occurred in the South Western Cape and that pollution, especially microbiological increased with flows and concentrations remained high over long periods.

The pollution problems reported in these areas is such that additional infrastructure for low cost, high-density settlements would not necessarily reduce the pollution levels. Installation of water borne sewerage and stormwater systems have in the past been reported to instead, exacerbated the contamination problem, since runoff from the affected areas usually follow direct pathways to receiving waters without any formal treatment or even indirect natural "treatment", such as ponding, infiltration or filtration.

a) Concerns on sources of pollution in informal settlements

Concerns on the sources of pollution in the informal settlements within the Berg WMA have been expressed by various officials, councillors and other parties mostly regarding the following:

- solid waste pollution,
- microbiological pollution,
- apparent lack of policies in dealing with the erection of informal structures,
- policing of structures and methods to curtail the erection of structures and demolishing thereof,
- servicing of informal areas,
- Spoornet concerns regarding the condition of areas around the railway lines,
- Eskom concerns regarding invasion of Eskom servitudes areas and risk associated with any structures erected under power lines.

The Engineering Department of Drakenstein Municipality's preliminary assessment of the Berg River downstream of Paarl and Wellington indicated that microbiological pollution was so high that it posed a high human health risk to people who come in direct contact with the water or use it for drinking water (Drakenstein Municipality, 2004).

b) Intervention mechanisms in informal settlements

DWAF released The National Strategy in September 2001 (Managing the Water Quality Effects of Settlements) (DWAF, 2001) which consisted of a series of strategies and guideline documents as part of the development of the strategy to manage the water quality effects of settlements. The strategy documents described the general approaches towards managing pollution from densely populated and often under-serviced communities and focuses on four waste streams:

- sewage;
- sullage or grey water;
- storm water; and
- solid waste.

The "Structured Facilitated" approach is generally used as a tool for identifying problems in each of the waste streams and the underlying physical, social and institutional issues. This is achieved by investigating the pollution problem in increasing depth until consensus and agreement can be reached on the root cause(s) of the problem.

It is evident that, although DWAF, the departments of Environmental Affairs and Agriculture have the shared responsibility of ensuring the reduction of pollution of the Berg River, dealing with the sources of water pollution issues around high density areas and informal settlements requires an integrated approach and efficient communication between various relevant local authorities and the community at large.

The issues of polluted runoff from densely populated informal settlements require intervention at the physical/technical, social, political and institutional levels if a long-term and sustainable solution is to be sought. A framework for municipal policies and decision making for addressing the various areas of concern has however, been considered (DWAF, 2004).

There has been intervention from some Local Municipalities such as the Drakenstein Municipality. The Drakenstein Municipality appointed Lyners Consulting Engineers (in 2004) to formulate an intervention plan to address the issue of polluted runoff from informal settlements within the Paarl/ Wellington area that are poorly services or have no service in order to minimise the water quality impacts on the Berg River. Many other programmes have been developed to monitor the water quality situation within the Berg WMA (refer to **Section 3.2**).

c) Lessons learnt from dealing with non-point source pollution

Some important lessons in dealing with non-point source pollution have been learned by DWAF from a number of settlements in the Western Cape Province, some of which are as follows:

- The affected communities need to take ownership of the problems as well as the solutions to it. Buy-in therefore is needed from the community to find long-lasting and sustainable solutions.
- The focus of people is always on the need for work and housing and little is done to address the main issue, which is pollution of water resources from the informal settlements. It is important to explain to the people the capacity problems and constraints the municipalities are facing which exacerbate the current water pollution problems.
- Systems need to be put in place by the Municipalities to direct problems to the appropriate department and reporting channels clearly defined.
- There is a need to educate people on the difference between the stormwater system and the sewerage system.
- Implementation of systems for collecting the necessary funds for cleaning communal toilets in a rotational manner with the cleaning family getting the funds for that month.
- Training of people in the local municipalities in basic plumbing skills to do maintenance, such as the initiative of the Department of Labour in Kayamandi.
- The need to close all open channels, such as in Fairyland where children play in the water of open channels.
- The need to appoint community leaders as members of the steering committee.

4.4 WATER QUALITY OF THE RIVERS IN THE BERG WMA SUB-AREAS

As discussed in Section 2.3 (**Table 2-1** and **Figure 2-3**), the further sub-division of the Berg WMA into eight management sub areas as defined by the NWRS (**Figure 4-1**) was necessary to facilitate assessment of water quality issues and concerns which could require further investigation and/or intervention to facilitate water quality planning and licensing.

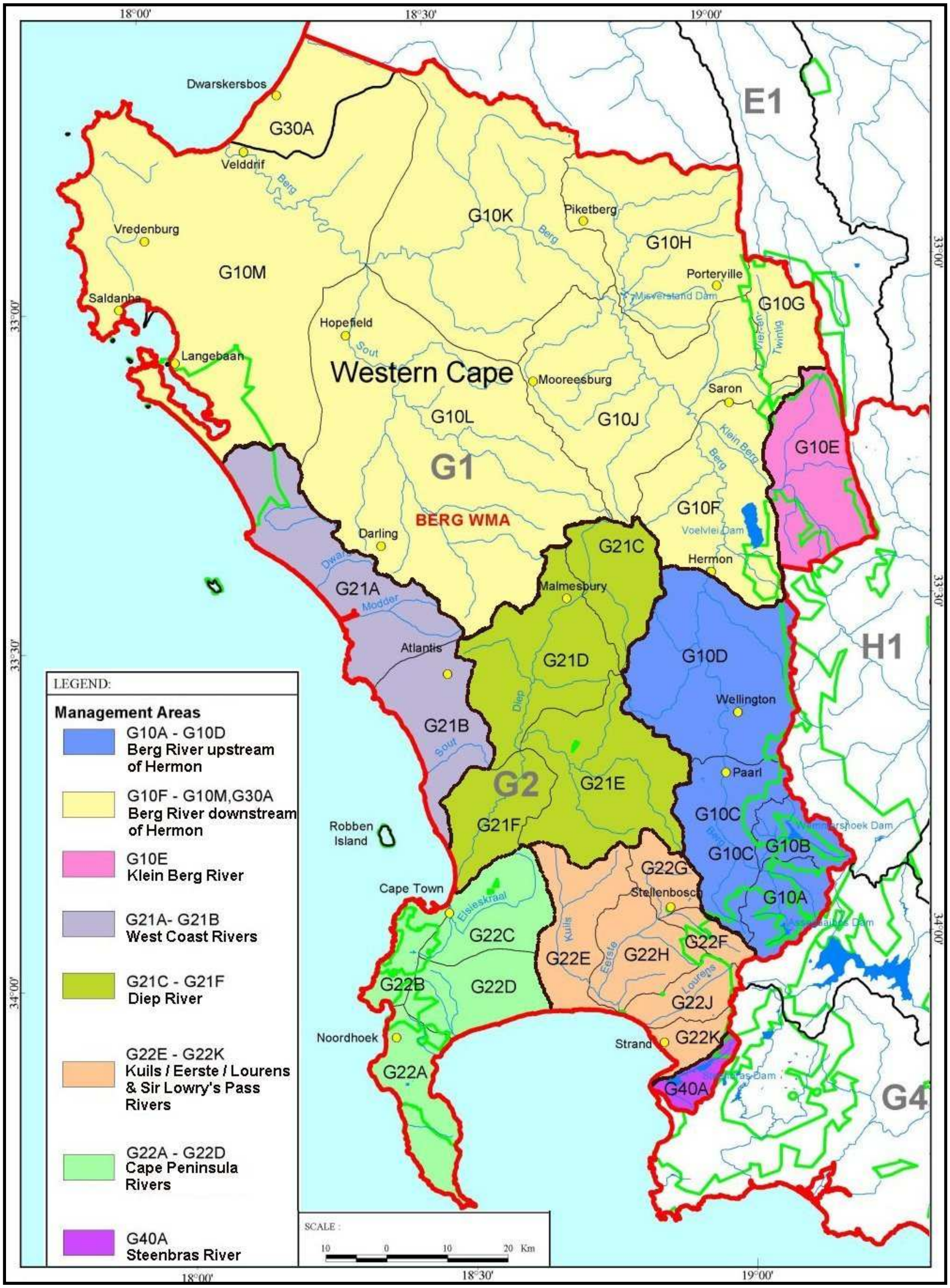


Figure 4-1 **Management sub-areas of the Berg WMA as defined in the NWRS**

A brief description of the rivers in the sub-areas and the water quality issues and concerns captured in this water quality literature review report is provided below:

4.4.1 The Berg River upstream of Hermon

The sub-area consists of four quaternary catchments (G10A - G10D) and extends from the source of the Berg River in the Groot Drakenstein Mountains, to the flow gauging station (G1H036) at the bridge near the town of Hermon. The sub-area covers approximately 1 310 km^2. The topography is characterised by high mountain ranges in the south and east which drain towards the Berg River. The maximum mean annual precipitation (MAP) in the high lying southern areas reaches 3 200 mm which declines to about 600 mm at the town of Hermon.

