

**CATCHMENT DIAGNOSTIC FRAMEWORK FOR
THE KLIP RIVER CATCHMENT, VAAL BARRAGE,
OCTOBER 1998 - SEPTEMBER 1999.**

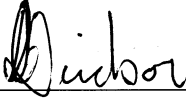
Celene Davidson

A research report submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Master of Science.

Johannesburg, 2003

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



This 11th day of August 2003

ABSTRACT

This research report is a completed Catchment Diagnostic Framework (CDF) for the Klip River catchment (Johannesburg) for the period October 1998 to September 1999.

The framework consists of a catchment description and a diagnostic index which provide a simple and representative view of the catchment and its characteristics and assist in identifying problem areas.

GIS maps, graphs and tables are used to provide a background of the catchment. The Diagnostic Index is based on a set of Indicators that are calculated and then scored according to a rating system allowing for the calculation of an overall value for the catchment. The indicators and description cover resource conditions, socioeconomics, water quantity, water quality and management.

Using this CDF it was found that the Klip River catchment is highly altered due to mining, urban, industrial and agricultural development. All of these have impacts on the beneficial use of the Klip River itself and on the downstream users of the Vaal Barrage.

ACKNOWLEDGEMENT

I would like to acknowledge the Water Quality and Environmental Services Department and Catchment Management Section of Rand Water for the time and facility they gave me to gather and process information for this project.

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1. INTRODUCTION

Mzuri Consultants designed a catchment Diagnostic Framework (CDF) for Rand Water in March 2000. The framework consists of two sections, the catchment Description and the catchment Diagnostic Index. This framework should provide a simple and representative view of the catchment and its characteristics and assist in identifying problem areas (Walmsley, 2000).

The Catchment Description comprises GIS maps, graphs and tables that are used to provide an extensive background of the catchment involved. Aspects relate to study area, natural conditions, socioeconomics, water quantity, water quality and management. The Catchment Diagnostic Index (CDIX) is based on a set of Indicators that are calculated and then scored according to a rating system. This allows the calculation of an overall CDIX value for the catchment. The CDIX value can then be used to compare different catchments and to monitor changes in these catchments through time. The indicators cover resource conditions, socioeconomics, water quantity, water quality and management.

The CDF will allow for:

- comparison of different catchments
- determination of most critical catchments for interventions
- measurement of success of interventions
- evaluation of status of catchment information systems
- identification of strategic information and monitoring needs
- adequate and effective reporting on the state of water resources at the catchment level
- easy to use process for decision-makers.

A prototype study using the framework was completed for the Rietspruit sub-catchment (part of the Klip River catchment - Vaal Barrage) in December 2000 (Davidson and de Fontaine, 2000). The study was completed using data for the October 1998 to September 1999 hydrological year. In order to have an understanding of the entire Klip River catchment, a CDF will be completed for the entire Klip River catchment – this includes the Upper Klip, the Lower Klip and the Rietspruit sub-catchments - for the time period October 1998 to September 1999.

In Section 2 of this document, various aspects of the Klip River catchment and its associated sub-catchments will be discussed. The indicators that were developed by Mzuri Consultants will be included in this section as a discussion of the relevant aspect of the catchment. The complete indicators for each sub-catchment are shown in Appendix 1 (Tables 46 - 48) and calculations of the indicators are shown in Appendix 2 (Table 49).

Section 3 will include a summary of the findings of the indicators as well as any recommendations made.

2. CATCHMENT DESCRIPTION

2.1 General

2.1.1 Location, boundaries and size

The Klip River catchment is located in the Vaal Barrage catchment in the Gauteng Province of South Africa. The Vaal Barrage catchment lies within the Upper Vaal water management unit. Figure 1 indicates the location of the Klip River catchment within Gauteng Province and Figure 2 indicates the location of the Klip River catchment within the Upper Vaal water management unit.

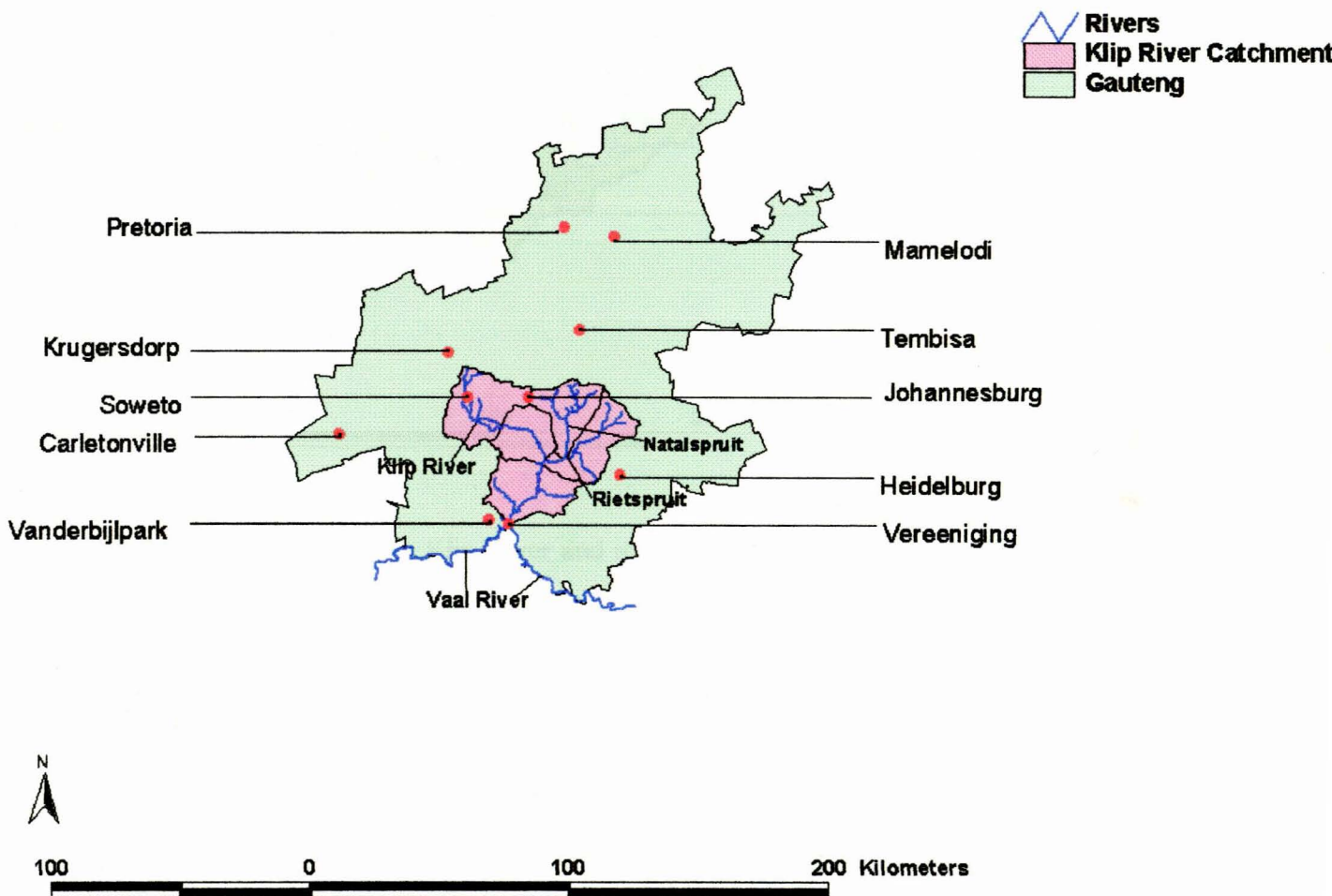


Figure 1: Location of the Klip River catchment within Gauteng Province.

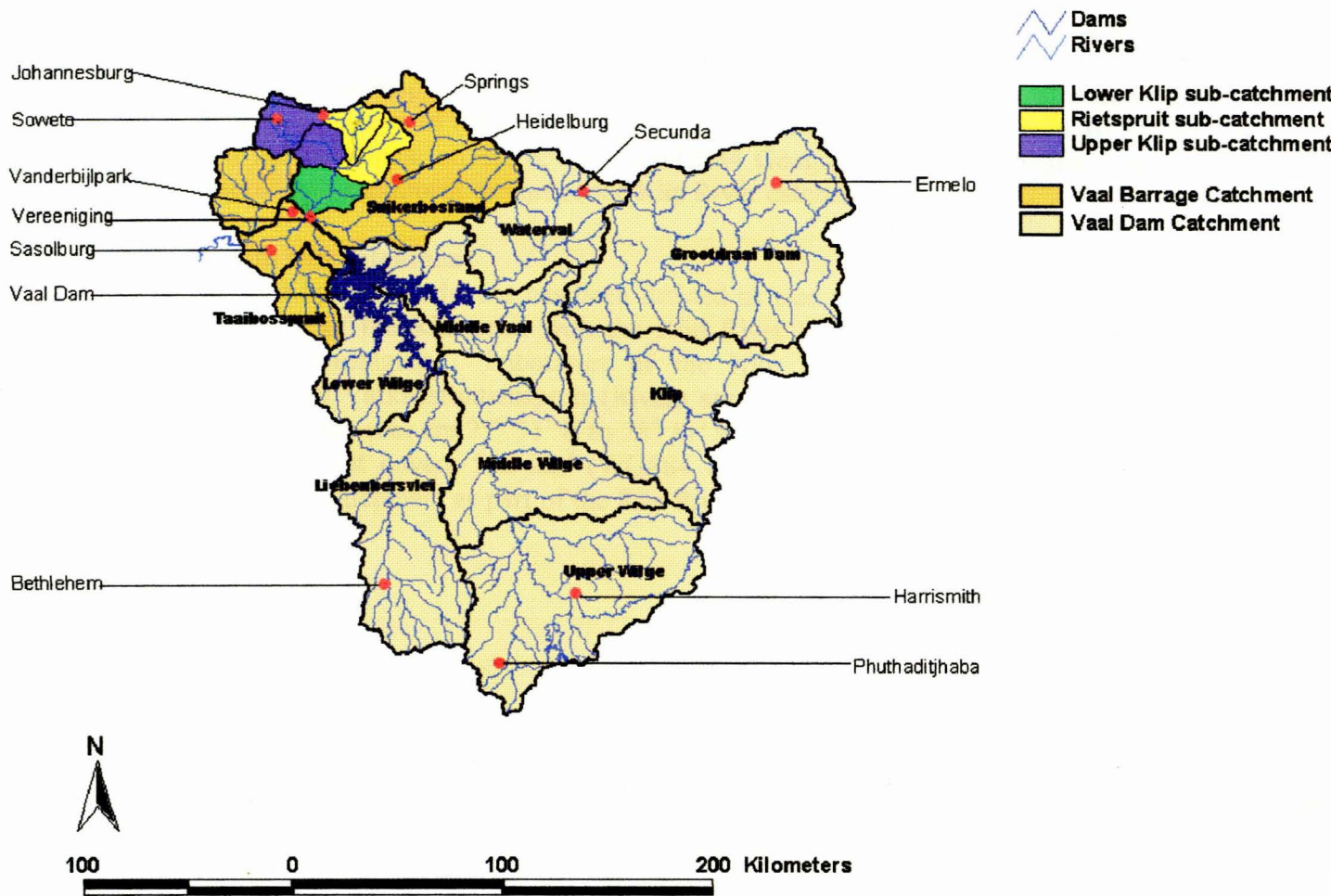


Figure 2: Location of the Klip River and its associated sub-catchments within the Upper Vaal water management unit.

Upper Klip sub-catchment

The Upper Klip sub-catchment has been defined as the natural drainage area from the source water areas of the Klip River in eastern Krugersdorp and western Roodepoort, to the confluence with the Rietspruit near Henley-on-Klip. Tributaries include the Klipspruit (Fordsburg Canal, Robinson Canal, Diepkloofspruit, Russell Stream), Harringtonspruit, Bloubosspruit and Glenvistaspruit (Rivers are dealt with later on in the text). The co-ordinates of the area are $27^{\circ} 45' E$ to $28^{\circ} 07' E$ and $26^{\circ} 07' S$ to $26^{\circ} 27' S$. The Upper Klip sub-catchment covers 893 km^2 (WGS84 Geographic, 2002). Figure 3 shows the Upper Klip sub-catchment as part of the Klip River catchment.

Rietspruit sub-catchment

The Rietspruit sub-catchment incorporates the natural drainage area of the Rietspruit including its tributaries, Natalspruit, Elsburgspruit, Withokspruit and Valsfontein to its confluence with the Klip River near Henley-on-Klip (Rivers are dealt with later on in the text). The co-ordinates of the area are 28 05' E to 28 25'E and 26 10'S to 26 30'S. The Rietspruit sub-catchment covers 856 km² (WGS84 Geographic, 2002). Figure 3 shows the Rietspruit sub-catchment as part of the Klip River catchment.

Lower Klip sub-catchment

The Lower Klip sub-catchment has been defined as that natural drainage area south of the confluence of the Rietspruit with the Klip River to the confluence with the Vaal Barrage in Vereeniging. Tributaries of the Klip River in this area include the Fouriespruit and Varkensfonteinspruit (Rivers are dealt with later on in the text). The co-ordinates of the area are 27° 51' E to 28° 11' E and 26° 25'S to 26° 40'S. The Lower Klip sub-catchment covers 532 km² (WGS84 Geographic, 2002). Figure 3 shows the Lower Klip sub-catchment as part of the Klip River catchment.

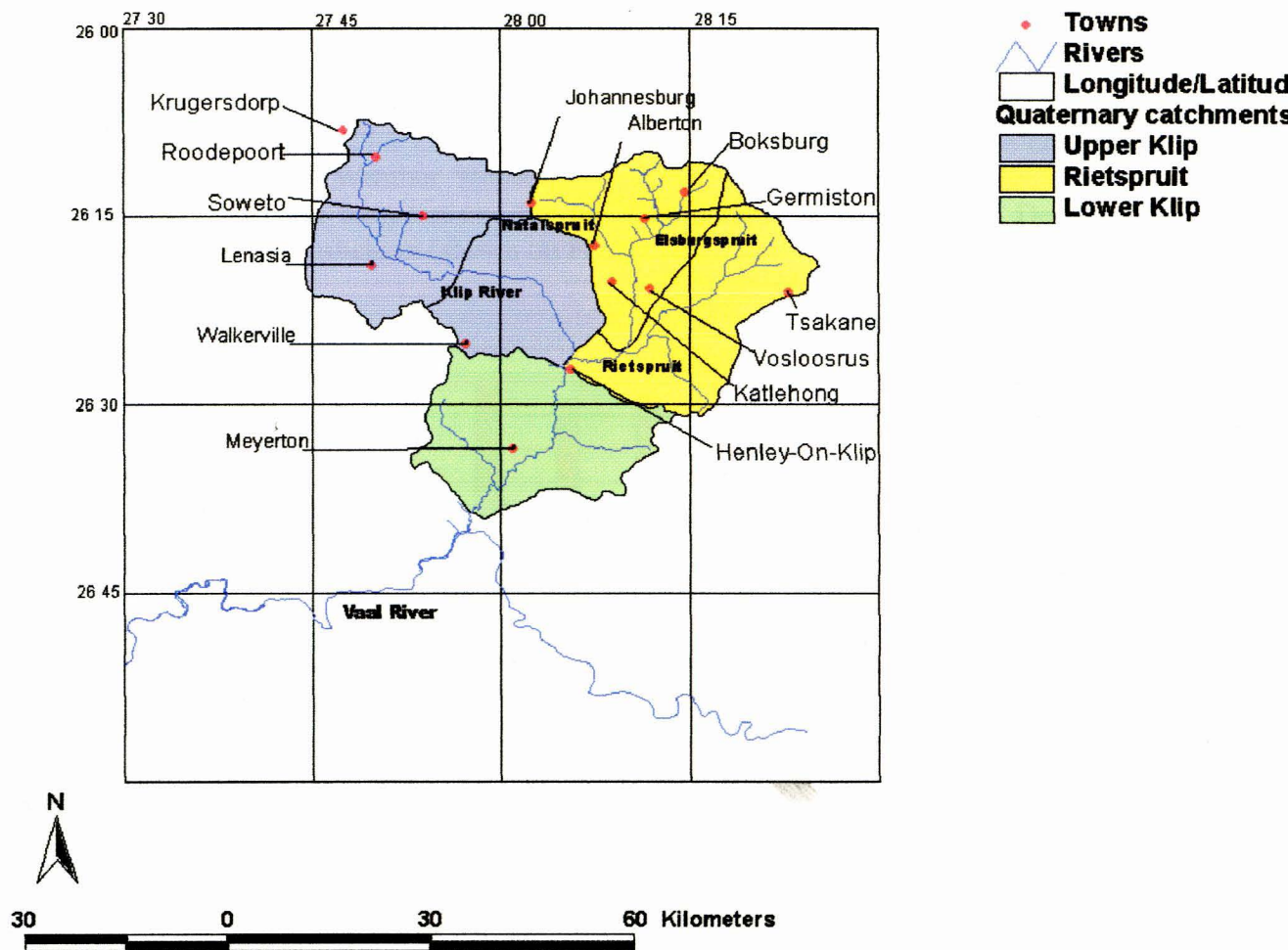


Figure 3: Klip River catchment showing associated Upper Klip, Rietspruit and Lower Klip sub-catchments (WGS84 Geographic, 2002).

2.2. Natural conditions

2.2.1 Climate

The entire Klip River catchment has a typical Highveld climate with warm to hot summers (October – March) and cool but generally cloudless winter days with cold nights. Light frost is common and snow is an exceptional occurrence (Bohlweki, 1999).

2.2.1.1. Temperature

Upper Klip sub-catchment

The warmest month in the Upper Klip sub-catchment is January with an average maximum temperature of 27.1°C. June is the coolest month with an average minimum temperature of -2.5°C (Weather Department, 2002). Figure 4 indicates the average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Zuurbekom (shown on Figure 10).

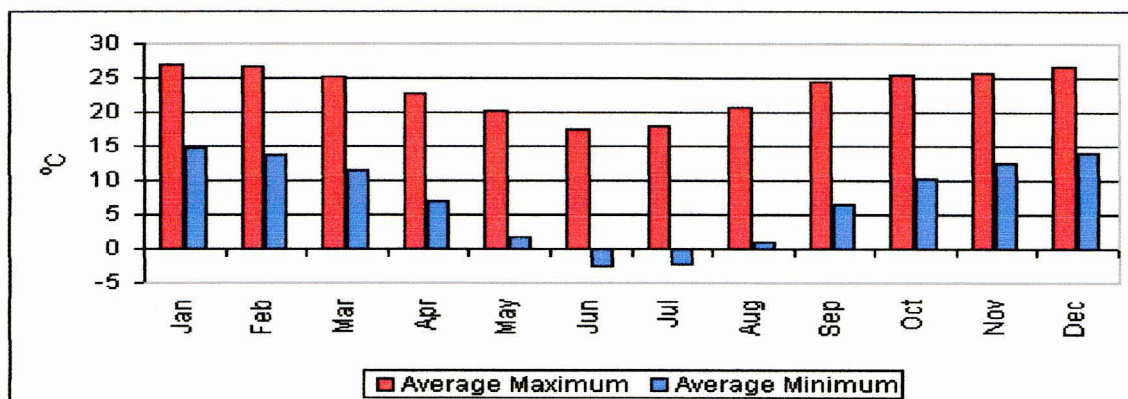


Figure 4: Average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Zuurbekom.

Rietspruit sub-catchment

The warmest month in the Rietspruit sub-catchment is January with an average maximum temperature of 25.7 °C. June is the coolest month with an average minimum temperature of 3.9 °C (Weather Department, 2002). Figure 5 indicates the average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Johannesburg International Airport (shown on Figure 10).

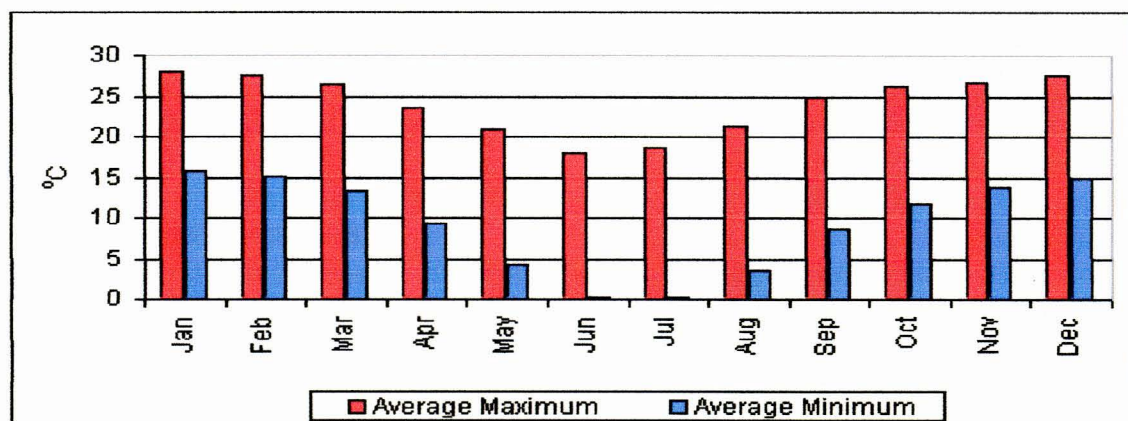


Figure 5: Average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Johannesburg International Airport.

Lower Klip sub-catchment

The warmest month in the Lower Klip sub-catchment is January with an average maximum temperature of 27.9 °C. June is the coolest month with an average minimum temperature of 0.2 °C (Weather Department, 2002). Figure 6 indicates the average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Vereeniging (shown on Figure 10).

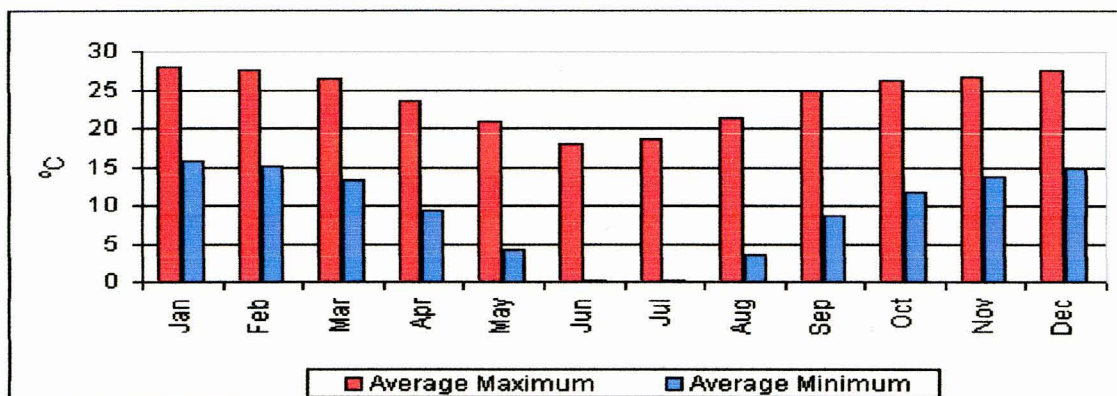


Figure 6: Average minimum and maximum temperatures for the time period January 1960 to December 1999 as measured at Vereeniging.

2.2.1.2 Rainfall

Upper Klip sub-catchment

The Upper Klip sub-catchment has a summer rainfall regime with the hydrological year running from October to September. The highest rainfall occurs in January and the lowest in July. Figure 7 indicates the monthly average rainfall for the time period January 1960 to December 1999 measured at Zuurbekom and Zwartkoppjes (shown on Figure 10). The winter months are usually very dry and periodic droughts do occur. The northern parts of the Upper Klip sub-catchment (corresponding to the higher lying areas) receive 700mm of rain per annum. The central and southern regions of the sub-catchment receive 600mm per annum (Midgley et al., 1994a). Figure 10 indicates the mean annual precipitation for the area.

Rietspruit sub-catchment

The Rietspruit sub-catchment has a summer rainfall regime with the hydrological year running from October to September. The highest rainfall occurs in January and the lowest in July. Figure 8 indicates the yearly average rainfall for the time period January 1960 to December 1999 measured at Ophirton, Turffontein and Rosherville (shown on Figure 10). The northern and southern parts of the Rietspruit sub-catchment (corresponding to the higher lying areas) receive 700mm of rain per annum. The central regions of the sub-catchment receive 600mm per annum (Midgley et al., 1994). Figure 10 indicates the mean annual precipitation for the area.

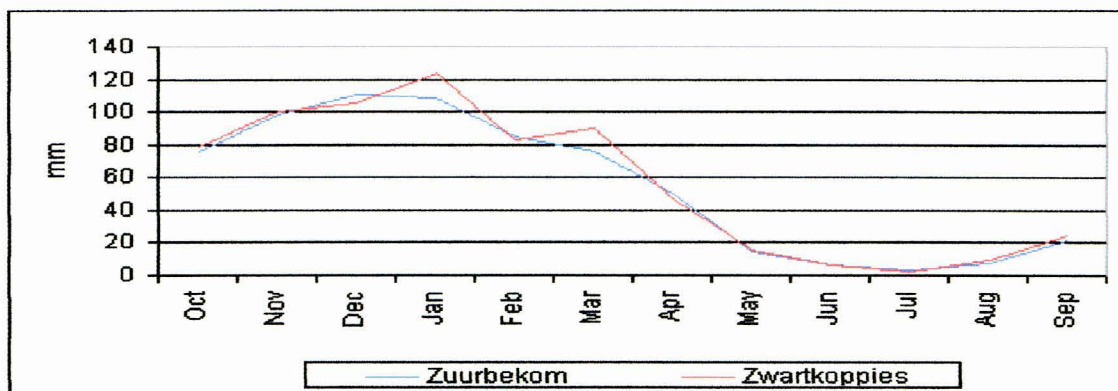


Figure 7: Average monthly rainfall for the time period January 1960 to December 1999 measured at Zuurbekom and Zwartkoppies (Weather Department, 2002).

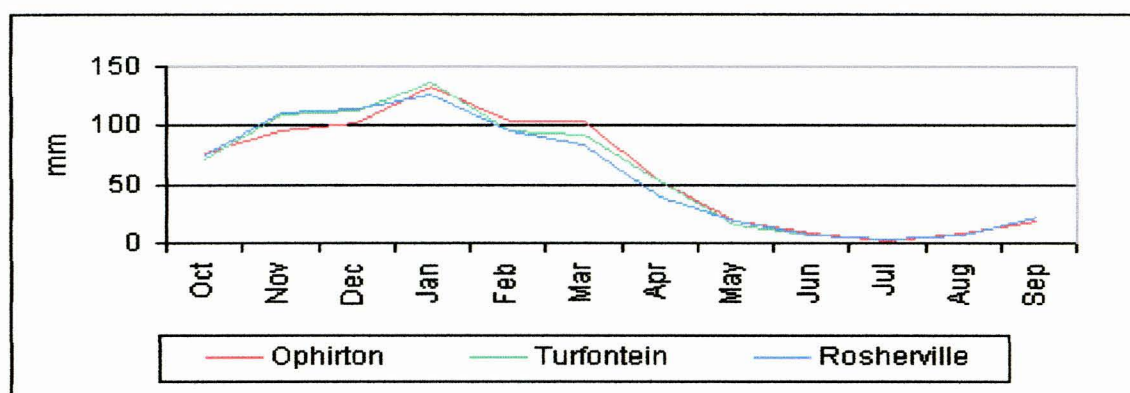


Figure 8: Average monthly rainfall for the time period January 1960 to December 1999 measured at Ophirton, Turfontein and Rosherville (Weather Department, 2002).

Lower Klip sub-catchment

The Lower Klip sub-catchment has a summer rainfall regime with the hydrological year running from October to September. The highest rainfall occurs in January and the lowest in July. Figure 9 indicates the yearly average rainfall for the time period January 1960 to December 1999 measured at Meyerton and Vereeniging (shown on Figure 10). The southeastern parts of the Lower Klip sub-catchment (corresponding to the higher lying areas) receive 700mm of rain per annum. The rest of the sub-catchment receives 600mm per annum (Midgley et al., 1994). Figure 10 indicates the mean annual precipitation for the area.

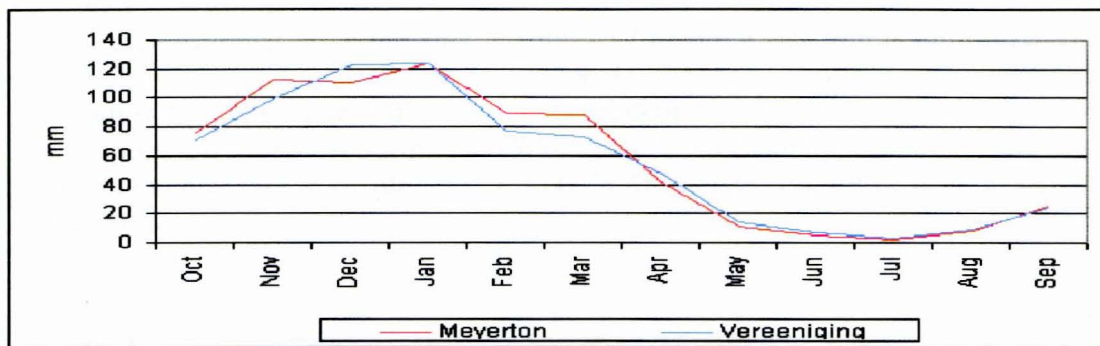


Figure 9: Average monthly rainfall for the time period January 1960 to December 1999 measured at Vereeniging and Meyerton (Weather Department, 2002).

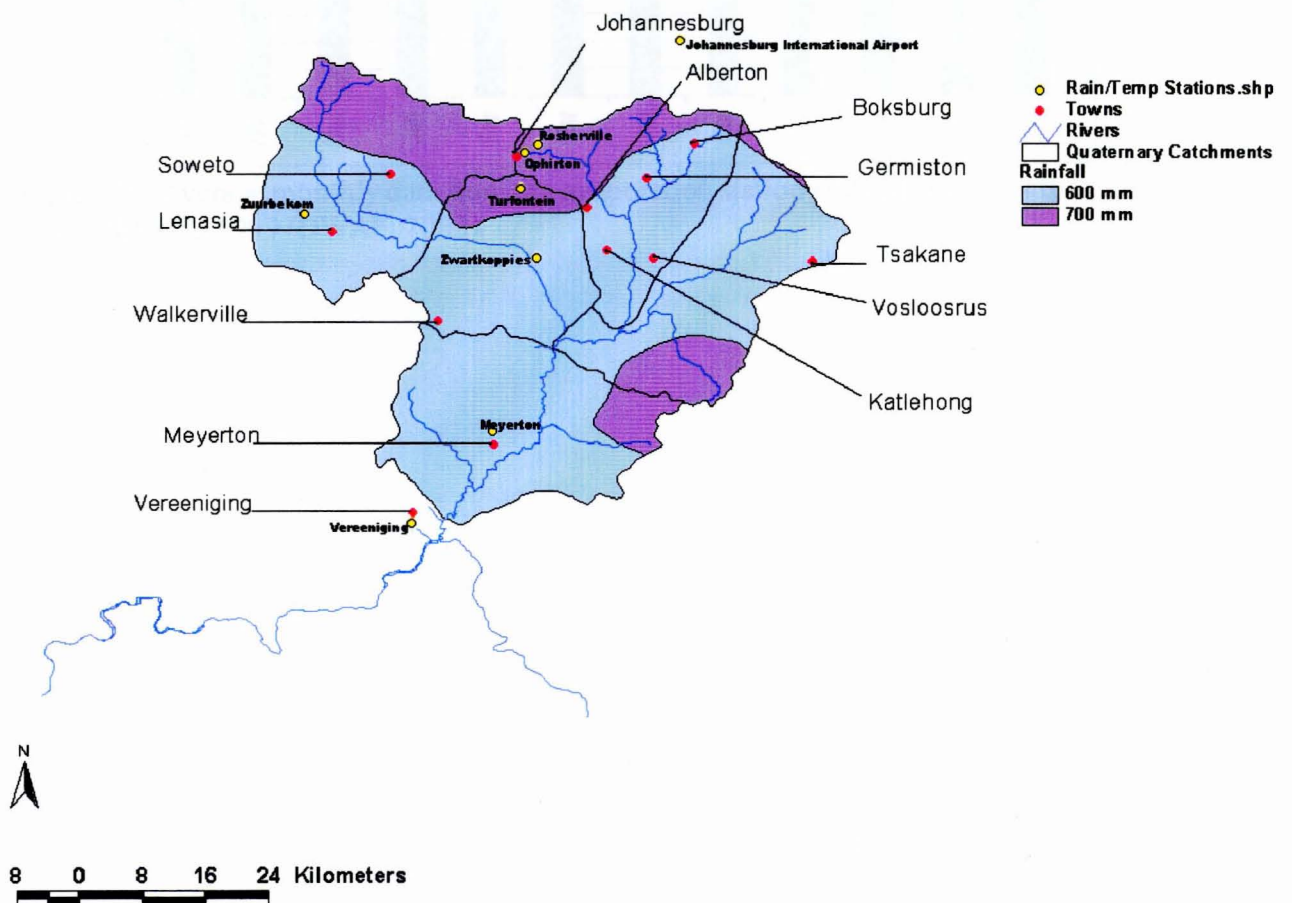


Figure 10: Mean annual precipitation for the Klip River catchment (Geomatics, 2002).

2.2.1.3 Evaporation

The average evaporation in the area is 1600 - 1700 mm a year and is uniform over the entire Klip River catchment (WRC, 1990 - 1994). Figure 11 shows the average monthly evaporation for the evaporation station at Zuurbekom for the time period 1960 to 1999. The evaporation is highest during the summer month of December (176mm) and lowest during the winter month of June (70 mm) (DWAF, 2002). Figure 12 is an evaporation map of the area.

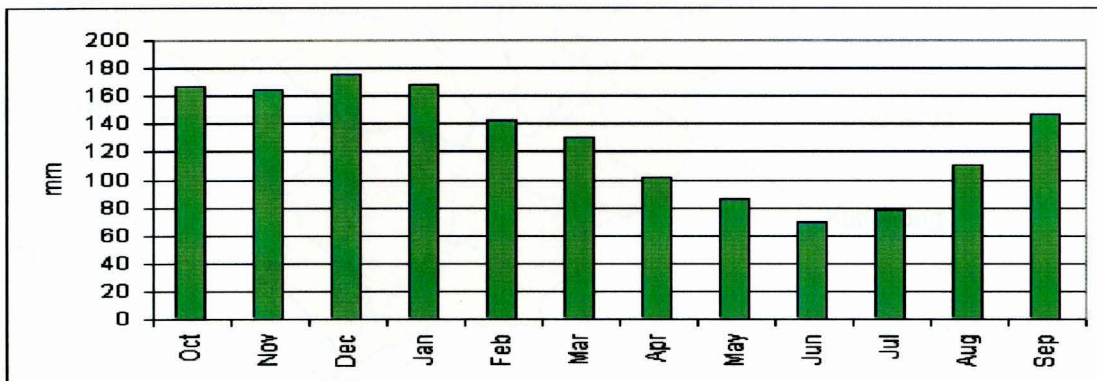


Figure 11: Average monthly data from the evaporation station at Zuurbekom for the time period 1960 to 1999 (DWAF, 2002).

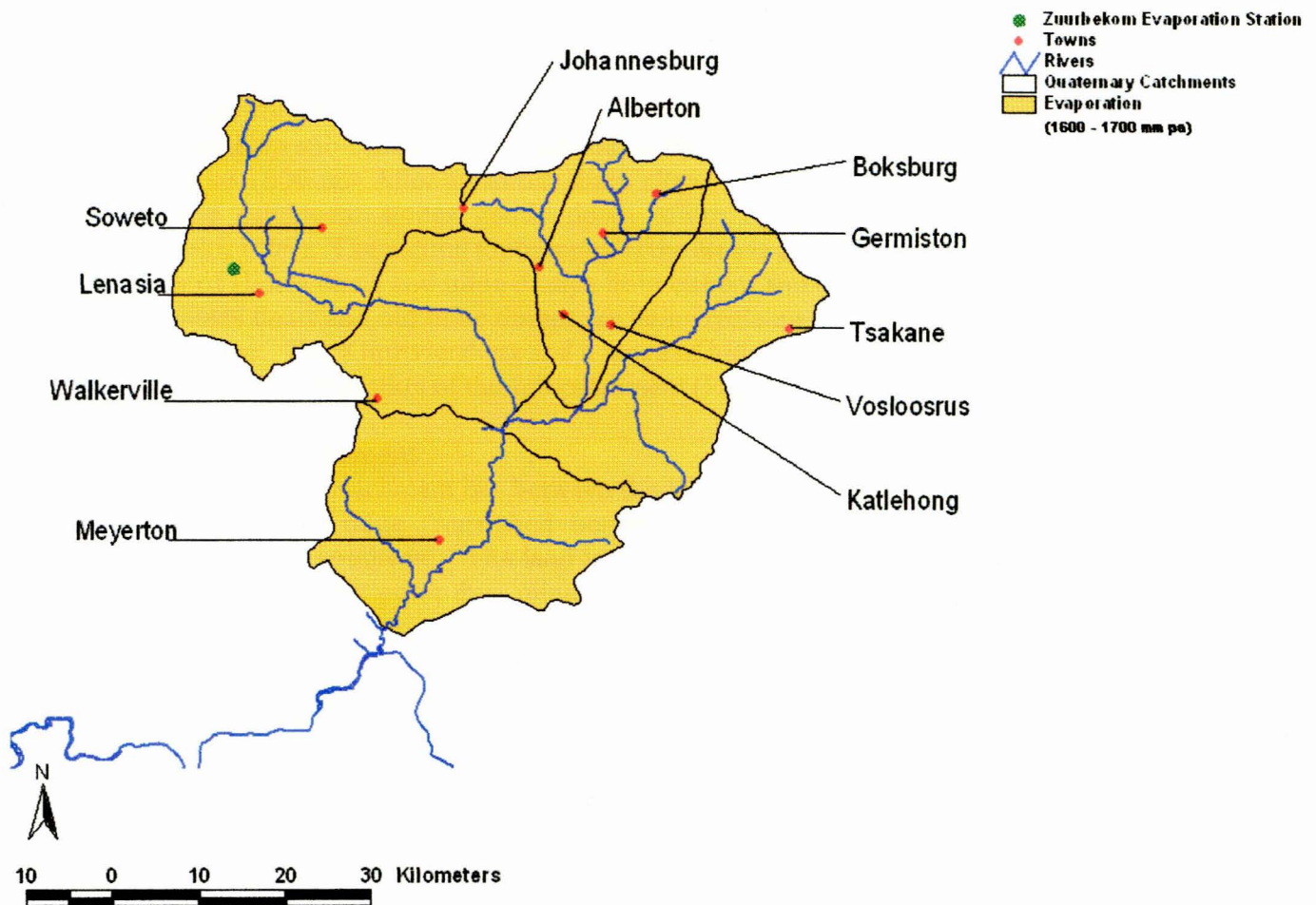


Figure 12: Evaporation for the Klip River catchment based on Zuurbekom evaporation station only (WRC, 1990 - 1994).

Discussion

From the preceding sections it can be seen that the rainfall within the Klip River catchment is between 600 and 700 mm per annum. The evaporation for the same area is between 1600 and 1700 mm per annum. The evaporation rate is much greater than the amount of rainfall in the area and thus droughts or shortages of water may occur. As will be discussed later, water is transferred into the catchment for potable purposes through Inter Basin Transfer schemes.

2.2.2 Topography

Upper Klip sub-catchment

The Upper Klip sub-catchment is bounded on the north by the Witwatersrand ridge with altitudes of 1800 m. After an initial sharp slope in the vicinity of the Witwatersrand ridge, the catchment slopes gently down towards the Lower Klip sub-catchment (Bohlweki, 1999). The natural topography of the area is altered in the northern areas by a number of slimes dams and mine dumps from current and old mine workings. Some of these slimes dams and old mine dumps are being reclaimed thus altering the features of the landscape. The Klipriviersberg and a range of hills to the north of Walkerville occur in the southwestern portion of the sub-catchment (Figure 13).

Rietspruit sub-catchment

The Rietspruit sub-catchment lies between the Witwatersrand ridge in the northwest and the Suikerbosrand ridge (watershed between Klip River and Suikerbosrand River catchment) in the southeast. The land is gently undulating and lacks any predominant topographical features other than mine dumps and slimes dams in the northern areas (Figure 13).

Lower Klip sub-catchment

The Lower Klip catchment has a gentle, southward sloping topography. The altitude of the catchment at the confluence of the Klip River with the Vaal River in Vereeniging is 1420 m (Bohlweki, 1999). The Lower Klip area is generally featureless as the wide flood plain widens towards the confluence with the Vaal Barrage. The foot of the Suikerbosrand ridge occurs in the eastern areas of the Lower Klip catchment. The Klipriviersberg, the Gatsrand and a range of hills to the north of Ennerdale and Walkerville occur in the northwestern portion of the sub-catchment (Figure 13).

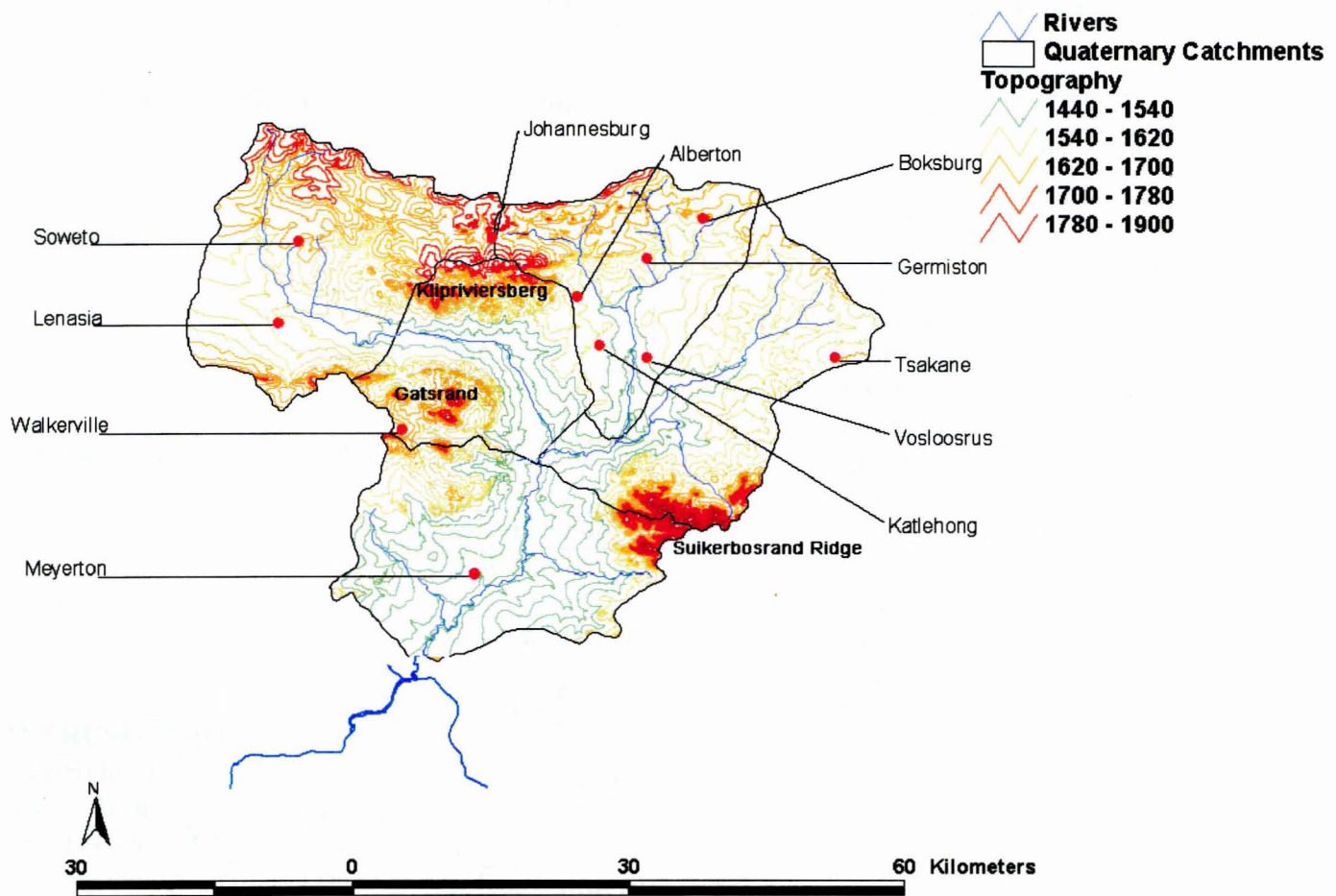


Figure 13: Topographical map of the Klip River catchment (GIMS, 2002).