The water quality of this section of the Berg River catchment is better than that of the lower reaches of the Berg River, where salinity problems occasionally occur. Certain of the headwaters of the Berg River are normally acidic and coloured brown as a result of dissolved humic substances. Although this has some impact in terms of treatment required to reach potable standards, it is not considered to be a significant problem. There are concerns that pesticide residues washed into the rivers through irrigation and the leaching of fertilizers as a result of irrigation, are impacting on water quality of the Berg River and its tributaries. The potential impact of aquaculture activities on water quality is a further concern (DWAF, 2004).

4.4.2 The Klein Berg River

The sub-area consists of only one quaternary sub-catchment, namely G10E which has an approximate area of 390 km^2. The Tulbagh Valley is bounded in the east by the Witzenberg Mountains and in the north by the Groot Winterhoek Mountains. The mean annual precipitation (MAP) for the catchment is 640 mm, with the highest rainfall being recorded along the south-east boundary, where the MAP reaches 1 000 mm.

Poor quality effluent discharged from the Tulbagh wastewater treatment works (WWTW), winery effluent discharged into the Klein Berg River, and pollution from informal settlements contribute to the poor water quality in this river. The extent of the direct discharge from the wineries into the river is not well established but may have a considerable cumulative effect.

Similarly, the impact on water quality of the return flows arising from over-irrigation (with winery effluent) in close proximity to the river, is also of concern. The Tulbagh WWTW is designed for domestic effluent, however traces of fruit waste are common. Vandalism and pipe blockages in the reticulation system cause spills from manholes into the stormwater system.

The water quality problem in the Klein Berg River is exacerbated at the start of winter due to diffuse pollution being washed into the river from adjacent informal settlements. As a result it is desirable that the runoff from the first winter rains is not diverted into Voëlvlei Dam, so as to minimise the impact on the water quality in Voëlvlei Dam. The management of the diversion in accordance with water quality has not yet been formally implemented, on account of the impacts of the potential loss of yield on the supply until the Berg Water Project is completed. There is therefore an urgent need to attend to the pollution risks in the catchment (DWAF, 2004).

4.4.3 The Berg River downstream of Hermon

The sub-area consists of quaternary catchments G10F - G10M, as well as G30A. It covers an approximate area of 7 450 km^2. The MAP in the most easterly quaternary (G10G) is approximately 1 300 mm (Groot Winterhoek Mountains). The average MAP over the remainder of the sub-area ranges from 450 mm (G10J) to as low as 300 mm (G10M), towards the coast.

In the Berg River, downstream of Voëlvlei Dam, water quality during the summer months is generally good because water is released from Voëlvlei Dam to supply downstream irrigators and regional water supply schemes. The water quality deteriorates further downstream on account of high salinity return flows and cannot be utilised for the environment and the estuary. However, nutrient rich inflows from the Klein Berg River together with the releases of nutrients in the dam sediments due to wave action, has resulted in algal blooms which cause taste and odour problems and must be removed at high cost by utilising activated carbon.

Occasionally during the winter months natural runoff from the more saline Malmesbury shale soils may result in salinity at Misverstand Dam exceeding 400 mg/l for periods of up to three weeks which is apparently detrimental to the processes at Saldanha Steel. Salinity concentrations and their duration will increase after the Berg Water Project is implemented and strategies for dealing with this are currently being investigated by DWAF's Directorate : Option Analysis. As one moves further downstream, the water quality becomes more saline, due to the further influence of the geology and return flows. At the lowest reach of the river, the tidal impact, together with the effect of the geology, results in a high salinity. Nutrients from upstream return flows and agricultural return flows annually result in extensive water hyacinth growth in the upper reaches of the Berg River Estuary (DWAF, 2006).

4.4.4 The West Coast Rivers

The sub-area consists of two quaternary sub-catchments, namely G21A and G21B, covering an area of approximately 830 km^2. The MAP of the region is approximately 410 mm and as a result, surface water resources are limited and recharge of the groundwater resource is not high.

There is a strong reliance in this sub-area on groundwater. The main concern is the extent of the impact on groundwater quality from the effects of land sub-division. This is primarily due to the increased abstraction by poor small-scale users under Schedule 1, coupled with the increased use of pit latrines in the absence of proper services. As a result, the primary coastal aquifers may be at risk. No specific problems have been identified with regard to the operation of WWTWs in this sub-area. Aquifer Storage Recovery is effectively utilised near Atlantis, by recharging with stormwater runoff and injecting treated effluent from the Wesfleur WWTW into the aquifer.

In the West Coast District Municipality area, high total dissolved solids (TDS) concentrations are a major concern for Saldanha Steel and other industries in the Saldanha Bay area. TDS concentration in Misverstand Dam is affected by the concentrations entering from immediate upstream tributaries i.e. Moorreesburg Spruit and the Matjies River. The effect of TDS in the Matjies River on the Berg River water quality is experienced on a larger scale since it is the largest contributor of TDS load to the Berg River and is accompanied by relatively high TDS concentrations (median above 1000 mg/l). It can be assumed that the Matjies River has a substantial influence on the seasonal distribution of TDS at Misverstand Dam but it is most certainly not the only influence on the TDS seasonal distribution (DWAF, 2006).

Monitoring of the intrusion of seawater, as a result of groundwater abstraction, is required. Surface runoff from the short coastal rivers is very erratic and of relatively high salinity.

4.4.5 The Sout River

The area consists of the Sout River catchment which rises in the low-lying hills east of Melkbosstrand, on the West Coast. The geology of the catchment comprises of primary shales of the Malmesbury Formation, characteristic of the Berg WMA. The Sout River is relatively short and measures only 18 km in length with a draining catchment of about 154 km^2 (Engelbrecht *et al*, 1997). A number of small streams and other drainage lines enter the river along its entire length, although, the only tributary of significance is the Donkergat River which joins in the region of Kleine Zoute Rivier farm. The MAP of the region is approximately 424 mm and occurs primarily during winter. The natural summer flows in the region, predominantly through agricultural land are low and probably remains ephermeral throughout it reaches with water remaining in small pools.

The water quality data in the Sout River is very limited. Effluent from the Wesfleur and Melkbosstrand WWTWs is discharged into the Sout River resulting in significant changes to the natural flows and water quality of the river (Day, 1998). The water flowing in the Sout River is brackish with high concentrations of dissolved salts measured as electrical conductivity (EC) which increases downstream along the river with values as high as 1600 mS/m upstream of the Melkbosstrand WWTW in summer. The water quality of this river is so poor in summer months to the extent that it has been reported to be unfit for irrigation or use by livestock for drinking. This deterioration in water quality could be attributed primarily to the influence wielded upstream of the Darling/Mamre Road Bridge and the large dairy farm (Die Anker) located south of the river. Continuous abstraction of fresh water from the river catchment aquifer to supplement irrigation water at Atlantic Beach could also exacerbate the salinities problems currently experienced in the lower reaches of the river.

4.4.6 The Diep River

The region consists of four quaternary sub-catchments (G21C - G21F) covering an area of approximately 1 500 km^2. The Diep River drains south-west from the Riebeek-Kasteel Mountains, to the north of Malmesbury, in the north-east of the sub-area, through the wheat producing areas of the Swartland, to enter the sea at Milnerton, via the Rietvlei wetland. The Mosselbank River (flow in the reaches of the Mosselbank River is seasonal) drains the south-eastern portion of the region, and is the main tributary of the Diep River. The MAP ranges from 530 mm in the east to 480 mm in the west.

The surface water quality of the Diep River is relatively poor and is dominated by high salt concentrations and elevated sodium and chloride concentrations. The high salt concentrations are to be attributed to the local geology in the catchment which is dominated by Malmesbury shale formations (Southern Waters, 2000). Salinity in the river is exacerbated by irrigation return flows from the cultivated land in the catchment (IWQS, 1997). As a result, the cultivation of high value crops in this area is limited.

The Diep River is also characterised by high TDS which could also be attributed probably to the leaching of Malmesbury shale which occurs naturally in the area, as well as to farming activities.

The deterioration in water quality upstream was ascribed to the results of both local impacts, such as livestock grazing and runoff from feedlots and the surrounding wheat-lands. There is also a relative deterioration in water quality downstream of the Malmesbury urban area that could be linked to the direct discharge of effluent from the Malmesbury WWTW. The results from two different monitoring tools used in the Diep River catchment study showed almost similar results in that the surface water quality of the Diep River is classed deteriorated.

Results of the CCT Scientific Services monitoring programme for a range of water quality parameters collected from sites on the Maasdrif Canal, upstream and downstream of Kraaifontein WTWW and downstream of Fisantekraal on the main stem of the Mosselbank River, indicate that the effluent discharged from the Kraaifontein WWTW has significantly influenced the water quality of the Mosselbank River.