2.2.3 Geology

The geology of the Klip River catchment consists mainly of formations of the Witwatersrand Super Group, the Transvaal Super Group and the Karoo Super Group along with igneous intrusions in the form of dykes and sills. Table 1 shows the generalized stratigraphy of outcropping geology in the area. Figure 14 is a 1:1 000 000 geological map of the catchment.

Table 1: Stratigraphic units and lithology for the Klip River catchment (Buttrick and Stapelburg, 1994).

Super Group	Group	Sub Group	Formation	Lithology
Karoo	Ecca			Sandstone, shale, coal, conglomerate
	Dwyka			Tillite
Transvaal	Pretoria			Andesite, agglomerate, shale, quartzite, chert breccia, conglomerate
	Chuniespoort	Malmani		Dolomite, chert
			Black Reef	Quartzite, shale, conglomerate
Witwatersrand	Central Rand	Turffontein		Quartzite, conglomerate, shale
		Johannesburg		Quartzite, conglomerate
	West Rand	Jeppestown		Shale, quartzite, conglomerate, lava
		Government		Quartzite, conglomerate, shale
		Hospital Hill		Quartzite, shale
INTRUSIVE ROCKS				
Klipriviersberg		Andesitic lava, tuff, basaltic lava		
Karoo Dolerite		Dolerite		
SEDIMENTARY ROCKS				
Tertiary and Quaternary Deposits		Eolian/Colluvial material, alluvium		

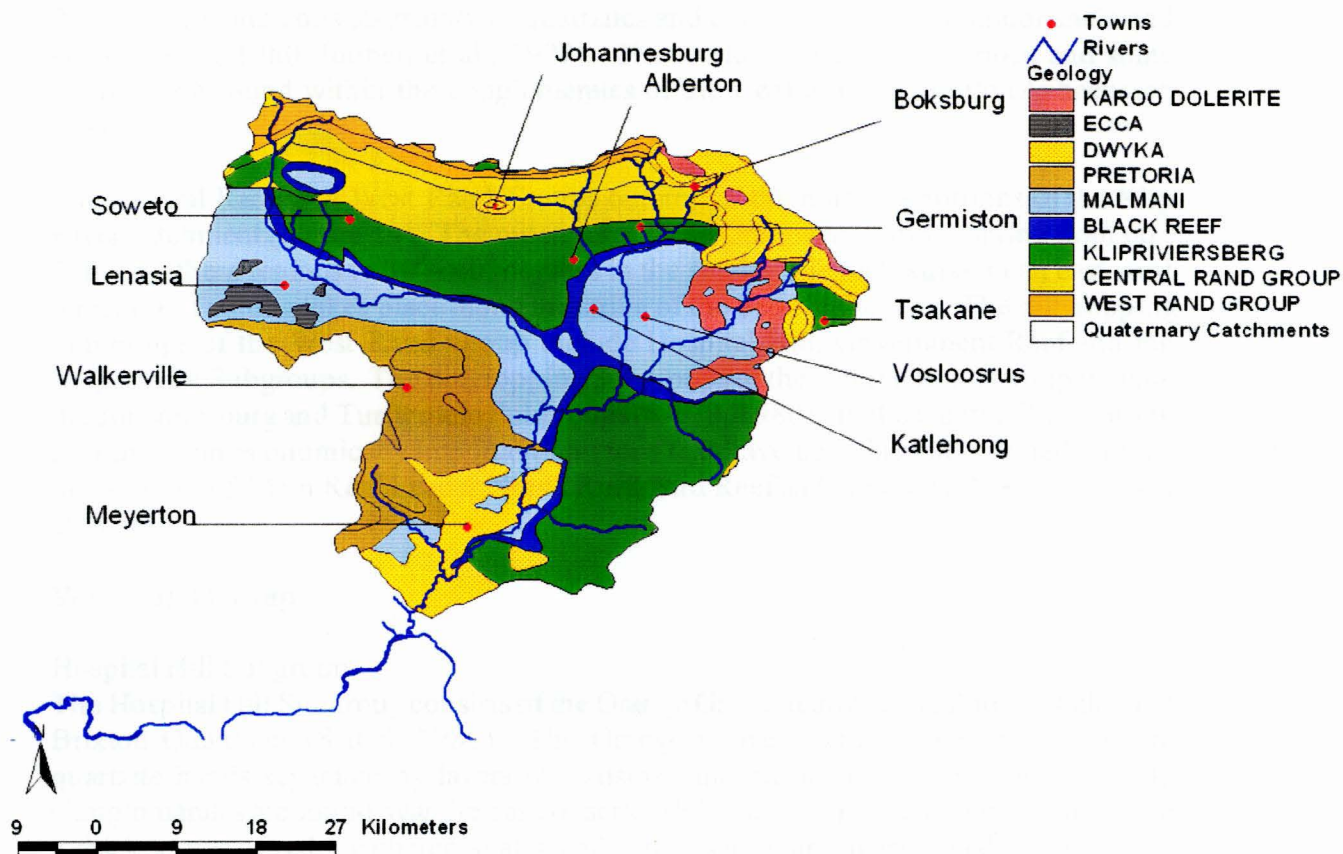


Figure 14: Geological map of the Klip River catchment (Council for GeoScience, 2000).

Witwatersrand Super Group

The formations of the Witwatersrand Super Group are a sedimentary cover on the Archean granite and greenstone basement rocks of the Kaapvaal Craton. The Ventersdorp lavas overlie the Witwatersrand formations unconformably. Overlying these rocks are the Transvaal Super Group and lastly the Karoo Super Group.

The Witwatersrand Super Group consists of alternating groups of argillaceous and arenaceous sediments. The materials of which the Witwatersrand formations are composed are most likely derived from the erosion of Basement granites and greenstones north west of the present Witwatersrand basin (Anhaeusser, 1986). Argillaceous beds predominate in the lower portion of the basin (West Rand Group). These beds are of shallow marine origin and consist of shales, quartzites, minor conglomerates, lava, diamictites and ironstones (Joubert et al., 1998). The West Rand Group is overlain by

formations of the Central Rand Group (SACS, 1980). The Central Rand Group is of fluvial origin and consists mainly of quartzites and conglomerates with minor shale and lavas (SACS, 1980, Joubert et al., 1998). The world's largest gold deposit and some uranium are found within the conglomerates of the Central Rand Group (Anhaeusser, 1986).

The Central Rand and West Rand Groups outcrop in the northern portions of the Klip River catchment (Figure 14). The outcrops of these Groups have dips varying from 60° in the northern regions to 30° - 40° degrees in the south. The beds strike in an east-west direction. Faulting takes place along the strike of the beds in the area. The outcropping Subgroups of the West Rand Group include Hospital Hill, Government Reef and the Jeppeshtown Subgroups. The outcropping Subgroups of the Central Rand Group include the Johannesburg and Turffontein Subgroups (SACS, 1980). In the Central Rand Group area the main economically important horizons that have been intensely mined include the Main Reef, Main Reef Leader, South Reef, Bird Reef and Kimberly Reef (Tankard et al., 1982).

West Rand Group

Hospital Hill Subgroup

The Hospital Hill Subgroup consists of the Orange Grove quartzites, Parktown shales and Brixton Quartzites (SACS, 1980). The Orange Grove quartzites are two prominent quartzite bands separated by layers of schistose and micaceous shales (SACS, 1980). Conglomerates are found near the base of series (SACS, 1980). The Parktown shales are a thick group of red weathered shales and slates with many marker beds or horizons. These horizons include quartzites and magnetic ferruginous slates. The Contorted bed is an important marker within the Parktown shale formation and is a strongly folded banded iron formation (SACS, 1980). The Brixton Quartzites are three thick green orthoquartzite beds separated by fuchsite and ferruginous shales. The orthoquartzites have a 'sago' texture that can be attributed to intense shear stress. The Rietfontein Fault, which cuts this portion of the Central Rand, may have provided the force for this texture (SACS, 1980).

Government Reef Subgroup

The quartzites occurring within the Government Subgroup differ from the Hospital Hill quartzites in that the quartzites are sub-graywackes instead of orthoquartzites. The ferruginous shales in this subgroup are also more magnetic (SACS, 1980). The Coronation Shale Formation is an important marker within this subgroup. This formation is black and highly magnetic (SACS, 1980).

Jeppeshtown Subgroup

The Jeppeshtown series consists mainly of shales with some quartzites. The shales within this subgroup are less ferruginous. A horizon of andesitic lava, volcanic breccia and tuff occurs in this series and is known as the Jeppeshtown Amygdaloid or Jeppeshtown lava (SACS, 1980). A lot of longitudinal faulting occurs within this Subgroup (SACS, 1980).

Central Rand Group

Johannesburg Subgroup

The Johannesburg Subgroup was previously known as the Main-Bird Series. This unit consists of quartzites and conspicuous conglomerate beds. The conglomerates in this Subgroup become finer towards the basin of the Witwatersrand Super Group (SACS, 1980). Many of the conglomerate beds within this Subgroup have economically viable gold deposits within them. Within the Krugersdorp Quartzite Formation is the chloritoid Bird Reef marker (SACS, 1980). The Booysens Shale Formation occurs in the subgroup and consists mainly of shale with lesser intervals of quartzites and dolomitic shales.

Turffontein Subgroup

The Turffontein Subgroup consists of quartzites and coarse gritty orthoquartzites. Large areas of conglomerates are incorporated with the quartzites. The Ventersdorp Contact Reef (VCR) occurs in the top section (Venterspost Conglomerate Formation) of this Subgroup. The VCR is a stand-alone unit, separate from the Witwatersrand and Ventersdorp Super Groups but is not developed in the Central Rand.

Reef Horizons in the Central Rand Group

Five main economically viable reefs occur within the Central Rand Group. These are the Main Reef, Main Leader Reef, South Reef and Bird Reefs in the Johannesburg Subgroup and the Kimberley Reef at the base of the Turffontein Subgroup.

More than 70 ore minerals are recognized in the Witwatersrand placers, 40 of which are detrital. The most important economic detrital minerals in decreasing order of abundance are pyrite, uraninite, brannerite and gold. Other detrital minerals include arsenopyrite, cobaltite, chromite and zircon. The crushed and milled conglomerate from which gold has been extracted ends up on tailings dams that abound in the Upper Klip and Rietspruit sub-catchments. These tailings dams contain significant quantities of pyrite and the detrital minerals noted above. It is the large quantities of pyrite in the slimes dams in particular, that, following oxidation lead to Acid Mine Drainage (low pH water) and high concentration of heavy metals such as Iron when the slimes and exposed faces underground come into contact with water.

Transvaal Super Group

The stratigraphic units of the Transvaal Super Group that outcrop in the Klip River Catchment area are the Black Reef, the Malmani Dolomite and the Pretoria Groups.

Black Reef Group

This group is made up of auriferous dark-coloured arenite and conglomerates and occurs at the base of the Transvaal Super Group (SACS, 1980). The Black reef Quartzite Formation consists of quartzites with lenses of grit and conglomerate. Shale is present near the top of this group, close to the overlying dolomites (SACS, 1980).

Malmani Dolomite Subgroup

The Malmani dolomites comprise of light grey to dark grey dolomite with some Fe and

Mn. Solution cavities are common in these rocks. These cavities from karstic features are known to collapse, thus forming sinkholes. This series lies unconformably on the Black Reef Group. The Malmani dolomites are divided into five formations that can be distinguished by their chert content as well as the presence or absence and the type of algal structures found in the dolomite (SACS, 1980).

Pretoria Group

This group consists predominantly of quartzite and shales together with a prominent volcanic unit, the Hekpoort Andesite formation and minor conglomerate, chemical and volcanic members (SACS, 1980). The group has high iron-rich units near Vereeniging and Henley on Klip. This has led to a number of early Iron mines within the area.

Karoo Super Group

In the Klip river catchment area there are outcrops of the Dwyka and Eccca Series. These form part of the Karoo Super Group.

Dwyka (tillite) Formation

The Dwyka series is a typical glacial deposit. This formation is characterized by diamictites, varved shales and mudstones with dropped pebbles, fluvioglacial gravel and conglomerates (SACS, 1980).

Eccca Group

The Lower Eccca shales overlie the Dwyka tillites. The Eccca Group consists mainly of shales (SACS, 1980). The Madzaringwe formation forms part of the Eccca Group in this area and consists of alternating black shale, micaceous sandstone, siltstones and interbedded coal seams (SACS, 1980). The coal seams are more prominent in the Blesbokspruit sub-catchment to the east of the Klip River Catchment.

Karoo dolerites

The Karoo dolerites are dark-coloured crystalline igneous rocks that intrude the sediments of the Karoo Super group. These medium grained rocks are made up of augite and plagioclase feldspar (SACS, 1980). Karoo dolerites are found mainly in the Rietspruit sub-catchment.

2.2.4 Soils

The soils in the Klip River catchment are mainly red-yellow-grey latosol plinthic catena with some black montmorillonite clays and red clays in the southern portions of the Lower Klip river sub-catchment (DEAT web reference, 2001).

Soils with hard plinthite are generally found over sandstones. The depth of the water table affects the colour of these soils. With deeper water tables redder soils predominate. Shallow water tables lead to the yellow-grey soils (Mpumulanga soil mapping project web reference, 2003). Black montmorillonite clay and red clay soils are found in areas with sandy shales.

Soils on the quartzites are virtually non-existent, extremely acid and of extremely low nutrient status. Shales and slates are more prone to weathering. The soils from this weathering occupy the depressions between the rocky quartzite ridges. These soils are more basic and have the potential to hold nutrients to a greater extent than the quartzites (<http://www.veld.org.za/>, 2002).

Soil texture (Figure 15) and Geology (Figure 14) can't be compared as the scale for the soil map is 1: 2 500 000 whereas the scale of the geology map is 1: 1 000 000. Small variations within the soil texture can thus not be seen. Figure 15 is an indication of Soil Texture and not Soil Type.

Sediment yield values are derived mainly from reservoir basin surveys carried out by Department of Water Affairs and Forestry. Sediment volumes are calculated from the observed decrease in reservoir volume over a period of years. These values are then converted to the annual average sediment yield per unit area (Midgley et al., 1990). Measuring points for the calculation of these values are not shown on Figure 16, as the information was not available on the GIS database used. There does not seem to be much correlation between the Sediment yields (Figure 16) and the Vegetation (Figure 18). This may be due to different scales or very broad groupings used in the data used for the maps.

The erodibility index is determined by combining the effects of slope and soil type, rainfall intensity and land use.

Upper Klip sub-catchment

The soils within the Central Rand area are shallow and the Klipriviersberg formations are overlain by clayey soils (Greater Johannesburg Metropolitan Council, 2002). The soil texture in the Upper Klip sub-catchment range from a sandy clayey loam texture over most of the catchment to a sandy loam with less clay texture in the south east of the sub-catchment (Midgley et al., 1994b). The soils in the area are derived mainly from the weathering of dolomites and sandstones. Deposits of young alluvium occur along the streams of the Klip River. The Upper Klip sub-catchment has a high erodibility index ranging from 6 in the majority of the sub-catchment to 7 in the southwestern part of the sub-catchment (Midgley et al., 1994b)(Figure 17). The Upper Klip sub-catchment yields between 14000 and 18000 tons of sediment per year (Midgley et al., 1994b)(Figure 16).

Rietspruit sub-catchment

The soil texture in the Rietspruit sub-catchment ranges from a sandy clayey loam texture in the northwest to a sandy loam with less clay texture in the rest of the sub-catchment (Midgley et al., 1994b). The Rietspruit Sub-catchment has a high Erodibility Index ranging from 6 in the majority of the Sub-catchment to 7 in the southern most part of the sub-catchment (Midgley et al., 1994b)(Figure 17). The Rietspruit Sub-catchment Yields between 11000 and 18000 tons of sediment per year (Midgley et al., 1994b)(Figure 16).

Lower Klip sub-catchment

The soil texture in the Lower Klip sub-catchment range from a sandy clayey loam texture in the west to a sandy loam with less clay texture in the far northeast of the sub-catchment (Midgley et al., 1994b). The Lower Klip sub-catchment has a high Erodibility Index ranging from 6 in the majority of the sub-catchment to 7 in the far northeastern most part of the sub-catchment (Midgley et al., 1994b)(Figure 17). The Lower Klip sub-catchment yields 17000 tons of sediment per year (Midgley et al., 1994b)(Figure 16).

Figure 15 is a map of the soil texture of the Klip River catchment, Figure 16 indicates the sediment yield of the area as tones per annum and Figure 17 indicates the erodibility of the area.

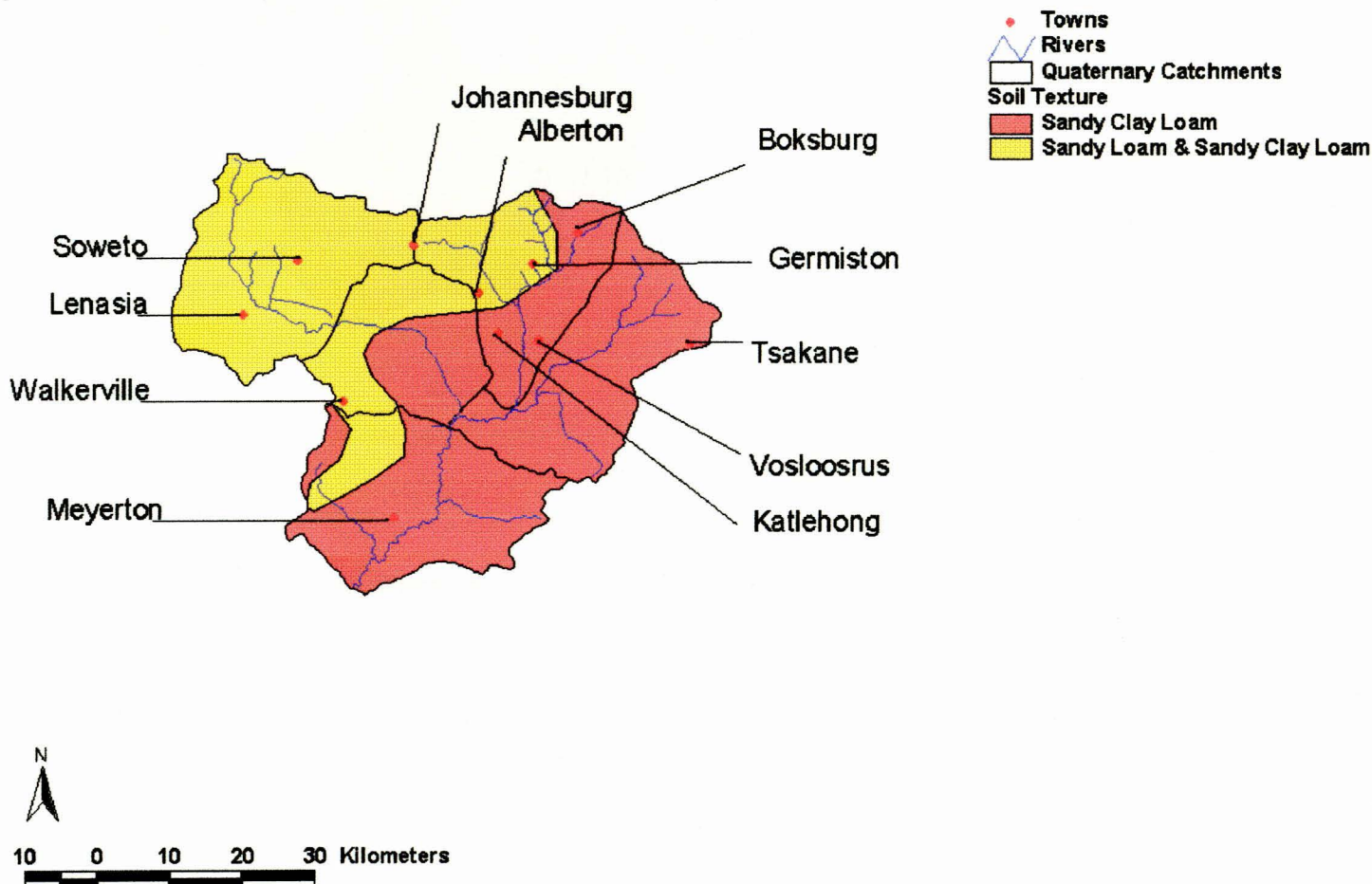


Figure 15: Soil Texture of the Klip River catchment (WRC, 1990 - 1994)

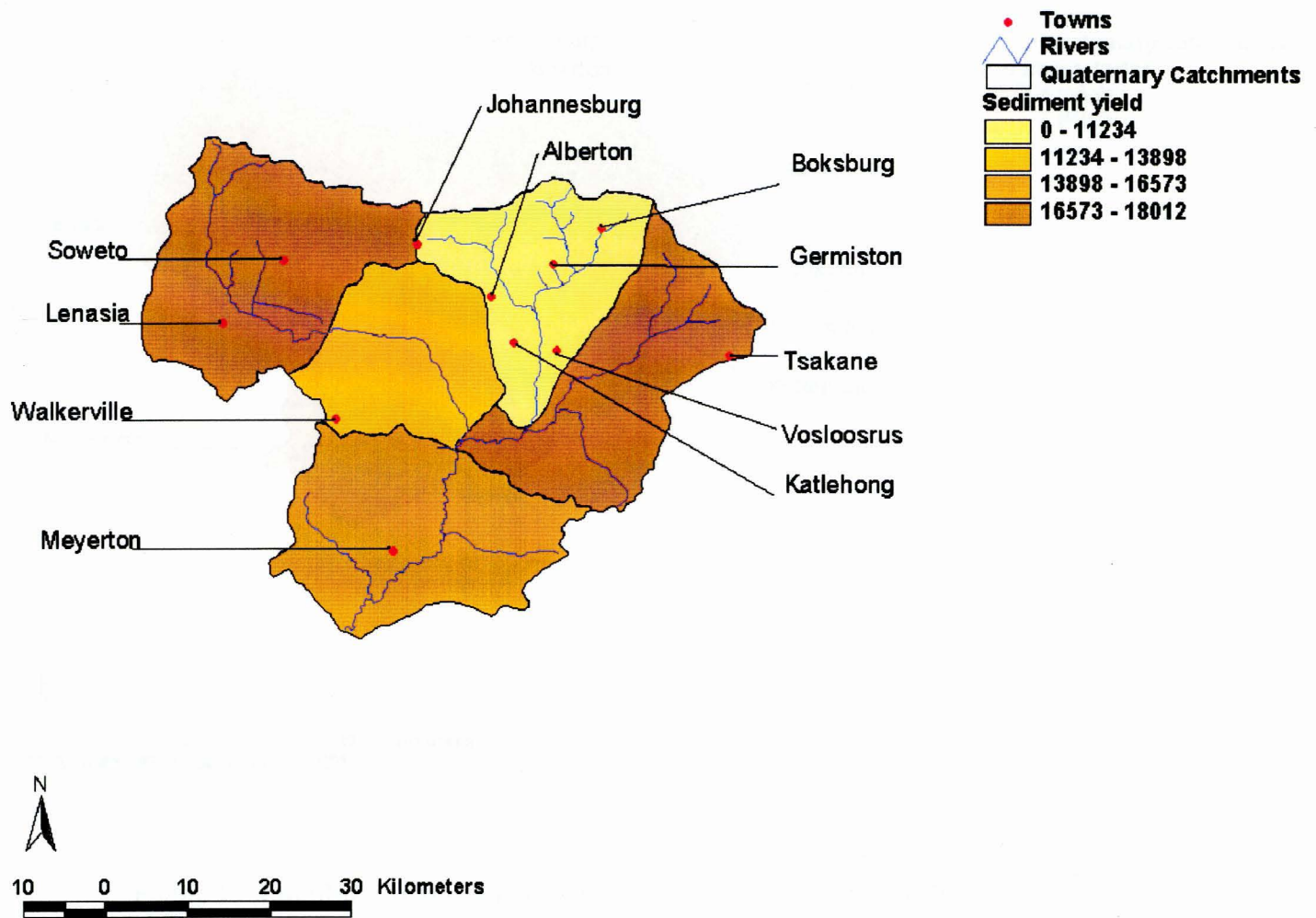


Figure 16: Sediment yield (tonnes per annum) of the Klip River catchment. (WRC, 1990 - 1994)

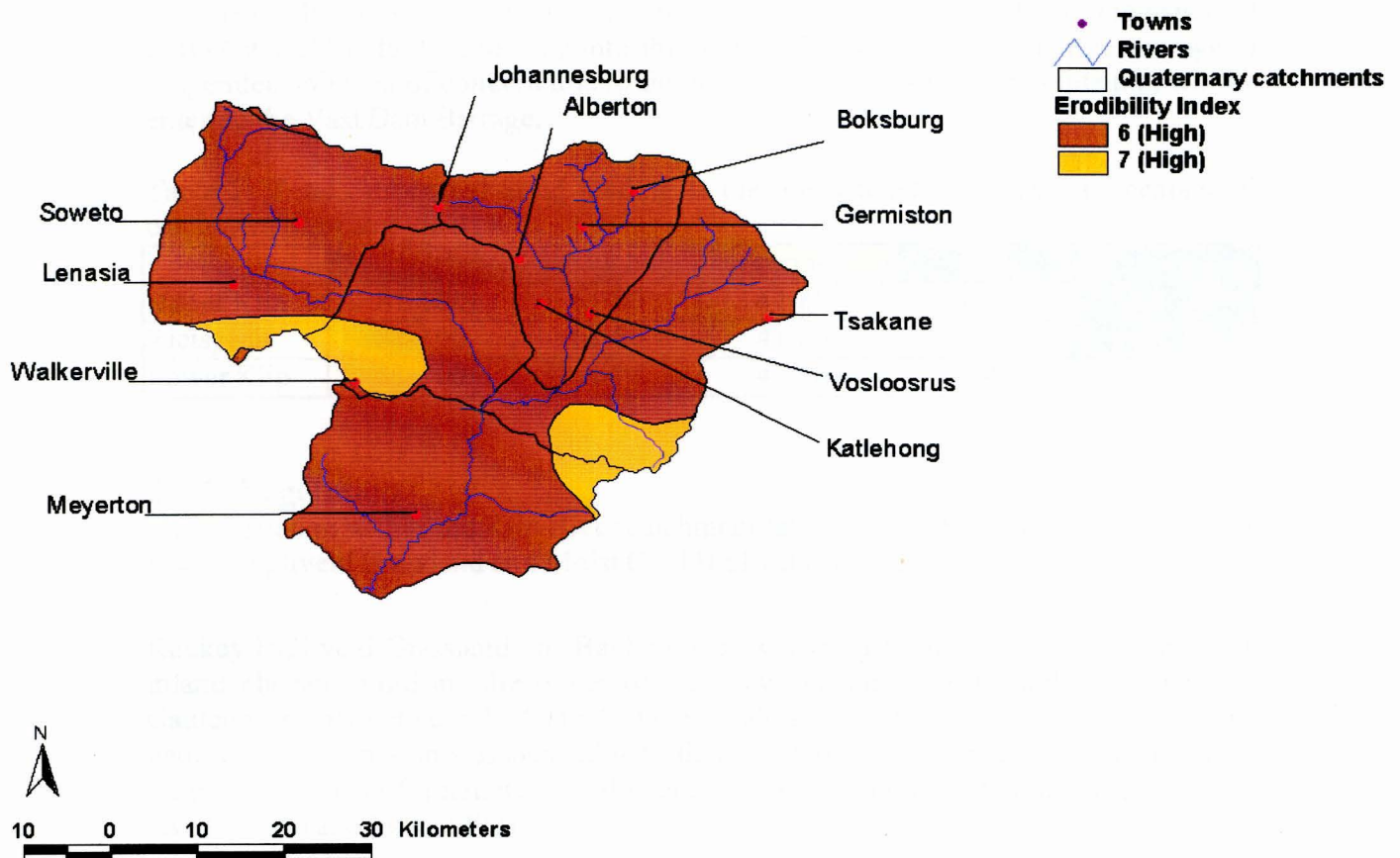


Figure 17: Erodibility of the Klip River catchment. (WRC, 1990 - 1994)

Discussion

The erodibility index and sediment yield throughout the catchment is high (Figure 16 and Figure 17). Due to the high erodibility index and sediment yields in the catchment it can be assumed that large amounts of sediment are washed into the rivers in the area. Table 2 below shows the Total Suspended Solids (TSS) loading at a downstream point (K21- Upper Klip, R6 - Rietspruit, K19 - Lower Klip) (Figure 59) as a percentage of the expected Sediment yield (Figure 16) in each of the three sub-catchments. These values are calculated in Appendix 2. From the table it can be seen that in the Upper Klip and Rietspruit sub-catchments, the TSS loading is within the Excellent (blue) range. This implies that very little suspended material is measured in the river water in these areas as compared to the expected sediment yield as portrayed in Figure 16. Between 0 and 20 % of the expected sediment yield is finding its way into the rivers of the area. In the Lower Klip sub-catchment the TSS loading is within the Below Average range. Larger amounts

of suspended material are measured in the river water in the area as compared to the expected sediment yield portrayed in Figure 16. Between 60 and 80 % of the expected sediment yield is finding its way into the rivers in the area. This high percentage of suspended solids is of concern due to the high volumes of salts and solids that will be entering the Vaal Dam Barrage.

Table 2: Total Suspended Solid loading at the downstream point as a percentage of catchment sediment yield (%).

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	81-100	61-80	41-60	21-40	0-20
Rietspruit	81-100	61-80	41-60	21-40	0-20
Lower Klip	81-100	61-80	41-60	21-40	0-20

2.2.5 Vegetation

The vegetation within the Klip River catchment falls into two broad categories, namely Rocky Highveld Grassland and Moist Cool Highveld Grassland.

Rocky Highveld Grassland or Bankenveld (A61) is a typical grassland of the high inland plateau found in the ridges of the Witwatersrand and the dolomite plains of Gauteng mainly between 1 500 to 1 600 m in altitude (Robelo and Low, 2002). The geology most commonly associated with this vegetation type is rocky mountains, hills, ridges and plains of quartzite, conglomerate, shale, dolomite and sometimes andesitic lava (Robelo and Low, 2002).

Characteristic grass species in the Klip River catchment are Giant Speargrass, Broadleaf Bluestem and Red Autumngrass. Many dicotyledonous forbs occur in this vegetation type, including Wild Sweetpea, Rough-hair Sage, Broom Ragwort, the xerophytic Parsley Fern and the leafy succulent *Crassula lanceolata*. Non-grassy forbs include Wild Squill and Bluntleaf Currant. Woody vegetation occurs as sheltered islands of temperate mountain bushveld within the Grassland Biome. Typical species include Common Hook Thorn *Acacia caffra*, Mountain Karee and Common Wild Currant (Robelo and Low, 2002).

Moist Cool Highveld Grassland is widespread, covering the central-eastern part of the highveld in the Free State, as well as the southern and eastern parts of Gauteng with altitude varying from 1 400 to 1 600 m (Robelo and Low, 2002). The geology and soils most commonly associated with this vegetation type are deep, red and yellow soils, mostly on Karoo Sequence sediments but also on shale (Witwatersrand Supergroup) and andesitic lava (Ventersdorp Supergroup) (Robelo and Low, 2002).

Characteristic grass species in this catchment include mostly Redgrass (under pristine conditions) while few other species occur, particularly dicotyledonous forbs. Other grasses often encountered include Broom Needlegrass, Sawtooth Lovegrass and Velvet

Signalgrass. Forbs include Fishbean, *Wild Petunia* and Brown Saffronbush. When overgrazed, Weeping Lovegrass replaces Redgrass and becomes dominant. When in poor condition, other elements invade, including karroid shrubs such as Bitterkaroo, Bankruptbush, Small Bietou. Woody dwarf shrubs such as Dwarf Buffalothorn and Elephant's Root occur as part of this vegetation type (Robelo and Low, 2002).

Mining in the northern part of the area has disturbed the soil profiles and thus the natural vegetation (Mogg, 1961).

Upper Klip sub-catchment

According to Robelo's classification (Robelo and Low, 2002), the natural vegetation type of the Upper Klip sub-catchment is a mix of two types of grassland, namely, rocky Highveld grassland in most of the area and moist cool Highveld grassland in the east (Midgley et al., 1994b). Exotic black wattle and blue gum are also found adjacent to the river in the area (Bohlweki, 1999).

Rietspruit sub-catchment

According to Robelo's classification (Robelo and Low, 2002), the natural vegetation type of the Rietspruit sub-catchment area is a mix of two types of grassland, namely, moist cool Highveld grassland in the central regions and rocky Highveld grassland in the northern and southern regions (Midgley et al., 1994b).

Lower Klip sub-catchment

According to Robelo's classification (Robelo and Low, 2002), the natural vegetation type of the Lower Klip sub-catchment area is a mix of two types of grassland, namely, moist cool Highveld grassland in the eastern regions and rocky Highveld grassland in the western regions (Midgley et al., 1994b).

Most of the natural veld types have either been ploughed up or disturbed to enable urban development. Intensive farming takes place in most of the lower catchment. The rocky ridges and low hills protect the few remaining natural veld type habitats where a number of Red Data flora species are known to occur (Bohlweki, 1999). Figure 18 is a map of the vegetation in the Klip River catchment based on Robelo's classification.

There does not seem to be much correlation between the Sediment yields (Figure 16) and the Vegetation (Figure 18). This may be due to different scales or very broad groupings used in the data used for the maps.

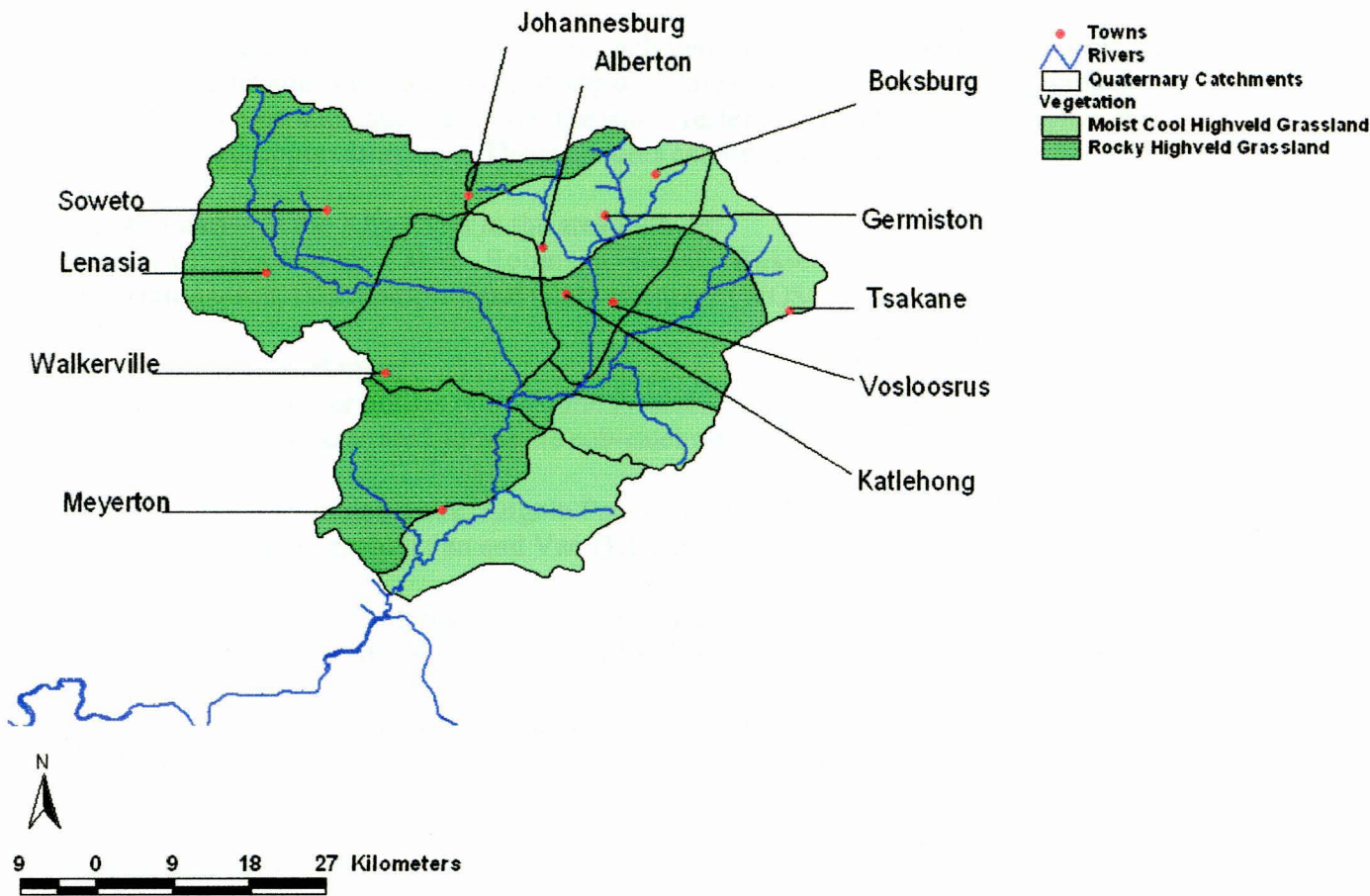


Figure 18: Robelo vegetation of the Klip River catchment (DEAT, 1990).

2.2.6 River systems and water resources

Upper Klip sub-catchment

In its natural state the Klip River would virtually run dry during winter months but due to the large amount of effluent return, the Klip River runs throughout the year. Impoundments or dams are confined mainly to the upper reaches of the catchment and are mostly man-made structures associated with earlier mining activities. These impoundments are predominantly used for recreational purposes. The impoundments within the Upper Klip sub-catchment include:

New Canada Dam, Florida Lake, Fleurhof Dam (Rand Leases Dam), Princess Dam and Orlando Dam (WGS84 Geographic, 2002) (Figure 19).

Other water bodies in the Upper Klip sub-catchment are sewage works maturation ponds, unnamed dams and water occurring on top of tailings dams. A number of wetlands occur in the Upper Klip sub-catchment from the southwestern edge of Soweto through to Rand Waters Zwartkoppies farm area. These features can be seen on figure 19.

The tributaries of the Klip River in the area include:

Klipspruit (Fordsburg Canal, Robinson Canal, Russell Stream, Diepkloofspruit), Harringtonspruit, Bloubosspruit and Glenvistaspruit (WGS84 Geographic, 2002).

Rietspruit sub-catchment

Numerous small water bodies both natural (vlei areas) and man-made (recreational, farm and mine dams) are scattered across the sub-catchment. The named impoundments in the area are:

Wemmer Pan, Germiston Lake, Angelo Pan, Cinderella Dam, Westdene Pan, Boksborg Lake, Amata Pan, Glenshaft Pan and Van Dyk Dam (WGS84 Geographic, 2002).

The tributaries of the Rietspruit in the area include:

Elsburgspruit, Natalspruit, Withokspruit and Valsfontein (WGS84 Geographic, 2002).

There are extensive wetland areas along the Elsburgspruit and the Natalspruit downstream of its confluence with the Elsburgspruit. These features can be seen on figure 20.

Lower Klip sub-catchment

The Lower Klip is a relatively fast flowing, single channel river. The man-made impoundments within the Lower Klip sub-catchment include:

Henley-on-Klip impoundment and Amcor Dam (WGS84 Geographic, 2002).

The tributaries of the Klip River in the area include:

Fouriespruit and Varkensfonteinspruit (WGS84 Geographic, 2002).

Figure 21 indicates these features that appear on the available GIS Land cover maps.