Table 4-2 shows a comparison of the key water quality parameters (median values) monitored at the Kraaifontein WWTW with those of DWAF special and general limits for effluent concentration (Southern Waters, 2000):

Although the monitoring was short-termed, the following points of interest could be noted:

- Although both the suspended solids and electrical conductivity comply with the DWAF Special Limits, nutrient loading is well in excess of the value specified by the Special limits and the 2010 standards (DWAF, 2000a). Nutrient concentrations have implications for rates of algal growth and the trophic status of the system.
- Ammonia concentration is well above the Special and the General limits and this is of concern since ammonia has a toxic component.

Table 4-2 Compliance of Kraaifontein WWTW key water quality parameters

Parameter	Wastewater effluent concentration		
	Special Limit	General Limit	
Chemical oxygen demand (mg/l)	30*	75*	70
PH	5.5-7.5	5.5-9.5	7.5-8.0
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)	1	3	13
Nitrate/Nitrite as Nitrogen (mg/l)	1.5	15	16
Suspended Solids (mg/l)	10	25	5
Electrical Conductivity (mS/m)	50[a]	70[b]	93
Electrical Conductivity (mS/m)	1 (median) 2.5 (maximum)	10	11
Ortho-Phosphate as phosphorous (mg/l)	30*	75*	70

- [a] Above background receiving water, to a maximum of 100 mS/m (Southern Waters cites this as 70mS/m for the Diep River).
- [b] Above background receiving water, to a maximum of 150 mS/m (Southern Waters cites the latter as 70mS/m for the Diep River).

Source: (Adapted from Day, 2004 after Southern Waters, 2000)

- The pH values are generally high both upstream and downstream of the Diep River, presumably due to runoff from industrial areas. High pH values are of particular significance, as they influence the conversion of ammonium to its toxic un-ionised form (DWAF, 1996).

- Intermittent drop in dissolved oxygen to dangerously low levels in the Maasdrif Canal downstream of the Kraaifontein WWTW was observed.
- Sharp peaks of phosphate concentrations were observed downstream of the Kraaifontein WWTW during the summer, presumably due to decreased quantities of non-effluent water which could help dilute the effluent.
- Higher nitrogen concentrations upstream of the Kraaifontein WWTW were frequently observed which also tend to be higher in winter than in summer, presumably due to increased flushing of surrounding urban and agricultural areas during the rainy seasons.

Some concerns in the variation of water quality parameters for the Diep River as noted by Southern Waters (2000) and reported by Day (2003) are provided below:

- The total dissolved solids (TDS) concentration increases downstream in the Mosselbank River and exacerbates with inputs from the Maasdrift Canal and the Klapmuts River. TDS values have been found to be consistently higher than 520 mg/l with a maximum in the lower reaches which decreases thereafter with the input of treated effluent from the Potsdam WWTW. It should however, be noted that high TDS values are characteristic of Western Cape Rivers, partly attributed to their passage through Malmesbury shales and the high rates of evaporation in the region (Davies and Day, 1998).
- The total suspended solids (TSS) concentration increases in the Mosselbank River, downstream of the Maasdrift Canal. This increase has been primarily attributed to runoff from the informal settlements, construction activities, agricultural practices and change in landuse patterns from rural to urban.
- High levels of ammonia (median values 12.8 mg N/l) have been reported in the Maasdrift Canal which could be attributed to the effluent from the Kraaifontein WWTW. The ammonia levels increases sharply at the lower reaches due to effluent from the Potsdam WWTW, but dispel further downstream, presumably due to nitrification in the wetlands.

An estimated 13 million m^3/a of developed groundwater yield suggests that this sub-area relies extensively on groundwater supply out of the primary coastal aquifers. Land sub-division is increasing the abstraction of groundwater under Schedule 1. This introduces the same risk of aquifer pollution as identified in the West Coast Rivers sub-area, namely from the use of pit latrines.

4.4.7 The Cape Peninsula Rivers

The sub-area consists of the four quaternary sub-catchments in the Cape Peninsula, namely G22A - G22D. This includes the Liesbeeck and Elsieskraal Rivers as well as smaller streams draining Table Mountain and the Peninsula. Quaternary G22B lies in the high rainfall area of Table Mountain and has a MAP of approximately 920 mm. The remaining three quaternary catchments, namely G22A, G22C and G22D have MAPs of approximately 680 mm, 600 mm and 740 mm, respectively.

Local water quality is highly variable ranging from the pristine mountain streams arising in the Cape Peninsula Mountains, to the severely modified urban rivers that serve as conduits for stormwater and treated effluent from WWTWs (see **Table 4-3**).

Many of the WWTWs currently discharge into severely modified rivers and the question needs to be asked as to whether or not it is acceptable to allow further degradation of these rivers, such as the Salt/Black River. **Table 4-3** shows the current points of discharge, and effluent quality compliance at each of the nine WWTWs in the Cape Peninsula area. There are three marine outfalls operated by the CCT in this sub-area.

In summary, the works are generally well operated and those rivers serving as conduits to sea are already severely degraded. Investigations by the CCT to remedy the high phosphate concentration in the Wildevoëlvlei are currently in progress.

Table 4-3 WWTW in the Cape Peninsula sub-area

Plant	Point of discharge	Effluent compliance
Athlone	Black River to Table Bay	General Standards are met on average
Cape Flats	To sea (False Bay)	NH_4 and total solids failure in summer
Mitchells Plain	To sea (False Bay)	Meets General Standard
Wildevoëlvlei	Into Atlantic ocean via vlei	High Phosphate concentration can cause algal blooms in the vlei
Simons Town	To sea (False Bay)	COD and NH_4 sometimes exceed the Standard
Llandudno	To sea (False Bay)	Meets relaxed General Standard
Oudekraal	To sea via Camps Bay outfall	Small biodisc plant – not monitored
Millers Point	To sea (False Bay)	Small biodisc plant – not monitored
Borcherds Quarry	Black River to Table Bay. Also golf course irrigation.	Extensive upgrade to plant in 2002/3.
Green Point marine outfall	To sea	Satisfactory
Camps Bay marine outfall	To sea	Satisfactory
Hout Bay marine outfall	To sea	Discharge rate requires increasing

Source: (DWAF, 2004 - Internal Strategic Perspective)

Limited monitoring of the Cape Flats Aquifer takes place and as such, the impacts of surface activities on the water quality of the aquifer are not well documented.

4.4.8 The Kuils/Eerste/Lourens and Sir Lowry's Pass Rivers

The sub-area includes six quaternary sub-catchments, namely G22E - G22K. It includes the catchments of the Kuils and Eerste Rivers, as well as that of the Lourens and Sir Lowry's Pass Rivers. The quaternary catchments in the extreme east (G22F and G22J) border on the Hottentots Holland Mountains and have MAPs of 1 400 mm and 1 000 mm, respectively. The MAPs reduce towards the west. Quaternary G22E has an MAP of 570 mm. The upper reaches of the Eerste River receive the country’s highest recorded rainfall of 4 000 mm per annum.

The Eerste River is classified as having good quality water upstream of Stellenbosch. The Plankenbrug River has a high pollutant load arising from the informal settlement at Khayamandi (DWAF, 1999a) which impacts on the quality of water in the Eerste River, downstream of the confluence with the Eerste River, where effluent from the Stellenbosch WWTW is also released into the river. The Kuils River has poor water quality due to urban impacts and the use of the river as a conduit for discharging treated effluent from the Bellville, Scottsdene and Zandvliet WWTWs. The Kuils River joins the Eerste River near the estuary into which the Macassar works discharges. The Lourens River water quality is high in the upper reaches but decreases downstream, probably as a result of urban impacts, as is the Sir Lowry's Pass River quality impacted. **Table 4-4** shows the current points of discharge and effluent quality at each of the seven WWTWs in this sub-area.

In summary, the works are all generally well operated. Rivers serving as conduits to sea are already degraded, downstream of the treatment works.

Table 4-4 WWTW in the Kuils/Eerste/Lourens/Sir Lowry's Pass sub-area

Plant	Point of discharge	Effluent compliance
Kraaifontein	Mosselbank River to Diep River to Table Bay	Occasional COD and NH_4 problems.
Scottsdene	To Kuils River then False Bay	Complies with permit requirements
Macassar	To Eerste River then False Bay	Required standards are met
Bellville	To Kuils River then False Bay	Required standards are met
Parow	Irrigation of golf course and sports fields	General Standards are met, except occasionally for e-coli.
Zandvliet	To Kuils River then False Bay	Occasional summer peaks of NH_4.
Stellenbosch	To Eerste River then False Bay	Required standards are met.

Source: (DWAF, 2004 - Internal Strategic Perspective)

4.4.9 The Steenbras River

This quaternary sub-catchment is situated between the Hottentots Holland and Kogelberg Mountains. It is an area of high rainfall and experiences an MAP in excess of 1 100 mm. With the exception of forestry, the Steenbras River catchment is relatively undeveloped.

In terms of water quality, the most significant factor is that of the Palmiet River (Breede WMA), from which inter-basin transfers into Upper Steenbras Dam, take place. This currently involves an average annual transfer of 23 million m^3/a (of a maximum capacity of 50 million m^3/a) via the Palmiet Pumped Storage Scheme. The point of abstraction in the Palmiet River (Kogelberg Dam) is downstream of the urban and industrial area of Grabouw, which has an impact on the Palmiet River water quality.

Also, the agricultural development in the Palmiet catchment, upstream of Kogelberg Dam is significant, and this can have a diffuse runoff type impact on the water quality of the Palmiet River. The dilution effect on the water transferred from the Palmiet River into the Upper Steenbras Dam plays a role in mitigating the extent of the impact on the Steenbras water. Normally, volumes transferred range from 2 to 3 million m^3 per transfer into a receiving volume of between 10 and 20 million m^3 in Upper Steenbras Dam. Information on the water quality of the

Steenbras River needs to be assembled. There is only one monitoring point in the catchment and that is in the dam itself.

4.5 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.

4.6 SUMMARY OF WATER QUALITY IN THE BERG WMA PRIOR TO 1993 AND FROM 1994 - 2006

The water quality in each sub-area of the Berg WMA before 1993 as was reported in the Western Cape System Analysis (WCSA) (DWAF, 1993) and how the situation has changed since them (1994 - 2006) in terms of the objectives of this study is presented below.

Table 4-5 Summary of water quality conditions for the Berg WMA

Period prior to 1993	Period 1994 - 2006
Berg River Basin • Water from the upper Berg River Basin and tributaries draining Table Mountain Sandstone were found to be ideal for all users, however, all tributaries draining Malmesbury Shales were unacceptable for all uses. • Lower river experienced water quality problems brought about by high levels of TDS, phosphorous and chloride derived, primarily from non-point sources, causing pumping problems for domestic and agricultural abstractors, eutrophication of farm dams and potential corrosion of pipelines. • Non-point source drainage governed the water quality of the main river channel. The major point source pollution included treated wastewater discharges of Paarl and Wellington. Non-point pollution contributed a large proportion of the mass export of TDS, phosphorous and suspended solids. • Increasing concentrations of TDS, chloride, phosphorous and suspended solids were observed from head waters. The rivers had high TDS concentrations during low flow periods and during high flow periods, low TDS concentration as well as high suspended solids and phosphorous concentration. • Variation of water quality was influenced by effluent discharges, abstraction for domestic and agricultural use, catchment transfer, and non-point source drainage.	**Berg River upstream of Hermon** • Aquaculture impacts on the water quality of rivers and dams are such that the future Berg River Dam could lead to increases in the costs of water purification. • Management of aquaculture activities from a water quality perspective need to be considered and appropriate charges considered for this water use. • Changing land-use through reduction of afforestation and removal of invasive alien plants may result in additional surface water runoff, the extent of which is dependant on any new demands resulting from new land-uses and eventually to deterioration in water quality. • Operation and maintenance of the Theewaterskloof tunnel inlet shafts requires attention. • An Agricultural Practises Strategy is required to address the impact on water quality from agricultural methods and irrigation return flows. • Salinity, particularly in the Lower Berg River, is experienced from time to time.
Palmiet and Steenbras River • The water quality of both the Palmiet and Steenbras Rivers was ideal for use for both	**Steenbras River** • Changing land-use due to the possible removal of afforestation from the catchment initially resulted in

<table>
<tr><th>Period prior to 1993</th><th>Period 1994 - 2006</th></tr>
<tr><td>domestic and agricultural purposes.
Low calcium and TDS concentrations were reported.
Main sources of contamination of the Palmiet River was from the treated effluents from Grabouw and Elgin Fruit Juices.
Water quality data indicated that minimal deterioration occurred between the upper and the lower reaches.
No long-term changes in water quality of the rivers were reported.</td><td>increased surface water runoff but the net effect will be dependant on the subsequent land use and possible new water demands. This would likely affect the water quality of the river.
There is no monitoring of water quality in the Steenbras River. Future monitoring will be required for the purposes of the Reserve.</td></tr>
<tr><td>Diep River
High salinity, high concentrations of dissolved and suspended solids were reported for the river which made it unsuitable for both domestic and agricultural uses and for future water resource development.
The river system was reported to be highly degraded and received large proportions of TDS and nutrient load from non-point sources, and treated effluent from Malmesbury and Kraaifontein municipalities.
In the bottom water of the river, the conductivity was between 92 and 349 mS/m and in the bottom reaches between 144 and 810 mS/m.
Insufficient data was available at the time to determine long-term changes in the water quality.</td><td>Diep River
Nitrate rich diffuse pollution occurs throughout the WMA, from feedlots, piggeries and chicken farms. The Diep River catchment is of particular concern.
Development and sand mining in particular, are causing siltation problems in the Diep River.
Increased groundwater abstraction at Riverlands, and the use of pit latrines may be impacting on the groundwater quality. This needs monitoring.
There is potential pollution of groundwater resources in the area by irrigation return flow. Chemical use in farming practises is a threat to the quality of groundwater abstracted from shallow, weathered Malmesbury bedrock.
Land sub-division, increased groundwater use, and the use of pit latrines in the Riverlands area may be impacting on groundwater quality.
There is little understanding of the impacts of current irrigation practises and return flows, on water quality.
There are contaminated solid waste sites in this area but no official guidelines for rehabilitation of such sites are in place, and this could be impacting on water quality of the river.
Siltation of the Diep River is taking place due to development and sand mining activities.</td></tr>
<tr><td>Kuils/Eerste/Lourens River Basin
Water was ideal for all uses in the upper reaches of the Eerste River. In the lower reaches, however, the combined influence of point and non-point sources, as well as reduced flow during summer caused deterioration in water quality which was also unsuitable for use both for domestic and irrigation.
High ammonia concentration was reported.
Main sources of contamination was the discharge of treated effluent from Bellville and Kuils River into the Kuils River and accounted for high TDS and nutrient concentrations.
River water quality was influenced directly by point</td><td>Kuils/Eerste/Lourens/Sir Lowry's Pass Rivers
Diffuse pollution into the Plankenbrug River, particularly after heavy rains, is taking place in the Stellenbosch area. Khayamandi residential area has an effluent spill problem.
Pollution in the Plankenbrug River (Stellenbosch) is impacting on the water quality of rivers in this area. The Khayamandi residential area in Stellenbosch has inadequate services resulting in diffuse pollution, particularly after rains. Potential future schemes on the Eerste River may require pre-treatment, which has cost implications.
Spillages from industry and wineries may be reaching the rivers due to an inadequate first line of protection, such as bund walls and cut-offs.</td></tr>
</table>

Period prior to 1993	Period 1994 - 2006
	Klein Berg River • Diffuse pollution from settlements in close proximity to the Klein Berg River, which feeds Voëlvlei Dam, is impacting on water quality in the dam. Runoff from the first winter rains is the main source of pollution and should preferably be allowed to bypass the dam in an attempt to reduce the impact. • Poor management of the municipal WWTW and the diffuse pollution into the Klein Berg River from informal settlements and agricultural activities affects water quality. • Poor water quality in the Klein Berg River (which feeds Voëlvlei Dam) at the start of winter makes it preferable that the first winter runoff is bypassed.
	The Cape Peninsula Rivers • A monitoring protocol for recharge and water quality of the Cape Flats aquifer and aquifer head protection is required.

CHAPTER 5: WATER QUALITY MANAGEMENT IN THE BERG WMA

5.1 OVERVIEW

Water quality in the Berg WMA needs to be appropriately managed to ensure that there is water of acceptable quality available to meet the needs of the environment and of all users in the area.

The NWRS defines two complementary approaches for the protection of water resources:

- Resource Directed Measures (RDM) which focuses on the character and condition of the in-stream and riparian habitats; and
- Source Directed Controls (SDC) which focuses on the control of water use at the point of potential impact, through conditions attached to water use authorisations (licences).

It is not economically viable, nor always necessary; to protect and manage all water resources to the same degree. Each water resource needs to be classified in terms of the degree of protection it should be accorded. This in turn influences the allowable extent of utilisation. A classification system is being developed by the Directorate: Resource Directed Measures (RDM) to provide a protocol for the classification of rivers.

5.2 WATER RESOURCE MANAGEMENT

Much of the emphasis in water resource management has revolved around ensuring that users have sufficient quantities of water. However, as more water gets used and re-used, as quantities get scarce and feedback loops get even tighter, it is quality that begins to take on a dominant role.

Water availability is only as good as the quality of that water. Both quantity and quality need to be considered at the correct level of detail, and this can mean that at times they should be considered with similar emphasis and with similar expenditure of resources. Too often we have failed to integrate the issues of quantity and quality – both with regard to surface water and groundwater. The concept of available assimilative capacity, the ability of the water resource to absorb a level of pollution and remain 'serviceable', is as important in water resource management as is the concept of systems yield.