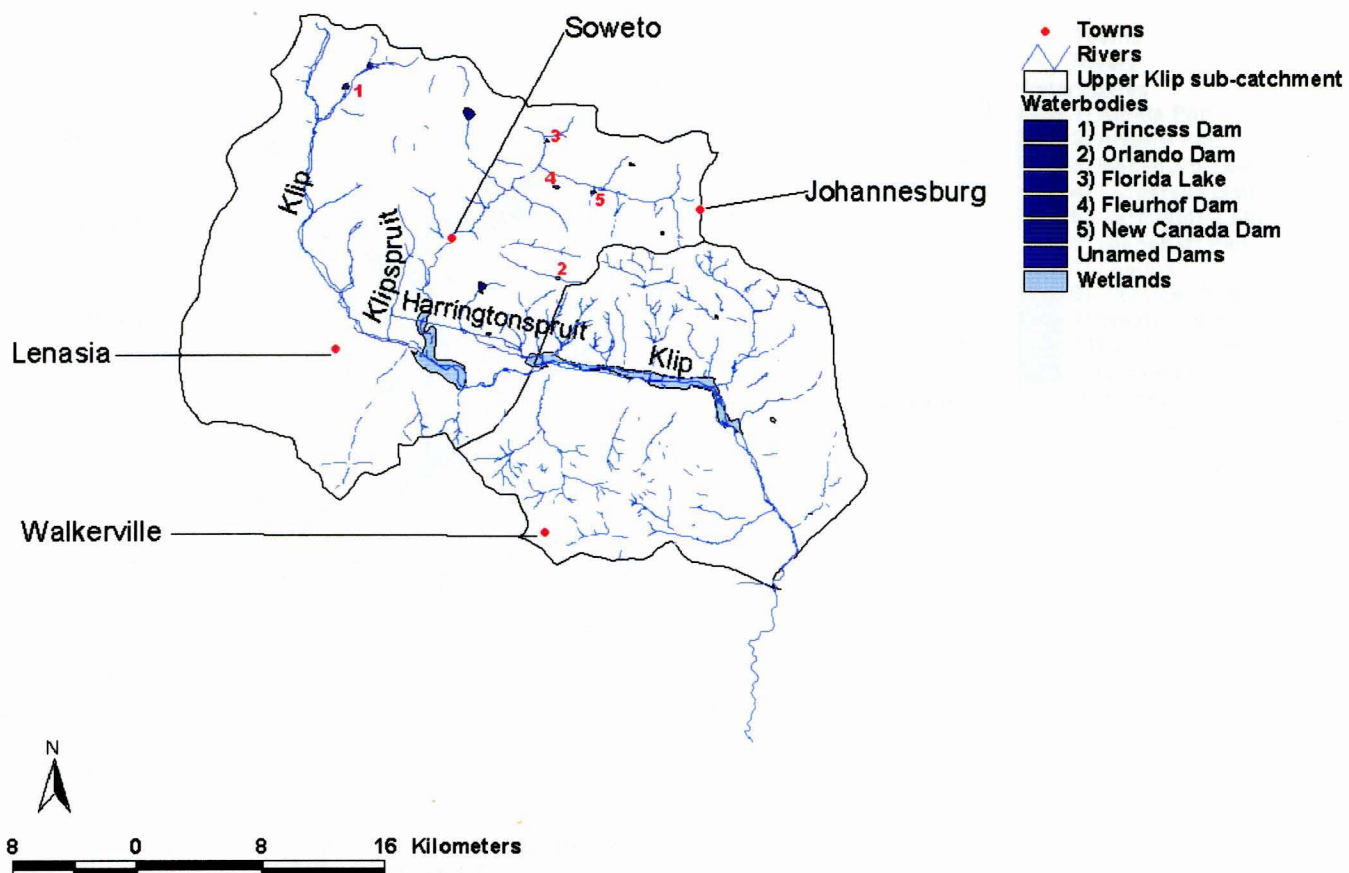


Figure 19: Rivers, wetlands and impoundments in the Upper Klip sub-catchment (WGS84 GEOGRAPHIC, 2002).

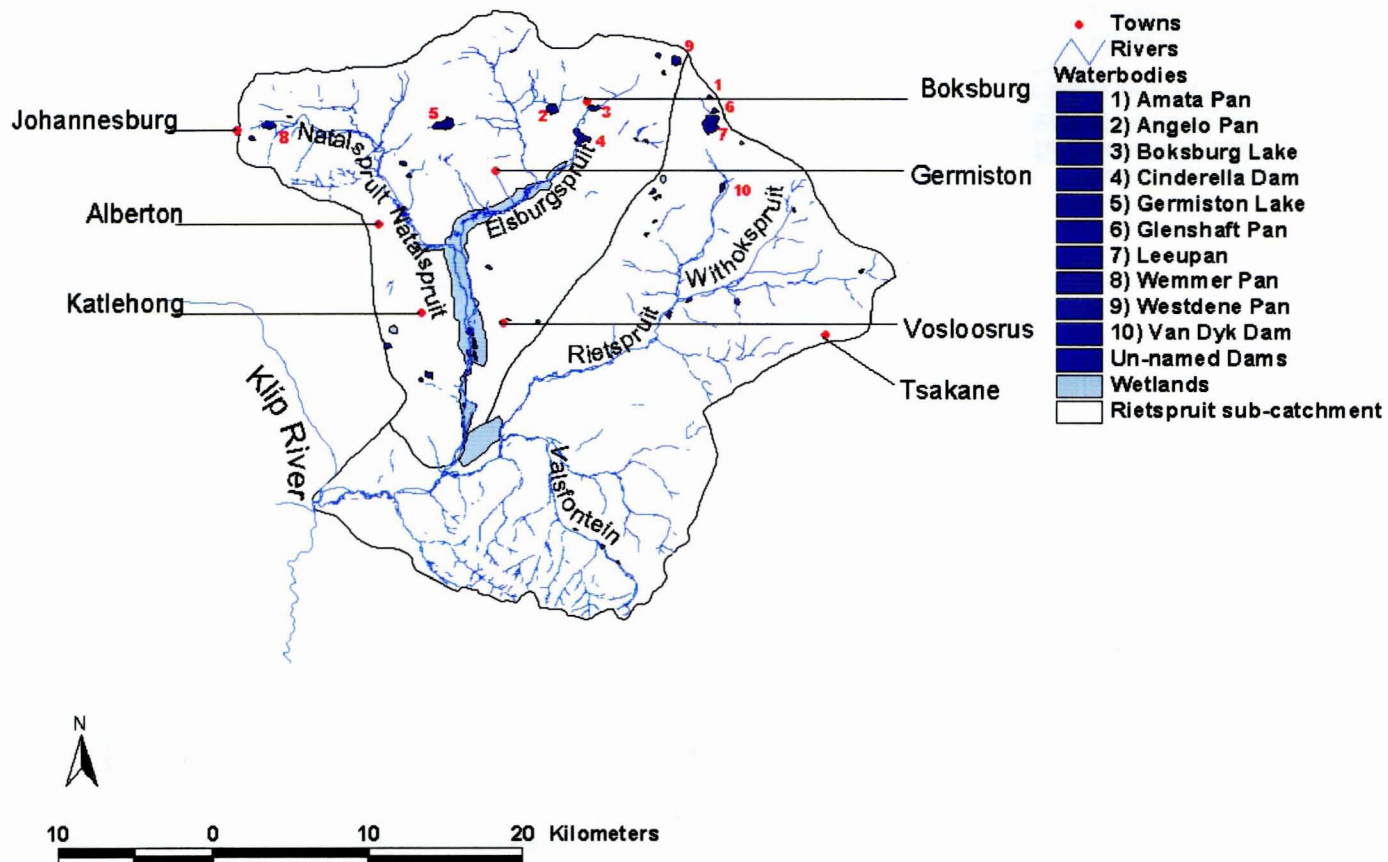


Figure 20: Rivers, wetlands and impoundments in the Rietspruit sub-catchment (WGS84 GEOGRAPHIC, 2002).

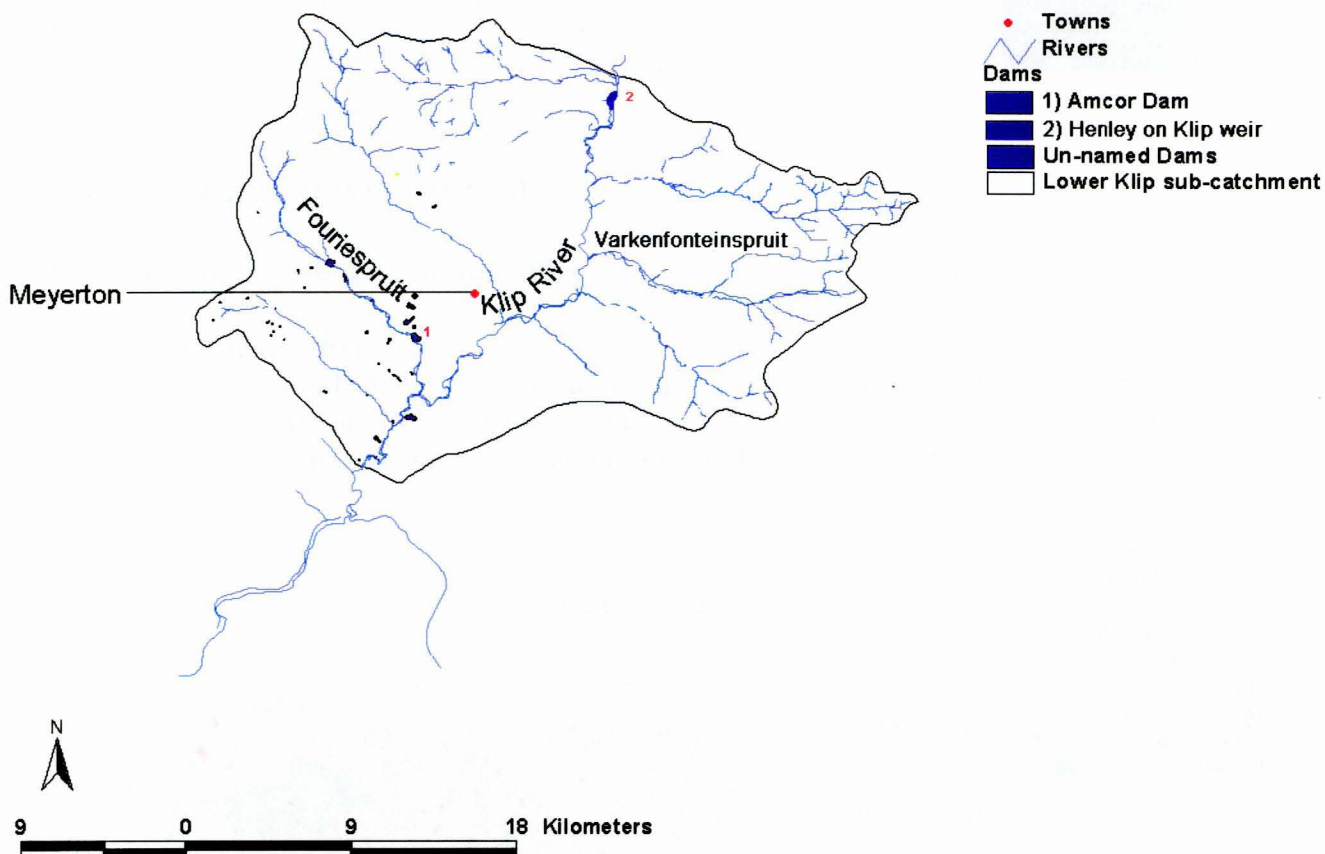


Figure 21: Rivers, wetlands and impoundments in the Lower Klip sub-catchment (WGS84 GEOGRAPHIC, 2002).

Discussion

None of the natural or man-made dams within the Klip River catchment are classed as Department of Water Affairs and Forestry (DWA) regulated Dams. Table 3 is the indicator for the DWA reservoir capacity of the percentage of total water available. According to the indicators as set out by Mzuri consultants, a highly regulated system or one containing many regulated dams should be viewed negatively (Walmsley, 2000). Thus a system with more natural dams and dams without control systems such as dam walls and sluice gates in place, scores higher on the indicator rating than a system with regulated dams. This catchment thus scores an Excellent rating, as there are no DWA regulated dams.

Table 3: DWAF Reservoir capacity as a percentage of total water available (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	> 100	70 - 100	41 - 70	21 - 40	0 - 20
Rietspruit	> 100	70 - 100	41 - 70	21 - 40	0 - 20
Lower Klip	> 100	70 - 100	41 - 70	21 - 40	0 - 20

2.3 Economic development

2.3.1 Demographic characteristics

Upper Klip sub-catchment

The total population of the Upper Klip sub-catchment is approximately 1 626 465 people (Statistics South Africa, 1999). These people are distributed within an 893 km² area. Figure 22 shows the population distribution throughout the entire Klip River catchment.

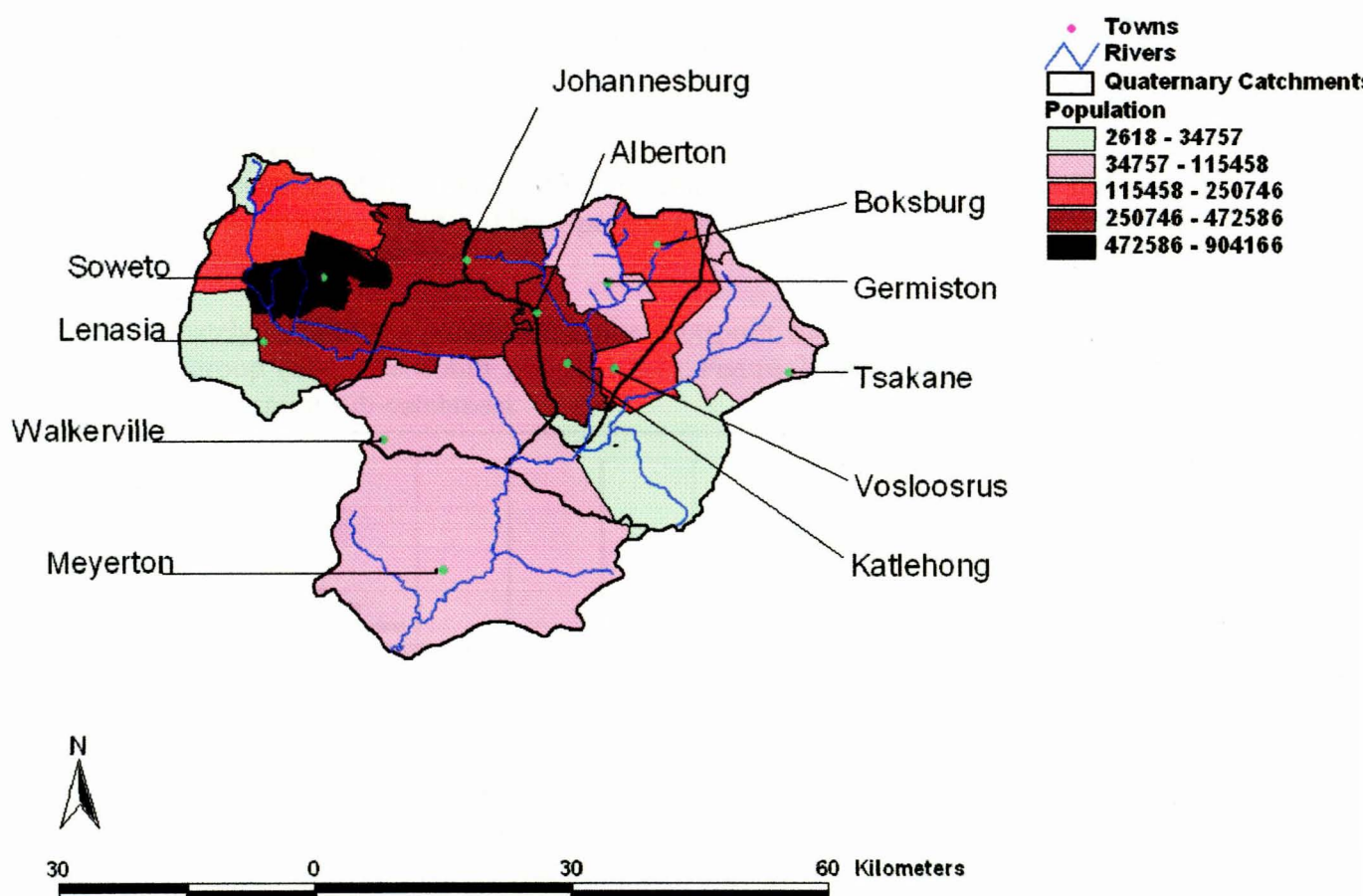


Figure 22: Population distribution in the Klip River catchment (Stats SA, 1996).

Approximately 40% of the population in the Upper Klip sub-catchment lies in the 20 - 40 year age group (Statistics South Africa, 1999). Figure 23 indicates the age distribution within the Upper Klip sub-catchment.

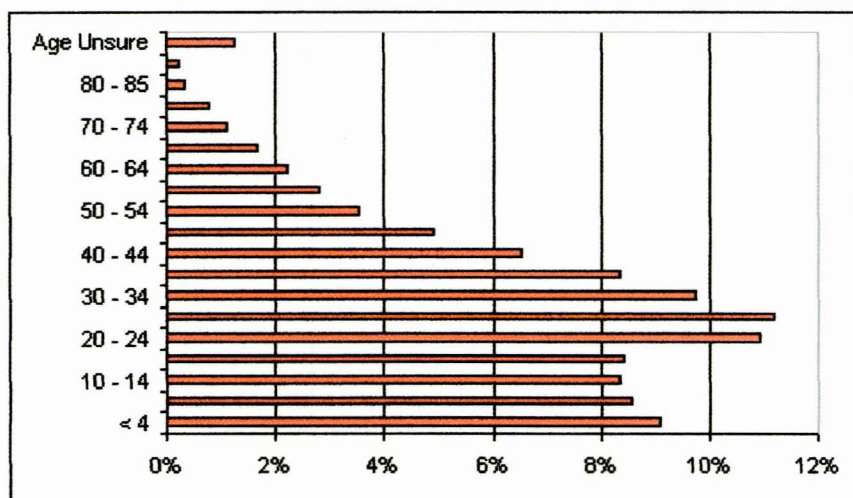


Figure 23: Age distribution within the Upper Klip sub-catchment.

Rietspruit sub-catchment

The total population of the Rietspruit sub-catchment is approximately 1 099 085 people (Statistics South Africa, 1999). These people are distributed in the 856 km² catchment area as illustrated in Figure 22.

Approximately 41% of the population in the Rietspruit sub-catchment lies in the 20 - 40 year age group (Statistics South Africa, 1999). Figure 24 indicates the age distribution within the Rietspruit sub-catchment.

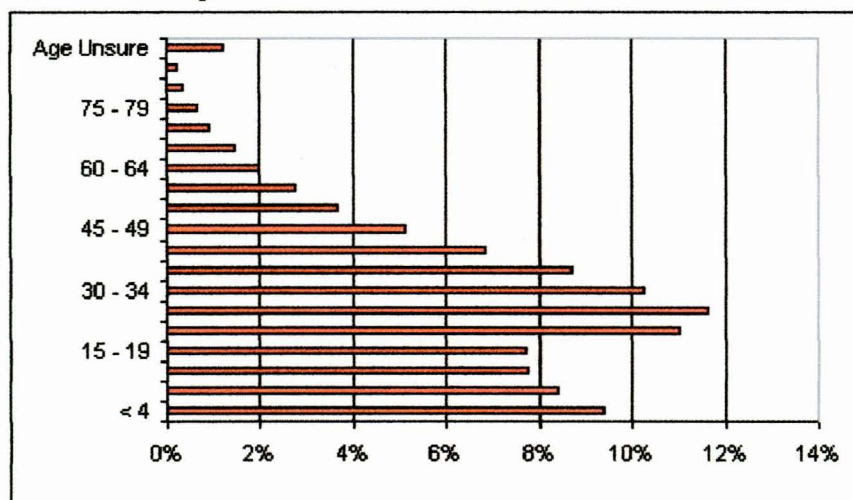


Figure 24: Age distribution within the Rietspruit sub-catchment.

Lower Klip sub-catchment

The total population of the Lower Klip sub-catchment is approximately 63 740 people (Statistics South Africa, 1999). These people are distributed in the 532 km² catchment area as illustrated in Figure 22.

Approximately 35% of the population in the Rietspruit sub-catchment lies in the 20 - 40 year age group (Statistics South Africa, 1999). Figure 25 indicates the age distribution within the Lower Klip sub-catchment.

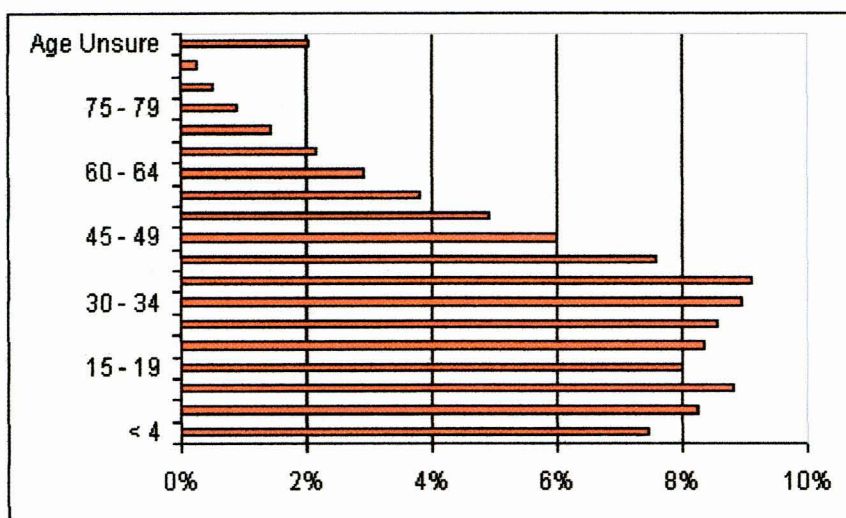


Figure 25: Age distribution within the Lower Klip sub-catchment.

Discussion

From figure 22 it can clearly be seen that the population is higher around the Johannesburg urban areas. Population decreases as one moves towards the rural areas. In the sub-catchments the majority of the population falls between the ages of 20 and 40. This may suggest that people of an economically active age enter the area in search of employment. Alternatively there may have been a decline in birth rate or an increase in child mortality as indicated by the lower number of people in the age groups less than 20 years. Interesting to note though is that the population under the age of 20 in the Lower Klip sub-catchment does not drop as drastically as in the Upper Klip and Rietspruit sub-catchments. This would suggest that people move to the more urban areas of the Upper Klip and Rietspruit sub-catchments in search of employment.

Table 4: Population Density (no./km²)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>200	101-200	51-100	11.0 - 50	0-10
Rietspruit	>200	101-200	51-100	11.0 - 50	0-10
Lower Klip	>200	101-200	51-100	11.0 - 50	0-10

Table 5: Urbanisation (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	80-100	61-80	31-60	11.0 - 30	0-10
Rietspruit	80-100	61-80	31-60	11.0 - 30	0-10
Lower Klip	80-100	61-80	31-60	11.0 - 30	0-10

Table 6: Catchment population as a proportion of the maximum sustainable population (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0-20	21-40	41-60	61-80	>80
Rietspruit	0-20	21-40	41-60	61-80	>80
Lower Klip	0-20	21-40	41-60	61-80	>80

2.3.2 Gross Geographic Product characteristics

Upper Klip sub-catchment

Over half the population (52.5%) in the Upper Klip sub-catchment live in houses. A fairly large group occupies informal dwellings (19.7%) including shacks and backyard shacks (Statistics South Africa, 1999). Figure 26 indicates the types of housing within the sub-catchment.

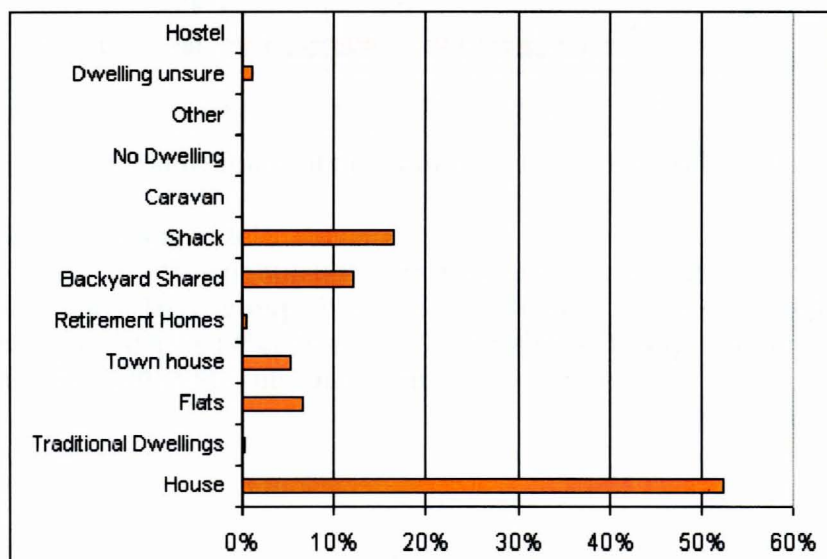


Figure 26: Housing distribution within the Upper Klip sub-catchment.

The majority (63%) of the people in the Upper Klip sub-catchment have a piped water supply in their dwelling. 25 % have a piped supply on site and 9% have access to a public tap (Statistics South Africa, 1999). Figure 27 indicates the types of drinking water sources within the sub-catchment.

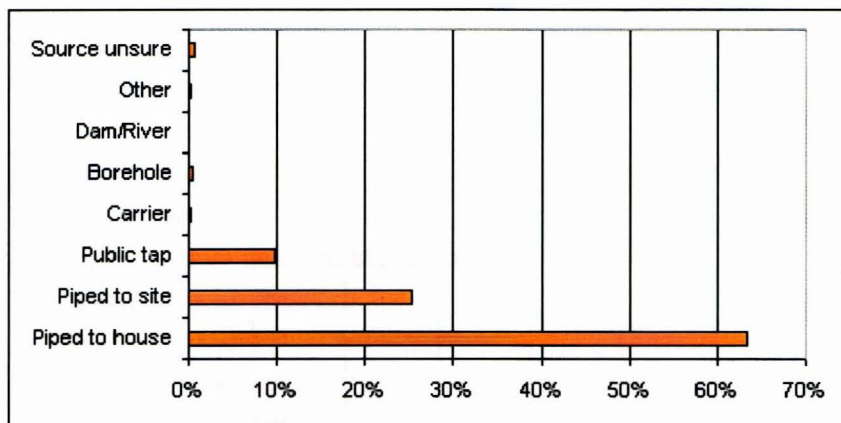


Figure 27: Drinking water sources within the Upper Klip sub-catchment.

Most of the people (92%) in the Upper Klip sub-catchment have flush or chemical toilets. 1.3% have no toilets (Statistics South Africa, 1999). Figure 28 indicates the types of sanitation facilities within the sub-catchment.

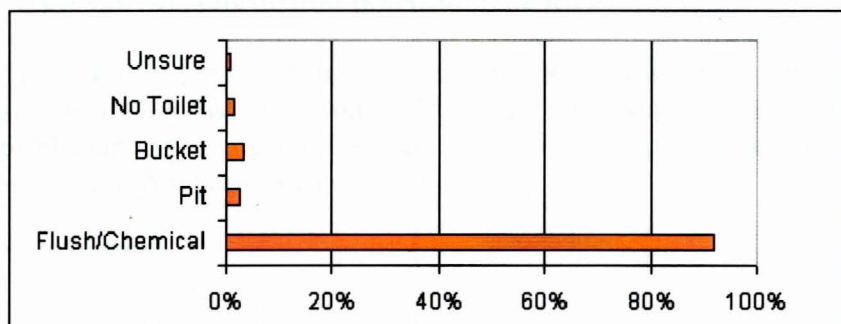


Figure 28: Sanitation facilities within the Upper Klip sub-catchment.

Rietspruit sub-catchment

Nearly half of the population (49%) in the Rietspruit sub-catchment live in houses. There is a fairly large group that occupy informal dwellings including shacks (19%) and backyard shacks (9%) (Statistics South Africa, 1999). Figure 29 indicates the types of housing within the sub-catchment.

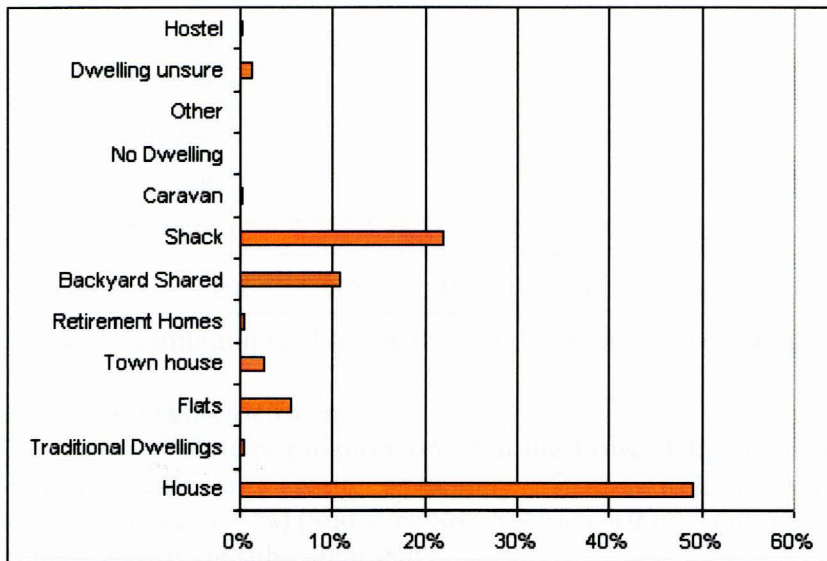


Figure 29: Housing distribution within the Rietspruit sub-catchment.

The majority (68%) of the people in the Rietspruit sub-catchment have a piped water supply in their dwelling. Some 17% have a piped supply on site and 12% have access to a public tap (Statistics South Africa, 1999). Figure 30 indicates the types of drinking water sources within the sub-catchment.

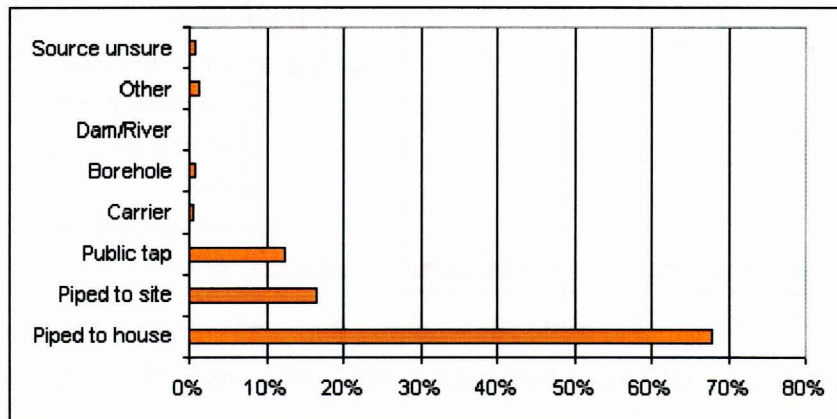


Figure 30: Drinking water sources within the Rietspruit sub-catchment.

Most of the people (86%) in the Rietspruit sub-catchment have flush or chemical toilets. 7% use pit latrines and 5% have no toilets (Statistics South Africa, 1999). Figure 31 indicates the types of sanitation facilities within the sub-catchment.

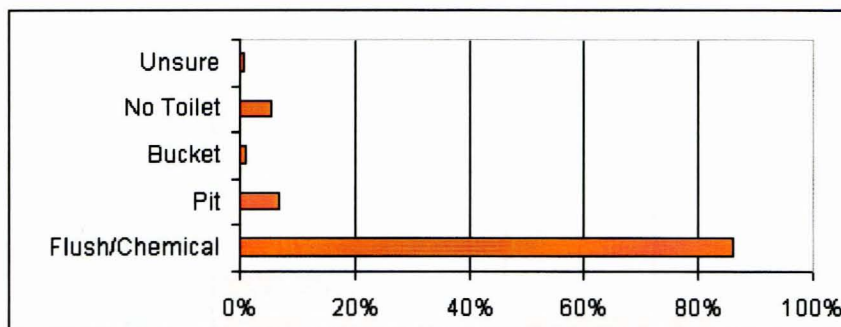


Figure 31: Sanitation facilities within the Rietspruit sub-catchment.

Lower Klip sub-catchment

The majority of the population (65%) in the Lower Klip sub-catchment live in houses. There is a fairly large group that occupy informal dwellings including shacks (7%) and backyard shacks (15%) (Statistics South Africa, 1999). Figure 32 indicates the types of housing within the sub-catchment.

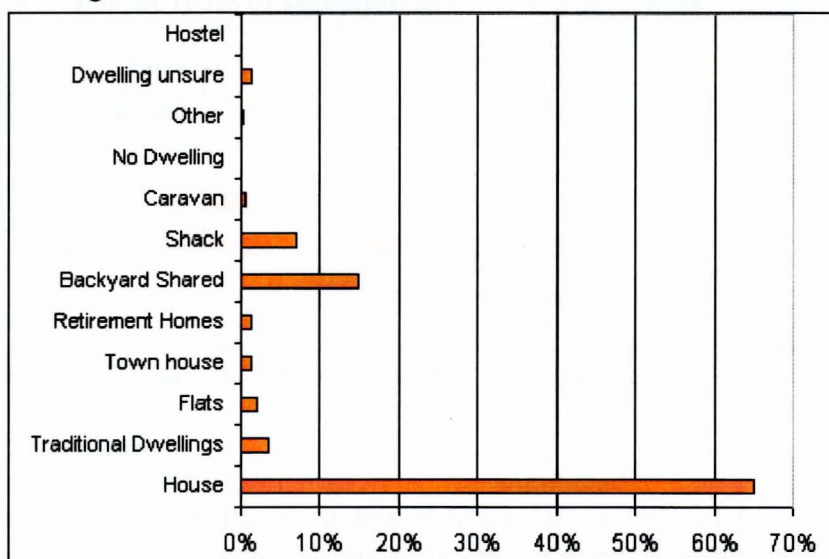


Figure 32: Housing distribution within the Lower Klip sub-catchment.

The majority (69%) of the people in the Lower Klip sub-catchment have a piped water supply in their dwelling. Some 16% have a piped supply on site and 0.5% have access to a public tap (Statistics South Africa, 1999). Figure 33 indicates the types of drinking water sources within the sub-catchment.

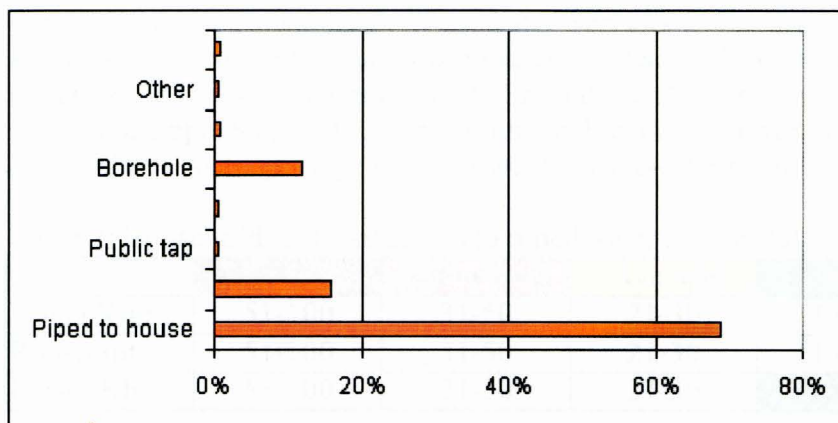


Figure 33: Drinking water sources within the Lower Klip sub-catchment.

Most of the people (79%) in the Lower Klip sub-catchment have flush or chemical toilets. 16% use pit latrines and 2% have no toilets (Statistics South Africa, 1999). Figure 34 indicates the types of sanitation facilities within the sub-catchment.

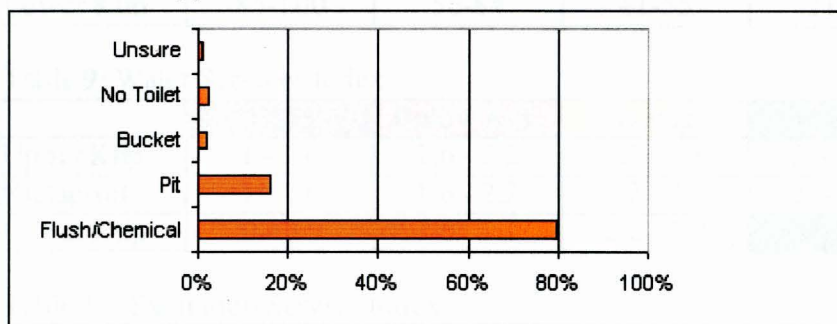


Figure 34: Sanitation facilities within the Upper Klip sub-catchment.

Discussion

From the 1996 census data it can be concluded that approximately 70% of the people within the Klip River catchment live in some form of formal housing (Houses, flats, retirement homes etc). Almost 70% of the population gets its drinking water from a tap within their homes and almost 80% of the people have flush toilets. These figures thus indicate that the majority of the population in the Klip River catchment should not be susceptible to water-borne diseases, as they are not consuming water from rivers or other untreated sources. The amount of sewage reaching the rivers directly from dwellings is also limited as most households have water-borne sewage facilities. Unfortunately however, the number of informal settlements that have developed since the 1996 census makes these results somewhat inaccurate. Large numbers of informal settlements do occur in the Klip River catchment. These settlements do not have drinking water supplied to their dwellings or the use of water-borne sewage. Tables 7 – 10 are the indicators for the above-mentioned factors. Table 7 indicates the percentage of households without piped water on site, Table 8 indicates the percentage of households without toilet facilities, Table 9 indicates the Water Services Index for the areas and Table 10 indicates the Sanitation Services Index. The calculation of all these indicators

can be found in Appendix 2. The Water Services Index indicates the drinking water services supplied to each household and the Sanitation Services Index indicates the level of sanitation services to a household. From these tables it can be seen that the facilities within the Upper Klip and Rietspruit sub-catchment are all within the Excellent range and in the Above Average range in the Lower Klip sub-catchment.

Table 7: Households without access to piped water on site (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	51-100	31-50	21-30	11.0 - 20	0-10
Rietspruit	51-100	31-50	21-30	11.0 - 20	0-10
Lower Klip	51-100	31-50	21-30	11.0 - 20	0-10

Table 8: Households without access to toilet facilities (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	85-100	56-84	41-55	21-40	0-20
Rietspruit	85-100	56-84	41-55	21-40	0-20
Lower Klip	85-100	56-84	41-55	21-40	0-20

Table 9: Water Services Index

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
Rietspruit	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
Lower Klip	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0

Table 10: Sanitation Service Index

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
Rietspruit	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
Lower Klip	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0

2.3.3 Employment and income

An income of R 800 per household per month is commonly used as an indicator of poverty (the breadline).

Upper Klip sub-catchment

Approximately 41 % of the population in the Upper Klip sub-catchment are unemployed and 31% employed. The remaining portions of the population are either of an unemployable age, in an institution, or are unsure of their employment status (Statistics South Africa, 1999). Figure 35 indicates the employment characteristics for the area.

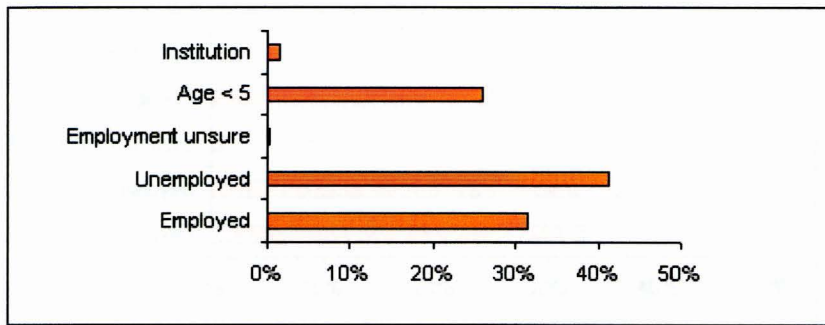


Figure 35: Employment characteristics for the Upper Klip sub-catchment.

In the Upper Klip sub-catchment, approximately 62% of households have a monthly income of less than R 1 000 and approximately 56% earn less than R 500 per month (Statistics South Africa, 1999). Figure 36 indicates the income characteristics for the area.

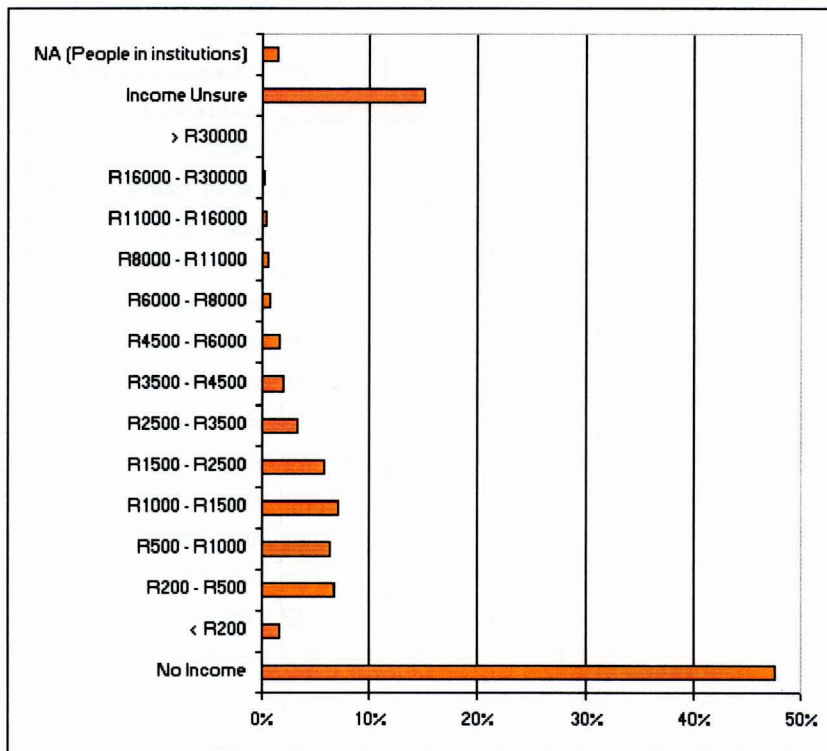


Figure 36: Income characteristics for the Upper Klip sub-catchment.

Rietspruit sub-catchment

Approximately 39% of the population in the Rietspruit sub-catchment are unemployed and 33% is employed. The remaining populations are either of an unemployable age, in an institution, or are uncertain of their employment status (Statistics South Africa, 1999). Figure 37 indicates the employment characteristics for the area.

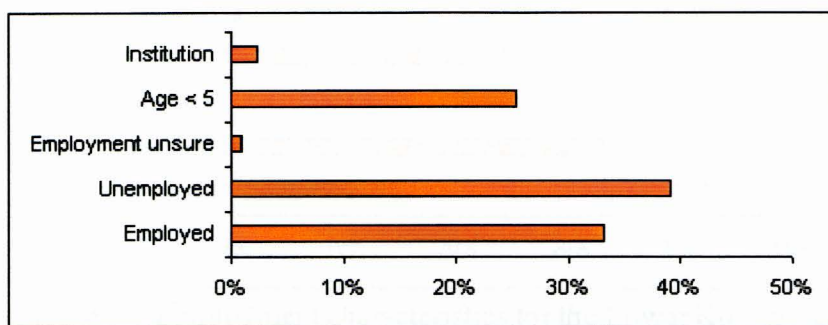


Figure 37: Employment characteristics for the Rietspruit sub-catchment.

In the Rietspruit sub-catchment, approximately 61% of households have a monthly income of less than R 1 000 and approximately 54% earn less than R 500 per month (Statistics South Africa, 1999). Figure 38 indicates the income characteristics for the area.