Quantity and quality can no longer be managed in isolation of each other. Not that this isolation has ever been total. The importance of releasing better quality water from Brandvlei Dam for freshening the saline water in the lower reaches of the Breede River, and of the addition of freshening releases from the Vaal Barrage to bring water back to an acceptable quality has, *inter alia*, long been standard practice. The consequences of irrigation, the leaching of fertilisers, and more importantly the leaching of salts from deeper soil horizons can render both the lands themselves and the receiving rivers unsuitable for use. Diffuse agricultural 'effluent' may be less visible than direct discharges of sewage or industrial effluent, but are no less pernicious.

Direct discharges to rivers are licensed and managed on the basis of assimilative capacities of those rivers, and on receiving water quality. Where these limits are exceeded, often through the cumulative impact of diffuse discharges, water becomes unavailable to some, or even all, users downstream. DWAF will licence users to take water, and again to discharge it in recognition that there is generally a cost to the resource in terms of a reduction in quality and a reduction in its further assimilative capacity. It is for this reason, and in order to bring about additional management and a strong incentive, that the Waste Discharge Charge System (WDCS) is being developed. Discharge users will be obliged to pay, depending on the quantity and quality of their discharge.

There are so many pollutants affecting surface water quality, including sediment and erosion, diffuse discharges from irrigated farmland (fertilisers and salinity), domestic and urban runoff, industrial waste, and sewage discharges. There is a problem of compliance with regard to local authorities and private operators responsible for waste management systems. Diffuse discharges only compound the problem by reducing the assimilative capacity until the water becomes unfit for use, very expensive to purify, and a danger to human health (as was indicated earlier).

Groundwater quality requires equal attention, and more so as we recognise the importance of groundwater in supplementing our meagre resources, and providing water to remote communities. Although our groundwater resources are for the most part found at a relatively deep level (typically 50-100 m) this water can easily be polluted by surface activity. The leaching of fertilisers is one such problem but of greater concern is the influx of nitrates, primarily a consequence of human habitation and sanitation. Pit latrines are on the one hand so necessary, and have the huge advantage of not requiring volumes of water, but disposal is ‘on-site’, and often responsible for the longer-term pollution of the underlying aquifers which feed and water the communities above. Prosperity for South Africa depends upon sound management and utilisation of our many natural and other resources, with water playing a pivotal role. South Africa needs to manage its water resources optimally in order to further the aims and aspirations of its people. Current government objectives for managing water resources in South Africa are set out in the National Water Resources Strategy (NWRS) and are summarised below:

- To achieve equitable access to water. That is, equity of access to water services, to the use of water resources, and to the benefits from the use of water resources.
- To achieve sustainable use of water, by making progressive adjustments to water use to achieve a balance between water availability and legitimate water requirements, and by implementing measures to protect water resources and the natural environment.
- To achieve efficient and effective water use for optimum social and economic benefit.
- The NWRS also lists important proposals to facilitate achievement of these policy objectives, such as:
- Water will be regarded as an indivisible national asset. The Government will act as the custodian of the nation's water resources, and its powers in this regard will be exercised as a public trust.
- Water required to meet basic human needs and to maintain environmental sustainability will be guaranteed as a right, whilst water use for all other purposes will be subject to a system of administrative authorisations.
- The responsibility and authority for water resource management will be progressively decentralised by the establishment of suitable regional and local institutions, with appropriate community, racial and gender representation, to enable all interested persons to participate.

5.3 WATER QUALITY MANAGEMENT ACTIONS

DWAF has commissioned studies at various levels of feasibility to address the salinity problems in the middle and lower reaches of the Berg River. In the interim, prior to any future interventions for potential water quality improvements, those industrial water users requiring reduced salinity concentrations will have to continue pre-treating water themselves.

The severely degraded rivers such as the Black/Salt and Kuils Rivers cannot be rehabilitated. Such rivers must however not be considered as entirely sacrificial and their condition should, at worst, be maintained at current levels. Further degradation will result in undesirable social, health and aesthetic impacts. The required standards for treated effluent discharged into such rivers should be appropriate to at least maintain the current condition.

The focus on improved operation and management of WWTWs must be on those works that are discharging into river systems that are not already severely degraded (e.g. Eerste River and Berg River) and those feeding highly sensitive wetlands and estuaries (e.g. Diep River).

Various management actions have been documented and appropriate recommendations made in the Internal Strategic Perspective (ISP) for the Berg WMA (DWAF, 2004). The following general management actions are, however, required:

- Investigate options for improved salinity management of water in the middle and lower reaches of the Berg River taking account of the future Berg Water Project and the needs of urban and agricultural users.
- Determine the extent of reduced salinity that may be achieved if releases of the first winter run-off water (high salinity) from Misverstand Dam were implemented.
- Investigate the benefit of using alternative abstraction points within Misverstand Dam.
- Investigate the options of diverting the small local tributaries (Moorreesburg Spruit and Nogo Spruit) around Misverstand Dam, so as to reduce the salinity concentration in the dam itself.
- Investigate the potential to desalinate water for sensitive needs, such as Saldanha Steel.

The implementation of these management actions is the responsibility of the DWAF Regional Office, together with the Directorate: Water Resource Planning Systems, taking cognisance of the National Water Quality Framework Policy (DWAF, 2002).

5.4 WATER QUALITY INFORMATION MANAGEMENT

There is a need to improve access and facilitate sharing of information and integrity of information between the various role players involved in water quality related studies in the Berg WMA. There are several databases housing water quality data for monitoring sites for the Berg WMA. Both the Scientific Services Division of the CCT and DWAF have extensive databases of information which are relevant to the water resource management and water quality monitoring in particular, for the Berg WMA. As such, information held by these bodies and other institutions (Government and private) should be shared appropriately.

DWAF Regional Office implemented the HYDSTRA Water Quality Data Management from HYDSYS (Pty) Ltd in their Hydrology Unit which allows for data to be stored, verified and processed locally. This information will then be copied to the National database and as such, the local database serves merely as backups.

The following shortcomings were identified:

- Capturing of registration data is still in progress and verification of that data is required.
- There is a need to improve the sharing of information between DWAF and local authorities.

In this regard, the Western Cape Region has agreed to co-ordinate and share both water quality data collection and information management to the best of its ability. This will seek to enhance the process of information sharing while respecting organisational needs for data security and the maintenance of data integrity. DWAF should endeavour to ensure that the data it gathers and the information it has at its disposal is made available as widely as is practically possible and useful to the common benefit of the water resources and its users.

DWAF Water Management System (WMS) has been operational since 1999. WMS is currently used in many DWAF offices, including the Western Cape Regional Office. The system has been used with varying success in DWAF offices and some private laboratories (such ERWAT Laboratories).

According to Ulrich Looser (*Introduction to the Water Management System*, 2003), the WMS consists of three main sub-systems, which are:

- **Monitoring Management Subsystem**, used to manage resource quality operational monitoring on a national scale;

- **Water Resource Management Subsystem**, used to achieve the sustainable use of water and the protection of the quality of the water resource. This subsystem is also used to apply source control. This subsystem also manages users and water quality data exporting from WMS to other systems.

- **GIS subsystem**, used to geographically display water resource information in order to assist in interpreting and determining the quality and the status of the water resource.

Access to the WMS is provided to users via servers deployed in the regions and through the Winterm server-based "thin client" system. External organisations also have access to the Winterm server, but mainly for the purpose of data input. The data in the WMS is available within minutes after update at regional servers and central servers.

5.5 POLLUTION CONTROL

The approach to water resource protection in the NWA includes consideration of water quantity and water quality. Water quality management deals with both point sources and diffuse sources of pollution (refer to Section 0) through the control of discharging waste or contaminated water into rivers or other water resources.

The primary objective of the pollution control would be to improve the management of:

- river systems to achievable and acceptable water quality standards.
- point source pollution, diffuse pollution and spills.

Decisions about the nature and extent of resource pollution which can be permitted are guided by a hierarchical decision-making framework. The framework takes account of the balance between the need to protect water resources for sustainable use, and the need to allow water-polluting activities in order to support social and economic development. A Waste Discharge Charge System (WDCS) is currently being developed by DWAF in an effort to reduce and control wastewater discharges into water resources. This initiative is aimed at promoting more efficient water use, ensuring compliance with prescribed standards and water management practices and consequently, the proactive management of the water quality of surface water resources.

The entity discharging wastewater which is below the required standard is however, responsible for any pollution and must pay for the impact the discharges have on the environment and on the water quality of the water resource. This obviously depends on how the discharges impacts on the resource quality objectives (RQOs) of the catchment. Therefore, should the discharge not impact negatively on the RQO for the catchment, the WDCS would not be triggered. The National Water Act makes provision for the "polluter pays principle" as an economic way to achieve effective and efficient water use and protection.

The highest priority in the decision-making framework is to prevent water pollution through waste prevention and reduction, recovery, treatment and final safe disposal. It is, however, acknowledged that in many cases the discharge of pollutants into water resources is unavoidable, and in these cases the emphasis is on minimising the pollution and its effects on water resources. Where pollution has already caused degradation of water resources, or where contaminated land areas pose a threat to water quality, improvements and remediation must be effected where it is necessary and practical.

Each application for authorisation to discharge wastes into water resources within the Berg WMA, should be preceded by an assessment of the probable impacts of the discharge on the water resource and other water users. For hazardous wastes, the aim would be to prevent discharge wherever possible or, if this is not possible, to minimise the extent of the discharge and its impacts. For non-hazardous wastes the 'receiving water quality objectives' approach will continue to be used. This approach assumes that the water environment has a finite and quantifiable capacity to assimilate non-hazardous waste discharged into it without violating predetermined water quality objectives. The assimilative capacity, which will be different for each water resource and for each management class, must be equitably shared among all water users.

Pollution sources in the Berg WMA, such as irrigation return flows, land-use practice and reduced dilution due to upstream abstractions also impact on salinity and consequently the water quality. This is a particular issue in the Lower Berg River at Misverstand Dam. Wherever possible, best management practices, relating to the treatment and recovery of waste, will be incorporated into licence conditions / source-directed controls, to prevent water resources being polluted.

While the overall intention is to prevent further degradation of the quality of the country's (and Berg WMA), water resources and to effect improvements where possible, limited and short-term degradation of the water quality of specific water resources could be allowed if it can be demonstrated with confidence that the degradation will not be irreversible, and that pollution costs are not externalised to other users of the water resources.

5.6 HAZARDOUS SPILLS

DWAF's approach to water quality management is, as far as possible, to promote the reduction of discharges of waste or water containing waste into water resources. In emergency situations, where harmful substances are accidentally or negligently discharged into water resources, the NWA makes those who have caused the pollution responsible for remediating the impacts. At present all pollution incidents must be reported to DWAF, so that appropriate departmental responses can be co-ordinated with the relevant emergency services and disaster management centres.

5.7 PUBLIC HEALTH AND SAFETY

The objective of public health and safety in water quality management is in the first instance to prevent water-related disasters, and in the second to mitigate the effects of disasters which may occur. This should be done by implementing the strategies and policies which have already been developed through the National Disaster Management Act, as well as those developed by DWAF.

Disaster management planning, floods, dam safety, emergency pollution and droughts are all aspects of water resource management and which affect the water quality drastically and impact severely on public safety. The National Disaster Management Centre, established under the National Disaster Management Act, will be responsible for the development of the National Disaster Management Framework.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Water quality in the Berg WMA needs to be appropriately managed to ensure that there is water of acceptable quality available to meet the needs of the environment and of all users in the area. Water quality in the Berg WMA, varies not only between the individual river basins but also within individual river systems, such as the Berg River system. The natural geology, agricultural practises and point source polluters all play a role in determining the quality of water in this WMA.

6.1.1 Broad water quality trends for the Berg WMA: 1993-2006

The reports accessed for this study indicated the following broad trends in water quality along the Berg River:

- 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 use for domestic and irrigation supply. Salinity concentration and nutrient content must be reduced to the most practically manageable levels.
- The major sources of water pollution are agricultural runoff (fertilisers, pesticides) and return flows, urban runoff and effluent discharges (bacteriological contamination, salts and nutrients), industrial effluents (chemical substances), mining activities (acids and salts), and areas with insufficient sanitation services, mainly informal settlements (microbial contamination).
- The shale rivers (Vis, Doring, Sandspruit, Moreesburg/Moreesburg Spruit and Matjies Rivers) naturally have high salinities, in contrast to the TMS rivers (Banhoek, Klein Berg, Leeu, Kompagnies, Wolwekloof and Twenty Four Rivers) which have relatively low concentrations of TDS. All these rivers tend to be naturally brown in colour which could be attributed to dissolved humic acids (Baths, 1993a).
- Conductivities increased with distance downstream, particularly in the lower reaches of the Berg, with a sharp increase in the vicinity of Misverstand Dam. It is presumed that winter conductivities are influenced by inputs of saline water from shale tributaries. Mean summer conductivities are highest in the Moreesburg Spruit followed by the Sand Spruit and Matjies River. Summer elevations of conductivities are driven by irrigation return flows.
- The mean pH values of the shale rivers were generally higher than those of the TMS over both summer and winter periods. The pH generally increased with distance downstream, from the acid TMS areas into the alkaline shale areas.
- The water quality of the Berg River mainstream is mainly influenced by its tributaries and largely depends on the water quality of the respective flow regimes of each tributary. However, Fourie and Görgens (1977) reported that unseasonal rains in the catchments of the tributaries during periods of low flows, may influence the water quality of the mainstream Berg River.
- Major pollution point sources of the Berg River occurred in the area between Paarl and Wellington and are associated with discharges from the wastewater treatment works. Bath (1993a) reported that point sources contributed 11 to 64% of the TDS and phosphorous loads respectively for the river. Mean concentration of nutrients (e.g. nitrogen compounds

– NO_3-N and NH_4-N) and Phosphorous had increased in the system as a result of point and non-point sources impacts, primarily from sewage effluent and agricultural return flows. Suspended solids and ammonia tended to be associated with high flow periods.

- There is a likelihood of pesticides-contaminated runoff reaching the Berg River and its tributaries which would have a great influence on the water quality. This is highly probably since there is a strong influence of agriculture in the area coupled with the widespread use of pesticides. No monitoring programme has however, addressed the impacts of pesticides on the water quality of the Berg (Day, 2004).
- The *Escheria coli* counts in the Berg River have been reported to range from 5 000 to 2 400 million per 100 mℓ compared to 1 000 in 100 mℓ in water for crop irrigation. The main sources of pollution are reported to be discharges from wineries, food processing factories, runoff from informal settlements and effluent from municipal sewerage systems and wastewater treatment works (The Water Wheel, 2005).

6.1.2 Summary of water quality situation for the Berg WMA: 1950-2006

Significant changes occurred in the water quality of the Berg River System during the following periods:

a) The Period 1950 to 1980

There is no water quality information for the Berg River System on its natural or un-impacted state. Harrison and Elsworth (1958) undertook the earliest studies to ascertain the water quality of the Berg River. The water quality of the river was already impacted by the time it reached Franschhoek. However, the river was generally described in pre-1960 as having freshwater with low pH and nutrients in the upper reaches. Conductivity and total dissolved salts increased with distance downstream. Impacts on water quality of the river were localised and consisted of organic enrichment downstream of Franschhoek and runoffs from Pniel and neighbouring farms. Pollution from domestic and industrial sources occurred in Paarl and Wellington.

b) The Period 1980 to 1993

The upper reaches of the Berg River System remained unpolluted in 1980, but this significantly changed following the releases from the Theewaterskloof IBT Scheme which started in 1980. The water quality deteriorated downstream which was attributed to increased organic loadings from wastewater discharges to the river between Paarl and Wellington. From 1980, the Berg River showed increased mineralisation along its course from the upper reaches to the lower reaches. The lower reaches showed substantial deterioration of water quality, attributable to excessive rates of water abstraction, use of fertilisers and irrigation releases from the Voëlvlei Dam during the summer months which resulted in sharp increases in conductivity.

c) The Period 1994 to 2006

Water quality in the Berg River has changed considerably from 1993 to 2006. Salinity, conductivity, pH and suspended solids have continued to increase with distance downstream due to marked increased in agricultural return flows below Voëlvlei Dam, irrigation releases, urban and industrial runoff and wastewater discharges. Wastewater discharges from the Paarl and Wellington areas have been the major point sources of nutrients while the major sources of phosphorous into the rivers was the non-point sources.

6.1.3 Specific concerns on the water quality for the Berg WMA

Other major concerns expressed on the water quality of the Berg River Systems in the Berg WMA include:

- **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.

There are a number of 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).

- **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 (Cape Metropolitan Council, 2000). 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 streams 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**: 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, which flow through urban areas, have water quality problems that are generally associated with the impacts of urban areas on surface water bodies.

- **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.

6.2 RECOMMENDATIONS

This section of the report presents recommendation that could be implemented to better understand and improve the water quality situation in the Berg WMA:

- The flow patterns of most rivers in the WMA have been altered due to active water transfer schemes, dams, weirs, water abstraction, return flows to rivers and other impacts of land activities. Increasing population growth and economic development in the province has resulted in higher domestic, agricultural and industrial demand for water. There is therefore a need for careful and proactive management of all water resources within the Berg WMA to ensure that demand does not outstrip the available resources.

- The influence of inter-catchment transfer of water on water quality and flow reduction as a result of the transfer of water from headwaters is expected to cause deterioration in the quality of the rivers in the lower reaches. Such changes may have a deleterious influence on the estuary which is a unique ecological area. A management plan should be developed to schedule transfers to minimise their influence on user groups.

- The influence of increased volumes of wastewater discharged via tributaries of the upper Berg River (including Franschhoek and Dwars River) on domestic and agricultural use as well as the aquatic ecology. Site-specific receiving water quality objectives must be set to protect the headwaters of the river.

- Measures to investigate and address increases in salinity in the Berg River downstream of Hermon and of Misverstand Dam should be developed.