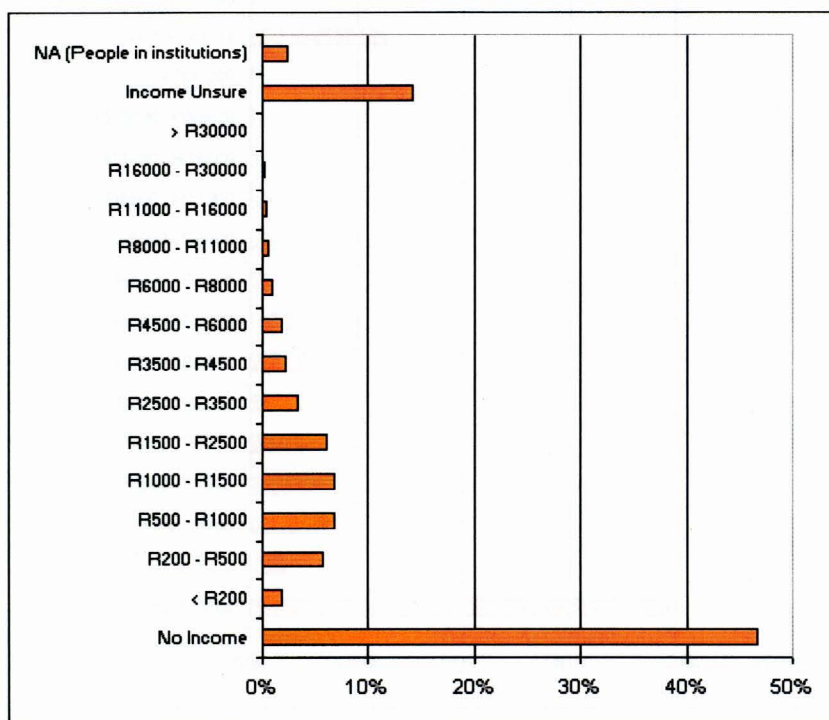


Figure 38 Income characteristics for the Rietspruit sub-catchment.

Lower Klip sub-catchment

Approximately 33% of the population in the Lower Klip sub-catchment are unemployed and 42% is employed. The remaining population is either of an unemployable age, in an institution, or are unsure of their employment status (Statistics South Africa, 1999). Figure 39 indicates the employment characteristics for the area.

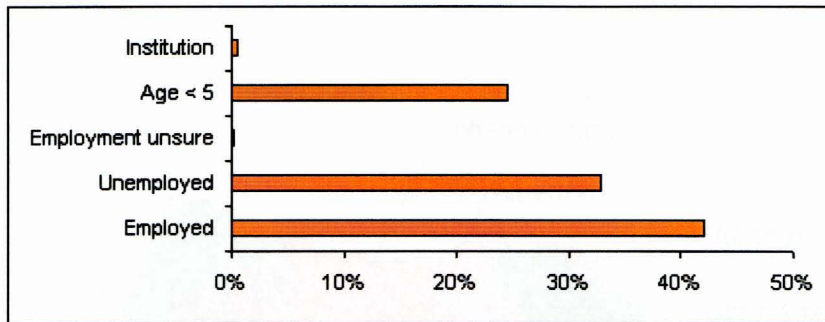


Figure 39: Employment characteristics for the Lower Klip sub-catchment.

In the Lower Klip sub-catchment, approximately 59% of households have a monthly income of less than R 1 000 and approximately 53% earn less than R 500 per month (Statistics South Africa, 1999). Figure 40 indicates the income characteristics for the area.

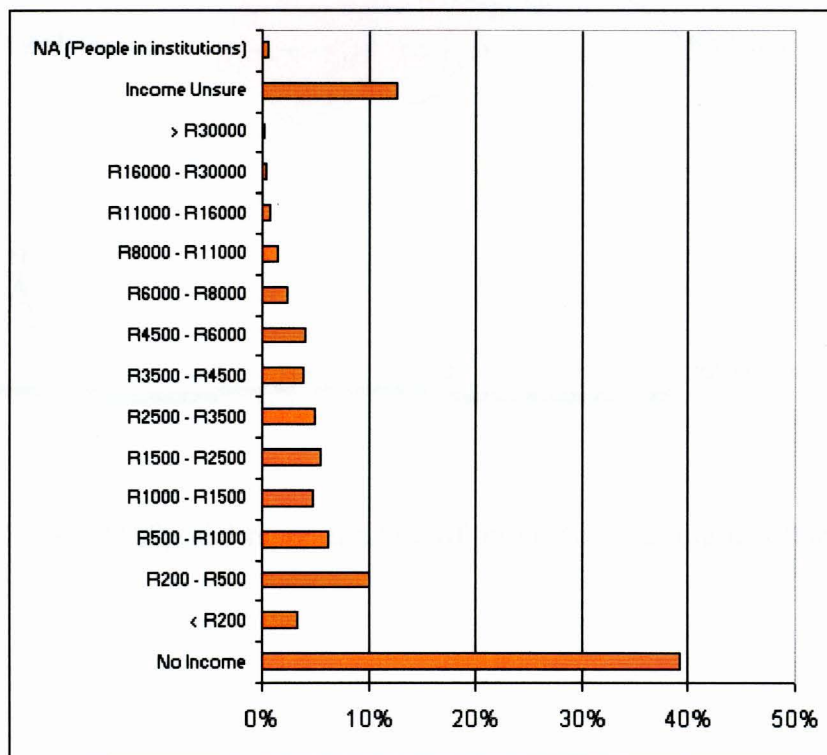


Figure 40 Income characteristics for the Lower Klip sub-catchment.

The spatial distribution of households in the entire Klip River catchment earning less than R1 000 per month and less than R500 per month are shown in Figures 41 and 42 respectively (Statistics South Africa, 1999).

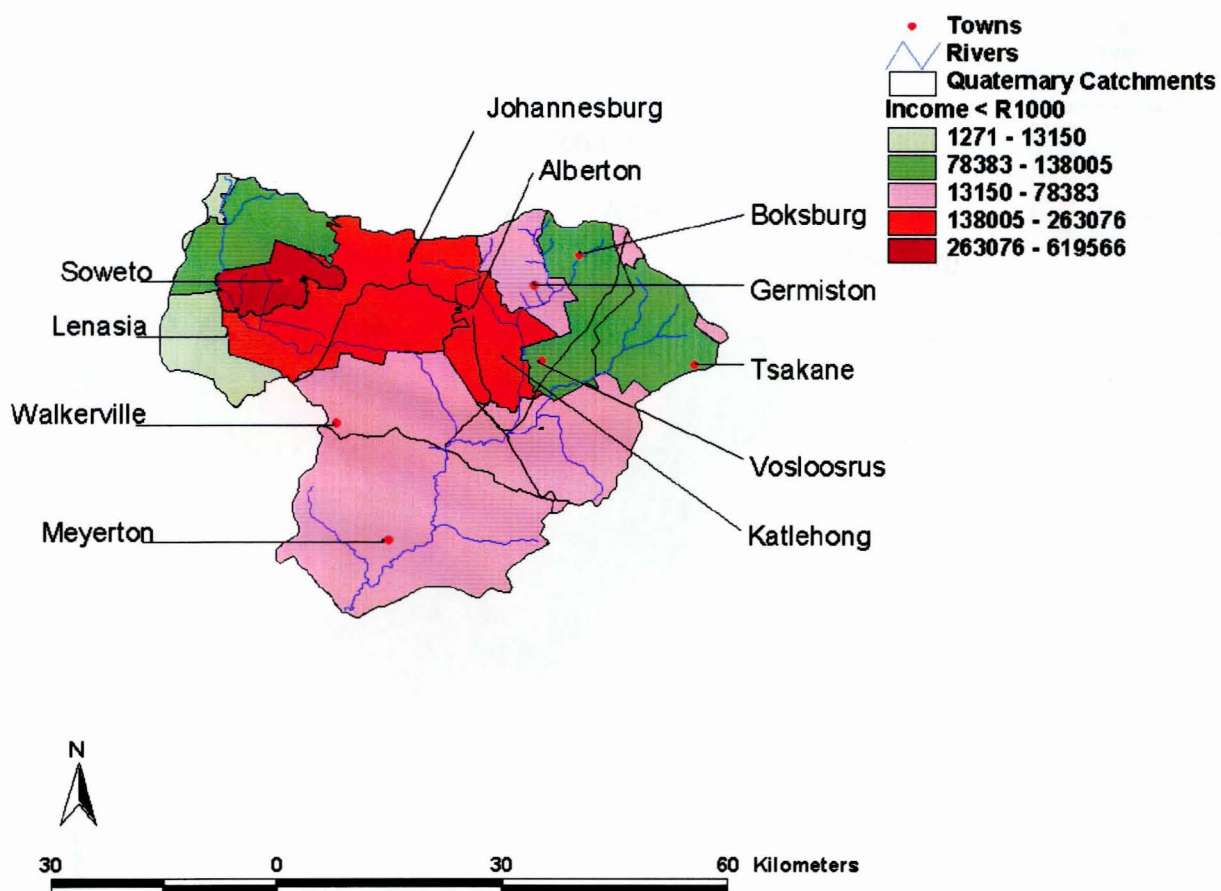


Figure 41: Spatial representation of population earning less than R1000 per year (Stats SA, 1996)

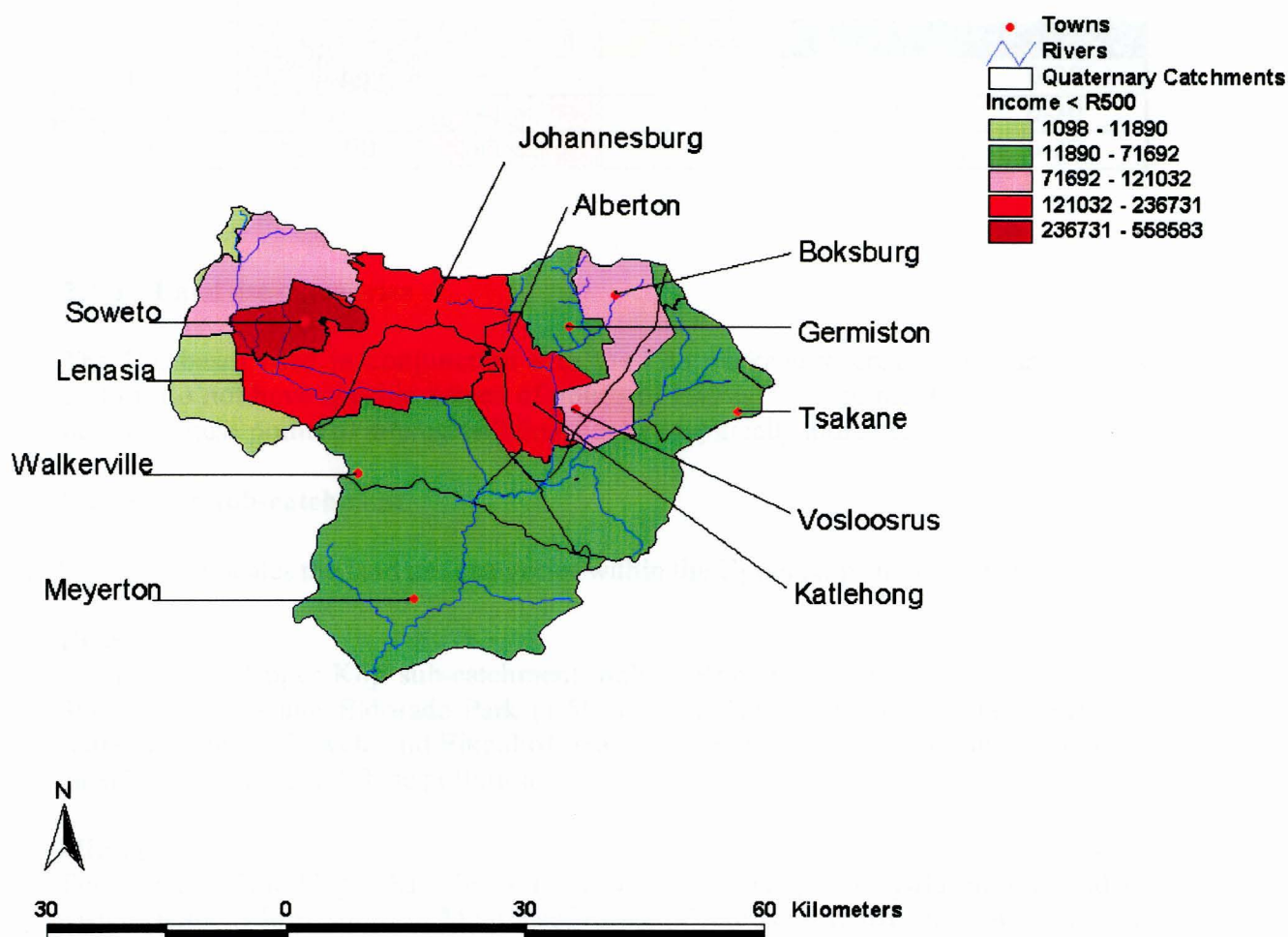


Figure 42: Spatial representation of population earning less than R500 per year (Stats SA, 1996).

Discussion

Throughout the catchment almost half the population is unemployed. This amount does not include children under the age of 5 and people in institutions. From figures 41 and 42 it can be seen that more people who earn less than R500 and R1000 a year live in and around the big cities in the area. As one moves to the rural areas, the number of people earning below the breadline decreases. Table 11 indicates that more than 56% of the households in the Upper Klip sub-catchment earn less than R6000 per annum. Between 41 and 55 % earn less than R6000 per annum in the Rietspruit and Lower Klip sub-catchments.

Table 11: Proportions of household earning <R6 000 per annum (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	56-100	41-55	31-40	21-30	0-20
Rietspruit	56-100	41-55	31-40	21-30	0-20
Lower Klip	56 -100	41-55	31-40	21-30	0-20

2.3.4 Land use categories

The Databases used in conjunction with the GIS package to create the maps in this section do not have specific names of points of interest that are mentioned in the text below. These points of interest will thus not be graphically indicated.

Upper Klip sub-catchment

Figure 43 indicates the land use categories within the Upper Klip sub-catchment.

Urban

Towns in the Upper Klip sub-catchment include Roodepoort, western Johannesburg, Soweto, Lenasia and Eldorado Park (1:50 000 topographical maps, 2002). Informal settlements in the Soweto and Eikenhof areas are increasing in size and number and are most likely leading to diffuse pollution.

Mining

The source of the Upper Klip lies on disused East Champ D'or gold mining land in eastern Krugersdorp, south of Main Reef Road. There is currently only one operating gold mine area in the area – Durban Roodepoort Deep (DRD). Underground mine water from the neighbouring Rand Leases Mine to the east is currently decanting into DRD (Bohlweki, 1999). Flooded underground mine workings in the central Johannesburg area are believed to be interconnected. Further east lies the disused mining area of the Consolidated Main Reef Gold Mine, the defunct Robinson Deep Gold Mine and the disused Crown Mines. Mine dumps in these areas are being reworked and reclaimed by Central Gold Recovery (Bohlweki, 1999). The Mines and Quarries indicated on Figure 43 represent all land that is currently being used as mining land. This figure includes old or abandoned mine dumps.

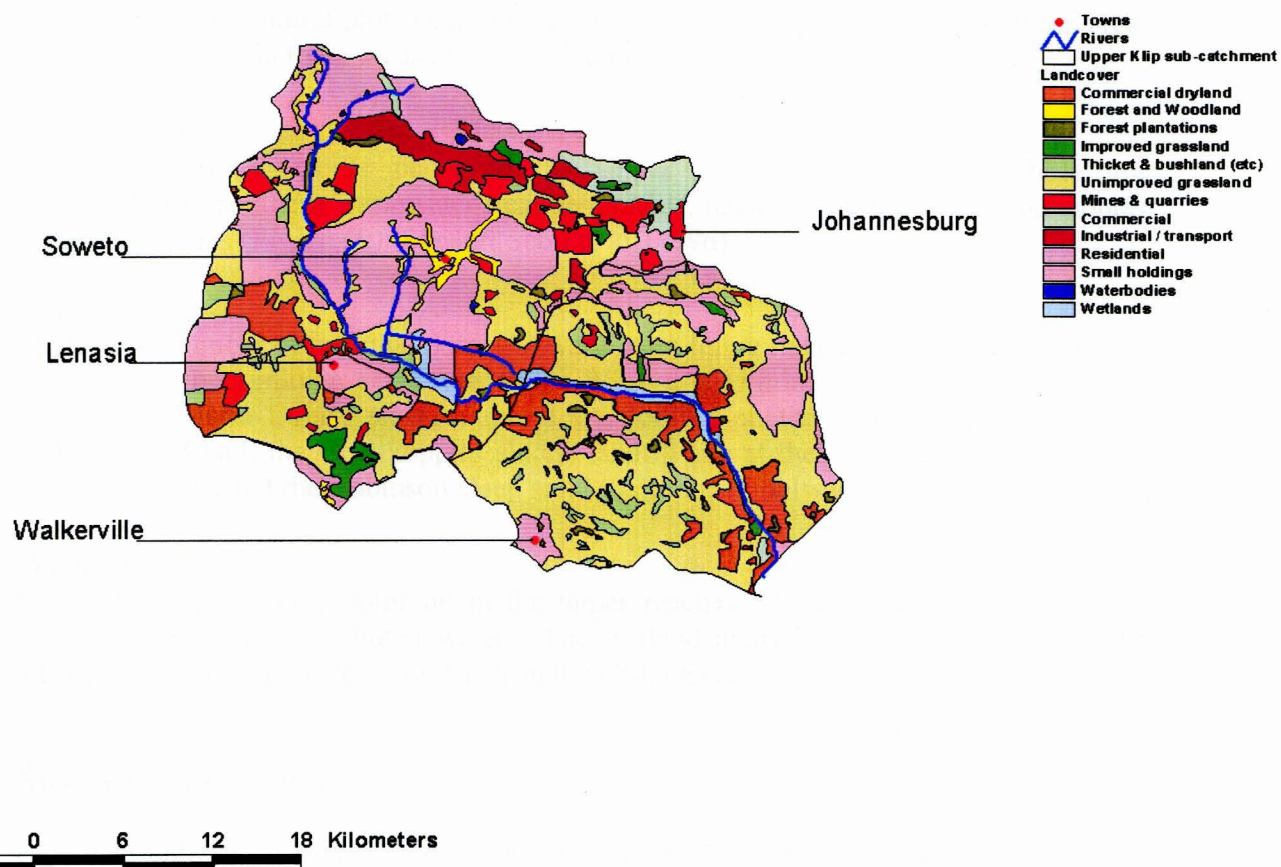


Figure 43: Land use categories within the Upper Klip sub-catchment (Landcover, 1999).

Industrial

The Upper Klip sub-catchment has an expanding number of manufacturing and service industries as well as a number of closed industrial sites that still cause pollution.

The existing industrial zones in the area are parts of the Chamdor industrial area, Factoria, Manufacta, Industria, Devland, Nancefield, Chrisville, Booyens, Selby, Ophirton, Newtown, Amalgam, Hippo quarries (Alpha sand and readymix) and the Everite and Nampak factories found near the town of Kliprivier (Bohlweki, 1999).

Agriculture

A number of agricultural plots occur in the Vlakfontein and Zuurbekom agricultural area. Farming activities in these areas are in the decline.

Sewage works

Three big sewage works occur in the Upper Klip sub-catchment. These are Johannesburg's southern wastewater treatment plants, namely, Olifantsvlei, Goudkoppies and Bushkoppies (Figure 59) (Stewart Scott et al., 1996).

Waste

There are a number of informal domestic waste sites lining the banks of the Klip River as well as at defunct mining areas such as the Wilford gold mine area. Formal waste sites include the Marie Louise waste disposal site located on the mining land adjacent to Dobsonville Road, the Goudkoppies sludge landfill site at the Goudkoppies wastewater treatment works and the Robinson Deep solid waste site (Bohlweki, 1999).

Wetlands

Wetland areas are quite common in the upper reaches of the Klipspruit and act as a natural purifier of the polluted water. The wetland areas intensify at the foot of the Klipspruit where it joins the Klip River in the Olifantsvlei wetland.

Rietspruit sub-catchment

Figure 44 indicates the land use categories within the Rietspruit sub-catchment.

Urban

The headwaters of the Rietspruit are found in the suburb of Dalpark in Brakpan on the East Rand. The Rietspruit flows through Alberton, Germiston, Kwa Thema, Vosloosrus, Kathlehong and Tokoza (WGS84 Geographic, 2002). These areas have both formal and informal settlements.