- The problem of the quantity and quality of irrigation return flows into the river needs to be addressed. The Berg River Dam at completion will result in increasing irrigation and consequently increases in return flows. These effects need to be quantified and monitored in future. Effort should be made to ensure that the salts loads from all return flows are effectively managed.

- The influence of point and non-point source discharges on the receiving water quality must be determined, with particular reference to the aquatic ecology. Proper water quality management requires an integrated approach at both technical and institutional level on a regional scale. In order to ascertain the water quality issues in the Berg WMA, inventories of pollution sources and pollution loads are essential in terms of determining various water quality parameters.

- Water quality monitoring data are continuously being collected by DWAF and the municipalities. These data and results found in different reports need to be integrated into a centralised and regularly updated and maintained database of water quality data, which builds on initiatives including the WMS. The results of such an exercise would have numerous benefits for the water quality status in the WMA such as:

- The results could be used to prioritize areas for improvements by examining regional water quality trends to identify candidate priority areas, and through examining the supporting trend analysis details to confirm the priority areas.
- The water quality responses to sources of pollution may be used to prioritise source reduction efforts to pollutants with the greatest impacts or greatest worsening trends.
- The results may be used to identify regional and local impacts on freshwater inflows and salinity regimes of the estuarine portions of the river systems.
- The results may provide background scientific results for incorporation into public education material such as the opportunity for improving water quality through local stormwater management.
- The results may provide a statistical framework for future monitoring of the effectiveness of management actions. For example, the effect of irrigation return flows may provide baseline conditions against which future responses may be compared.

- There is need for the integration of water quality data from various sources within the WMA. Currently, the national monitoring network co-ordinated by DWAF and other initiatives from the various municipalities are producing enormous amounts of data. However, for these data to be helpful, they must be processed and converted into timely information products that are useful and accessible to a broad community of decision makers, the public, and other potential end users. Monitoring data, whether newly collected or mined from old sources, should become part of a broad national environmental data management system. Such a system can combine data from many sources, to create information products. It will be key to merging all the monitoring data to create seamless products across the land/rivers interface.

- An integrated water quality monitoring network is also essential to support the move toward an ecosystem-based management approach that considers human activities, their benefits, and their potential impacts within the context of the broader biological and physical environment. While current monitoring helps track specific substances, it has been less effective in helping understand how various ecosystem components interact and change over the long term. The data and resulting information products collected from a national monitoring network, combined with broader assessment and observation efforts, will be the key to implementing truly effective and adaptive ecosystem-based management.

- Monitoring information will be of direct benefit to many people including DWAF, municipalities and their scientific services department charged with water quality monitoring, scientists, water services providers, independent water quality consultants and others. Formulating management actions based on better water quality monitoring will ultimately improve the quality of rivers within the Berg WMA.

- In addition to co-ordinating and expanding current efforts, an effective water quality monitoring network should have specific goals and objectives that reflect user needs and are helpful in assessing the effectiveness of management approaches. The overall system design should determine what and where to monitor, including the definition of a set of core variables. Technical expertise is needed to standardise procedures and establish quality control, data management, and reporting protocols. It is also important for the national monitoring network to be periodically assessed and modified as necessary. Most importantly, the data collected through the national monitoring network should be useful to managers and stakeholders in evaluating management measures, determining best management practices, and making continual improvements in reaching ecosystem goals. Specifically, the national monitoring network should include the following elements:

- a core set of variables to be measured at all sites, with regional flexibility to measure additional variables where needed.
- an overall system design that determines where, how, and when to monitor and includes a mix of time and space scales, probabilistic and fixed stations, and stressor- and effects-oriented measurements.
- technical coordination that establishes standard procedures and techniques.
- periodic review of the monitoring network, with modifications as necessary to ensure that useful goals are being met in a cost-effective way.

- Reforms to ensure that in the Berg River catchment, all environmentally significant activities (including significant new agricultural activities or the significant intensification of existing activities) are subject to a proper environmental impact assessment and approval process. Environmental assessments should address potential impacts on water quality. Appropriate conditions should be attached to the environmental authorisations and any licences from DWAF must ensure that activities are carried out in a manner that protects and, as necessary, improves water quality.

- Environmental management plans should be promoted for agricultural activities. These plans should promote farming practices that minimise downstream impacts, such as: minimising erosion through conservation cropping techniques, minimising nutrient loss by aligning fertiliser amount, type and application methodology to the physiological requirements of the crop, implementing integrated pest management practices (control pesticides use to those with minimal impacts on water quality).

- Ensure the Berg WMA water quality targets are reflected in the relevant provincial and local government legislations plans. Set up a catchment scale water quality model for the Western Cape/ Berg WMA.

REFERENCES

Bath, A J. 1989. *Phosphorus transport in the Berg River, Western Cape*. Technical report of the Department of Water Affairs and Forestry, Pretoria. TR 143.

Bath, A J. 1993a. Western Cape System Analysis. *Water Quality. Volume 1: General*. Ninham Shand report to DWAF. DWAF Report No. P G000/00/2891.

Bath, A J. 1993b. Western Cape System Analysis. *Water Quality. Volume 2*: Data for Berg River Basin. Ninham Shand report to DWAF. DWAF Report No. P G000/00/2891.

Brown, C. Fowler, J. and Day, E. 1998. *An assessment of the ecological condition of rivers within the Cape Metropolitan area that are affected by waters water treatment facilities*. Southern Waters Report for Cape Waste Water Consultants.

Cape Metropolitan Council. 2000. Cape Metropolitan Coastal Water Quality Committee. Annual Report 2000. CMC : Catchment Management Department.

Chandler, R. 1994. *Estimating annual urban non-point pollutant loads*. Journal of Management Engineering. Vol. 10, no. 6, pp. 50-54.

Chutter, F M. 1998. *Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers*. WRC Report No. 422/1/98. Water Research Commission, Pretoria.

Dallas, H F. 1995. *An evaluation of SASS (South African Scoring System) as a tool for the rapid assessment of water quality*. MSc Thesis, University of Cape Town.

Dallas, H F. 1997. *An assessment of the current status of aquatic macroinvertebrate communities of the Diep River system, south-western Cape, using SASS4*. Southern Waters report to the Institute for Water Quality Studies, Department of Water Affairs and Forestry.

Dallas, H F and Day, J A. 2004. *The Effect of Water Quality Variables on Aquatic Ecosystems: A Review*. WRC Report No. TT 224/04. Water Research Commission, Pretoria.

Dallas, H F and Janssens, M P. 1999. *The Biological and Chemical Database: User Manual*. Water Research Commission Technical Report.

Dallas, H and Ractliffe, G. (eds.). 2004. *Berg River Baseline Monitoring Programme. First Annual Report*. Anchor Environmental Consultants in association with The Freshwater Consulting Group. Department of Zoology, University of Cape Town.

Dallas, H F, Day J A, Musibono, E D and Day, E G. 1998a. *Water quality requirements for riverine biotas*. Report to the Water Research Commission. Pretoria.

Dallas, H F, Day, J A, Musibono, D E and Day, E. 1998b. *Water quality for aquatic ecosystems: tools for evaluating regional guidelines*. Report to the Water Research Commission. WRC Report No 626/1/98.

Dallas, H F, Day, J A and Reynolds, E. 1994. *The effects of water quality variables on riverine biotas*. Report to the Water Research Commission. WRC Report No 351/1/94.

Dallas, H F, Janssens, M P and Day, J A. 1999. *An aquatic macro-invertebrate and chemical database for riverine ecosystems*. Water SA. 25(1): 1-8.

Davies, B R and Day, J A. 1998. *Vanishing Waters*. University of Cape Town Press. Cape Town.

Day, E. 1998. *An assessment of the current status of aquatic macroinvertebrate communities of the Diep River system, south-western, Cape, using SASS4*. Southern Waters report to the Institute for Water Quality Studies, Department of Water Affairs and Forestry.

Day, E. 2004. Water Chemistry. In: Ractliffe G and Dallas H (eds.). *Berg River Baseline Monitoring Programme: Initialisation Report - Volume 1*. Anchor Environmental Consultants in association with The Freshwater Consulting Group. Zoology Department, University of Cape Town. Pp. 255–308.

Day, E, Harding, W and Brown, C. 1999. *Environmental guidelines for the maintenance of river courses in the Cape Metropolitan Area: Assessment of Ecological Status of selected major rivers within the CMA*. Southern Waters final report for Ninham Shand.

Day, J A and Dallas, H F. 1996. Skuifraam IFR Workshop: Water quality of the Berg River. Paper presented to the Berg River IFR Refinement Worksession, Skuifraam Feasibility Study (DWAF). Starter Document for Worksession of 31 January, 1 and 2 February 1996.

Department of Water Affairs and Forestry, South Africa. 1993. *Hydro-salinity Modelling of the Berg River Basin.* Prepared by G Dyke and G Howard of Ninham Shand Inc. in association with BKS Inc. as part of the Western Cape System Analysis. DWAF Report No. P G000/00/3392.

Department of Water Affairs and Forestry, South Africa. 1996. *South African Water Quality Guidelines Volume 7. Aquatic Ecosystems*. Pretoria.

Department of Water Affairs and Forestry, South Africa. 1996a. *South African Water Quality Guidelines, Volume 2 (2nd Edition): Recreational Use*. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa. 1996b. *South African Water Quality Guidelines, Volume 4 (2nd Edition): Agricultural Use: Irrigation*. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa. 1996c. *South African Water Quality Guidelines, Volume 7: Aquatic Ecosystems*. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa. 1996d. *South African Water Quality Guidelines, Volume 3: Industrial Water Use*. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa. 1999. *Resource Directed Measures for Protection of Water Resources Volume 3: River Ecosystems* Version 1.0. Pretoria. Resource Directed Measures for Protection of Water Resources, Pretoria, South Africa.

Department of Water Affairs and Forestry, South Africa. 1999a. *Managing the Water Quality Effects of Settlements*. Newsletter No 2. April 1999.

Department of Water Affairs and Forestry. 2000a. *Draft Regulations*. Draft 1.5 of 9 February 2000. In terms of Section 26(1)(h) and (j) of the National Water Act, 1998, regarding waste discharge standards.

Department of Water Affairs and Forestry. 2000b. *Water Quality Management Series*, Sub-Series No. MS7. National Water Quality Management Framework Policy, Draft 2 Pretoria.

Department of Water Affairs and Forestry, South Africa. 2001. *Managing the Water Quality Effects of Settlements: The National Strategy (Edition 2)*. Water Quality Management Series. Policy Document U1.3.

Department of Water Affairs and Forestry, South Africa. 2002. *Water Quality Management Series, Sub-Series No. MS7, National Water Quality Management Framework Policy*, Draft 2, Pretoria.

Department of Water Affairs and Forestry, South Africa. 2002. Berg Water Management Area : Water Resources Situation Assessment : *Main Report Volume 1*. Prepared by Ninham Shand (Pty) Ltd in association with Jakoet & Associates, Umvoto Africa and Tlou & Matji on behalf of the Directorate : Water Resource Planning. DWAF Report No. P19000/00/0101.

Department of Water Affairs and Forestry, South Africa. 2004. *Berg Water Management Area: Internal Strategic Perspective*. Prepared by Ninham Shand (Pty) Ltd in association with Jakoet & Associates, Umvoto Africa and Tlou & Matji for the Directorate: National Water Resource Planning. DWAF Report No P WMA19/000/00/0304.

Department of Water Affairs and Forestry, South Africa. 2004. *National Water Resource Strategy, First Edition*. DWAF. Pretoria.

Department of Water Affairs and Forestry, South Africa. 2006. *Pre-feasibility study of potential water sources for the area served by the West Coast District Municipality, Phase II, Impact of water quality on the possible abstractions from Misverstand reservoir*. (Ninham Shand DWAF Draft Report).

Drakenstein Municipality. 2004. Paarl: Berg River: *Investigation of Micro-biological Pollution from Informal and High-Density Areas*. Interim Report No 2. Prepared by Lyners Consulting Engineers in association with Ninham Shand (Pty) Ltd.

Ewart-Smith, J, Dallas, H F and Janssens, M P. 2003. *Rivers Database version 2.2: A User Manual*. National Biomonitoring Programme Report Series No 10 (2nd Version). Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

Fourie, J M. 2003. Address to the Minister of Water Affairs, Mr Ronnie Kasrels, re water problems of the West Coast.

Fourie, J M and Görgens, A H M. 1997. *Mineralisation studies of the Berg River : 1974 - 1976*. SA CSIR. National Institute for Water Research, Pretoria.

Harrison, A C and Elsworth, J F. 1958. *Hydrobiological studies on the Great Berg River, Western Cape Province. Part 1. General description, chemical studies and main features of flora and fauna*. Trans. Roy. Soc. South Africa. Vol 25.3: 125-226.

Henderson, F M, Hart, Hart, T F Jr., Orlando, L, Heaton, B, Portolese, J and Chasan, R. 1998. *Application of C-CAP protocol land-cover data to non-point sourcewater pollution potential spatial models in a coastal environment*. Photogrammetric Engineering and Remote Sensing. Vol. 64, no. 10, pp. 1015-1020.

Institute for Water Quality Studies (IWQS). 1997. *Terms of Reference: an assessment of the riparian vegetation and macroinvertebrate communities towards the determination of habitat and biological integrity of the Diep River.*

Kleynhans, C J. *1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvhuvu River (Limpopo System, South Africa)*. Journal of Aquatic Ecosystem Health. 5:41-45.

London, L, Dalvie, E, Cairncorss, E and Solomons, A. 2000. *The quality of surface and groundwater in the rural Western Cape with regard to pesticides*. Water Research Commission Report 795/1/00.

Millard, N A H and Scott, K M F. 1954. *The ecology of South African estuaries. Part IV. Milnerton Estuary and the Diep River, Cape*. Trans. Roy. Soc. S. Afr., 34(2): 279-324.

Ninham Shand and Chittenden Nicks. 1999. *Kuils River Moss Study : Final Report*. NS Report No. 2913/8070. Report for Cape Metropolitan Council.

Nitsche, N, Tukker, J, Kamish, W and Görgens, A H M. 2001. *Water Quality Information System for Integrated Water Resource Management : The Riviersonderend-Berg River System*. Draft Water Research Commission Report.

Peters, C R. 1990. *An investigation into the state/extent of water pollution of the Eerste River and its tributaries*. B.Sc. Thesis. Department of Civil Engineering, University of Cape Town, November 1990.

Petitjean, M O G. 1987. *Eerste River catchment management report*. Freshwater Research Unit, Department of Zoology, University of Cape Town.

Ractliffe, G and Dallas, H. (eds.) 2004. *Berg River Baseline Monitoring Programme: Initialisation Report - Volume 1. Introduction to the Berg River Catchment; Groundwater and Riverine Environment*. Anchor Environmental Consultants in association with The Freshwater Consulting Group. Department of Zoology, University of Cape Town.

River Health Programme. 2004. *State-of-Rivers Report: Berg River System*. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2005. *State of Rivers Report: Greater Cape Town's Rivers*. Department of Water Affairs and Forestry, Pretora.

Schoeman, A M, Mackay, H M and Stephenson, D. 2001. *A synthesis of South Africa urban run-off studies with special emphasis on run-off from high-density settlements*. Water Research Commission (WRC) Report no 598/1/1.

Snaddon, C D. 1998. *Some of the ecological effects of a small inter-basin water transfer on the receiving reaches of the Upper Berg River, Western Cape*. Unpublished M.Sc. Thesis, University of Cape Town.

Snaddon, C D and Davies, B R. 2000. *An assessment of the ecological effects of Inter-Basin Water Transfer on the Receiving Reaches of the Upper Berg River, Western Cape*. Unpublished M.Sc. Thesis, University of Cape Town.

Snaddon, K. 2004. *Riverine Invertebrates*. In: Ractliffe G and Dallas H (eds.). *Berg River Baseline Monitoring Programme: Initialisation Report - Volume 1*. Anchor Environmental Consultants in association with The Freshwater Consulting Group. Zoology Department, University of Cape Town. Pp. 357–384.

Southern Waters. 2000. *Proposed upgrade of the Kraaifontein Waste Water Treatment Works. Potential impacts of the upgrade on the freshwater ecosystems of the Diep-Mosselbank catchment*. Specialist report to Crowther Campbell & Associates and Africon for Cape Metropolitan Council.

Southern Waters. 2001. *River and vlei assessment and monitoring in the CMA*. Revisiting and refining the river importance and sensitivity maps. Report to Catchment Management Division, CMC.

Steffen, Robertson, Kirsten (SRK). 2002. *Final Scoping Report on the proposed Fisantekraal Wastewater Treatment Works and pipeline*. Report to the City of Cape Town: Cape Metropolitan Administration.

Steffen Robertson Kirsten. 2003. *Proposed Fisantekraal Wastewater Treatment Works and Pipeline*. *Hydraulic impact assessment report*. Report by B. Engelsman to SRK.

The Water Wheel. 2005. *Upfront – Dirty water a headache for water*. The Water Wheel September to October 2005. A Water Research Commission Bi-monthly magazine.

Ulrich Looser. 2003. *Introduction to the Water Management System (WMS)*. Available on DWAF website: http://www.dwaf.gov.za/iwqs/wms/index.htm. Published on 31 December 2003.

Van Wyk, J J, Moodley, P and Viljoen, P. 2003. *Towards balancing water resource protection with water resource use and development.* Second International conference on integrated water resources management (IWRM): Towards sustainable water utilisation in the 21^{st} century. University of Stellenbosch, 22-24 January 2003.

VKE Consulting Engineers (Pty) Ltd. 2000. *Development control guidelines in flood prone areas*. Report to the Cape Metropolitan Council. Cape Town.