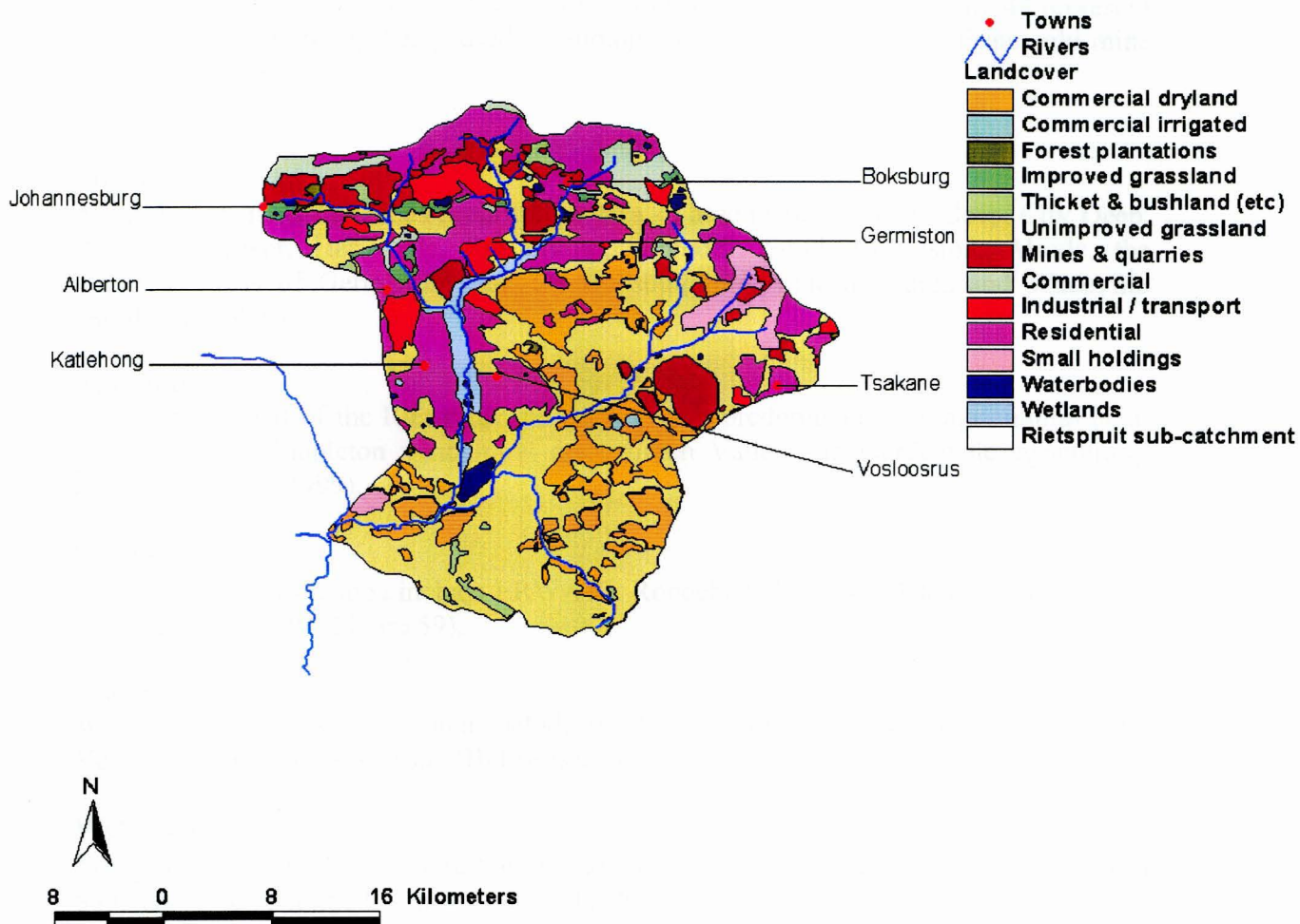


Figure 44: Land cover categories within the Rietspruit sub-catchment (Landcover, 1999).

Mining

Most of the mines within the Rietspruit sub-catchment are closed down. These include Van Dyk Gold Mine, the Vlakfontein Gold Mine area; the SA Lands (Sallies) mine property, Village Main Reef, City Deep Gold Mines, Primrose, Knights (Witwatersrand Gold Company) and Witdeep gold mines. The Sallies mine dumps are being reclaimed by the East Rand Gold Company (ERGO). The Sallies underground mine workings are presently decanting to the Grootvlei mine to the east, which discharges into the Blesbokspruit catchment. The main concerns with these old mines are the filling up of underground workings with low quality water that eventually reaches surface water and unvegetated mine dumps. The East Rand Proprietary Mines (ERPM) is still in

operations. (Bohlweki, 1999). The Mines and Quarries indicated on Figure 44 represent all land that is currently being used as mining land. This map also indicates old mine dumps in the area.

Industrial

A number of industrial zones occur in this area. These include Village Deep, City Deep, Benrose, Denver, Heriotdale, Rosherville, Driehoek, South Germiston, Alrode, the industrial areas of Germiston East, the Boksburg East industrial area and Wadeville (Bohlweki, 1999).

Agriculture

The southern part of the Rietspruit sub-catchment is predominantly an agricultural area. It includes the Mapleton agricultural area, Green Valley and Gardenvale agricultural areas (Bohlweki, 1999).

Sewage works

Sewage works in the area include ERWAT's Rondebult WWTW, Dekema WWTW and Vlakplaats WWTW (Figure 59).

Waste

Waste disposal sites in the area include the Platkop solid waste disposal site and the Verwoerd Park solid waste site (Bohlweki, 1999).

Wetlands

The Natalspruit and Elsburgspruit are predominantly wetland areas. The Rondebult Bird Sanctuary occurs in the Elsburgspruit wetlands.

Lower Klip sub-catchment

Figure 45 indicates the land use categories within the Lower Klip sub-catchment.

Urban

The main urban areas within the Lower Klip sub-catchment include Risiville, Three Rivers, Meyerton, Henley on Klip, Daleside, Roshnee and Rustervaal (WGS84 Geographic, 2002). Recreation areas including Vosloo Park and the Riviera Hotel complex bound the foot of the Klip River.

Mining

The Glen Douglas dolomite limestone mine and Springfield Collieries occur in this area (Bohlweki, 1999). The Mines and Quarries indicated on Figure 45 represent all land that is currently being used as mining land.

Industrial

A number of large industries as well as industrial zones occur in this area. The large industries include Samancor and part of Iscor's steelworks in Vereeniging. The industrial suburbs include the Daleside industrial area and the Meyerton industrial area (Bohlweki, 1999).

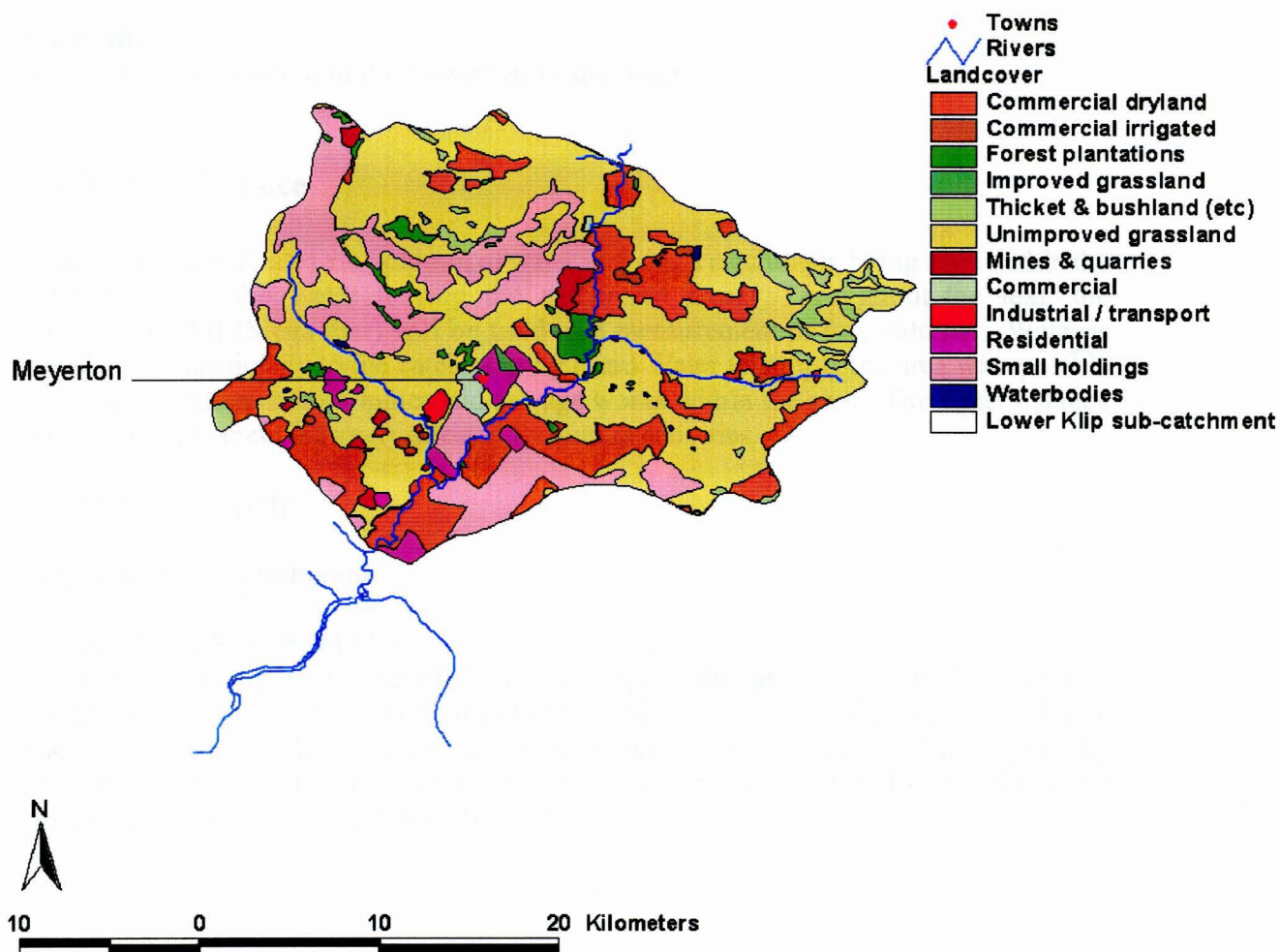


Figure 45: Land cover categories of the Lower Klip sub-catchment (Landcover 1999).

Agriculture

Most of the Lower Klip sub-catchment is agricultural area. This includes the Walkerville farming area (Bohlweki, 1999).

Sewage works

Two sewage works occur in the Lower Klip sub-catchment. These are Meyerton WWTW and ERWAT's Waterval WWTW (Figure 59).

Waste disposal sites

The waste disposal site in the area is the Waldrift solid waste site (Bohlweki, 1999).

Wetlands

No large wetlands occur in the Lower Klip catchment.

2.4 Water Balance

Water balance indicates the volumes of water entering a catchment, being used within the catchment and the water leaving the catchment area. Throughout the text, the abbreviation Ml (Mega liter) will be used as a measurement of this volume. Water is being added artificially to the catchment by Rand Water to supply the area with potable water and discharges from mines and sewage works within the area. The water balance within the catchment is largely affected by human activities.

2.4.1 Water supply

Upper Klip sub-catchment**Mean Annual Runoff (MAR)**

As indicated in Figure 46, the MAR for the Upper Klip catchment is 30.7 – 34.5 mm (WRC, 1990 - 1994). The net annual MAR is $28.6 \times 10^6 \text{ m}^3$ (Midgley et al., 1994 a). Figure 47 is the monthly averaged minimum, maximum and average for the Upper Klip sub-catchment measured at Rand Water's C-K21 weir (indicated on Figure 59) for the time period January 1993 to December 1999.

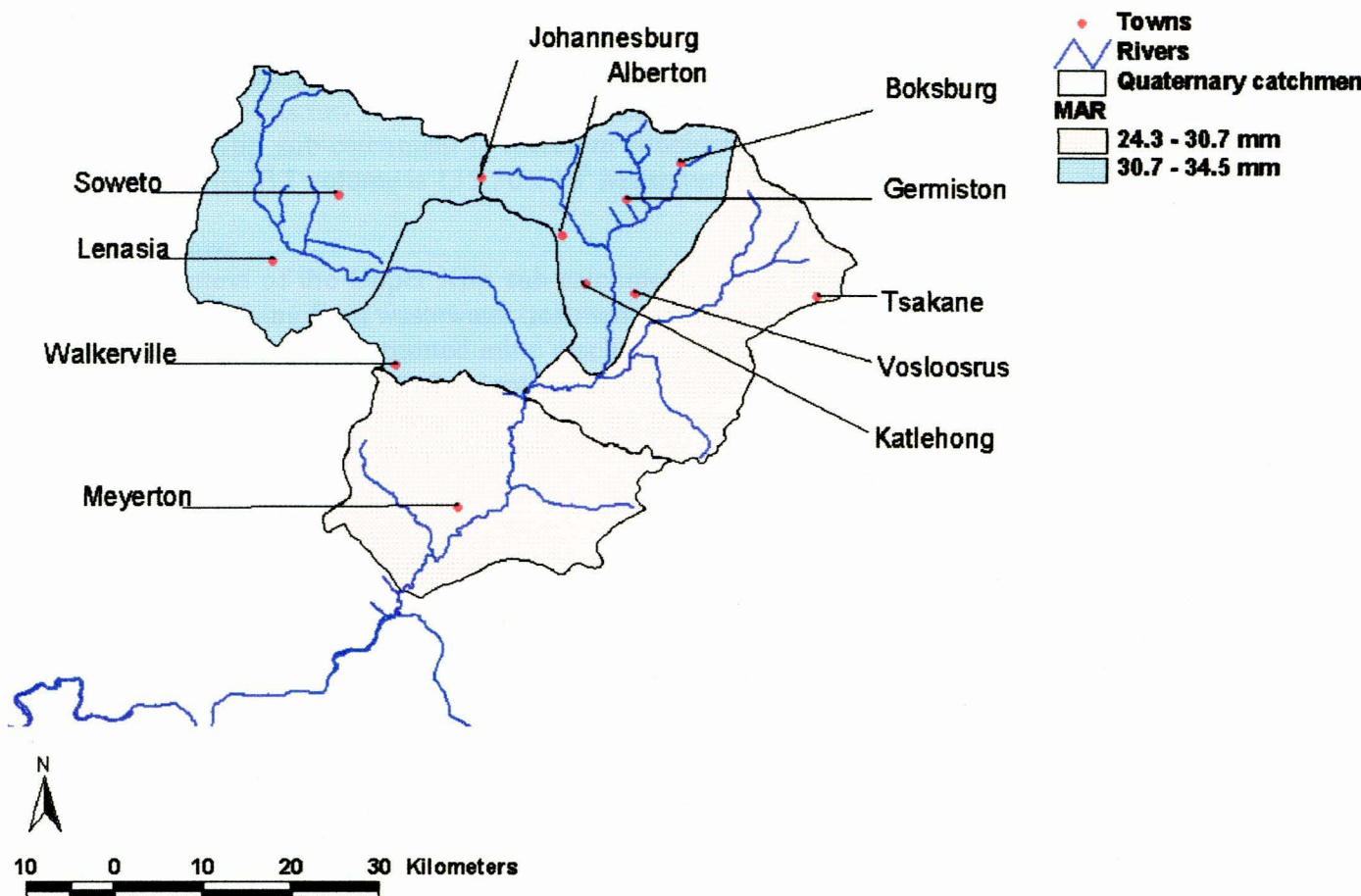


Figure 46: Mean annual runoff for the Klip River catchment (WRC, 1990 - 1994).

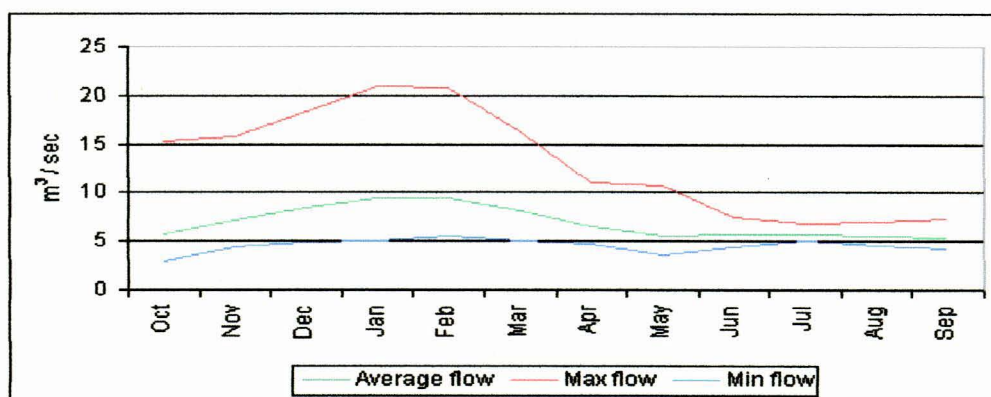


Figure 47: Monthly averaged minimum, maximum and average flow at C-K21 weir for the time period January 1993 to December 1999.

Inter Basin Transfers (IBT)

Rand Water, the bulk potable water supplier to the Upper Klip sub-catchment area, obtains most of its raw water from the Vaal Dam reservoir. The potable water supply to the Upper Klip sub-catchment is therefore considered as an inter-basin transfer (IBT) scheme. This IBT volume is 135.50×10^6 Ml/annum (Tavaras, 2002). *135.5 x 10^9 m^3/a*

Return flows

In the context of the Upper Klip sub-catchment, return flows have been identified as those flows arising from wastewater treatment works and mines in the sub-catchment. As there are currently no permitted mine discharges (and thus no readily available data for the time period October 1998 – September 1999), the return flow from the three sewage works (Figure 59) in the area is taken to be the return flow volume. This volume is 160.97×10^6 Ml/annum (Pitman, 2002). *see fig 48*

Groundwater

Little readily available information on the groundwater status of the Klip River catchment exists. All main river courses flow through wetlands or vleis areas with phreatophyte vegetation, indicating a shallow groundwater table. The Klip River compartment consists of numerous small sub-compartments where areas with similar groundwater tables are grouped. Most of these sub-compartments seem to be hydraulically linked to the Klip River (Bohlweki, 1999).

Rand Water has a permit to abstract groundwater from the Zuurbekom compartment for water supply purposes. Rand Water abstracts 3.65 Ml/annum from the Zuurbekom wells (Rand Water, 2002). This water is pumped out of the Klip River catchment for drinking water purposes.

Figure 48 indicates the water balance for the Upper Klip sub-catchment.

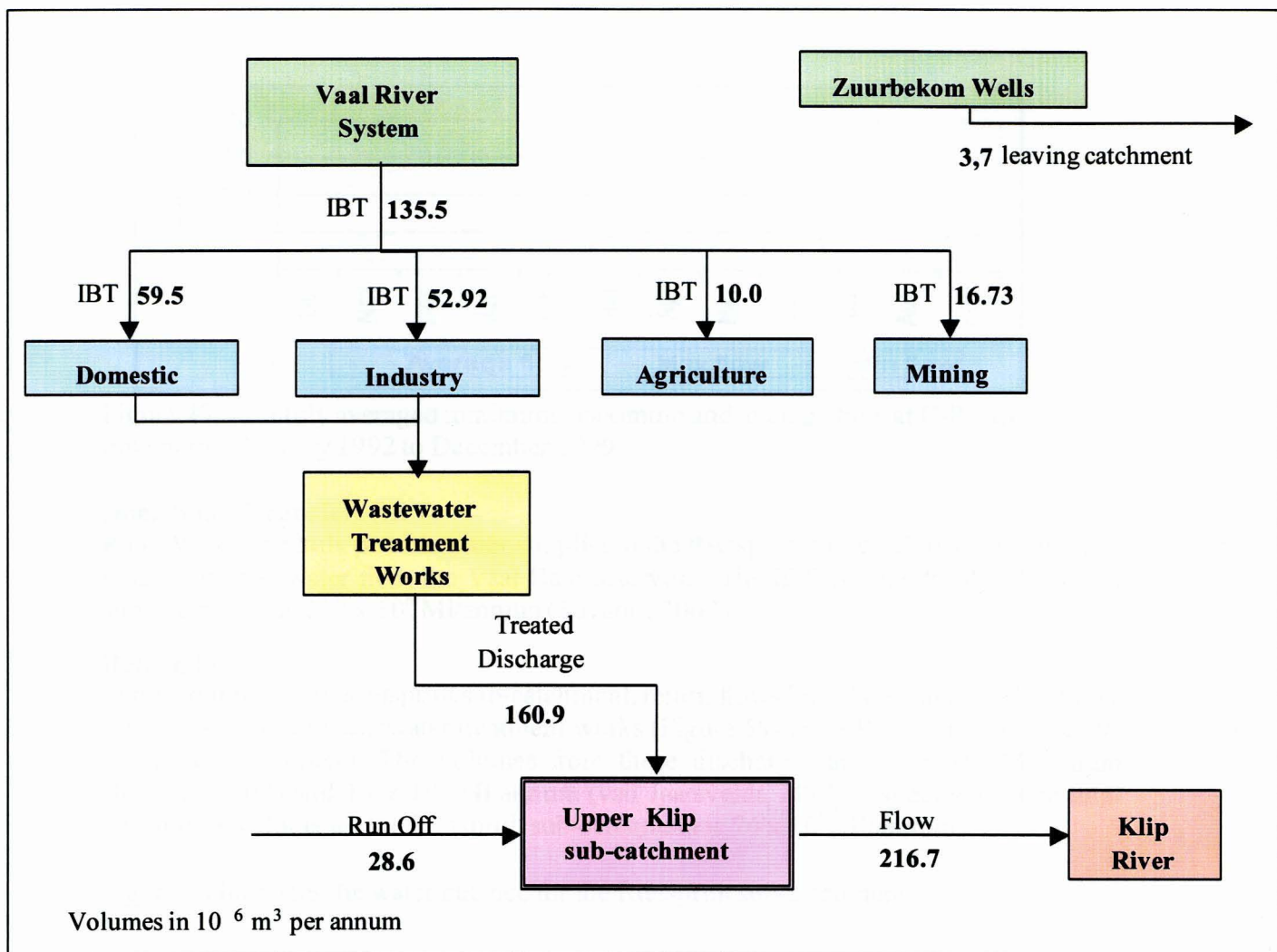


Figure 48: Water balance for the Upper Klip sub-catchment.

Rietspruit sub-catchment

Mean Annual Runoff (MAR)

As indicated in Figure 46, the MAR in the western portion of the Rietspruit sub-catchment is 30.7 – 34.5 mm (WRC, 1990 - 1994) and in the eastern section it is 24.3 – 30.7 mm (WRC, 1990 - 1994). The net MAR is $26.7 \times 10^6 \text{ m}^3$ (Midgley et al., 1994 a). Figure 49 is the monthly averaged minimum, maximum and average for the Rietspruit sub-catchment measured at Rand Water's C-R6 (indicated on Figure 59) weir for the time period January 1992 to December 1999.

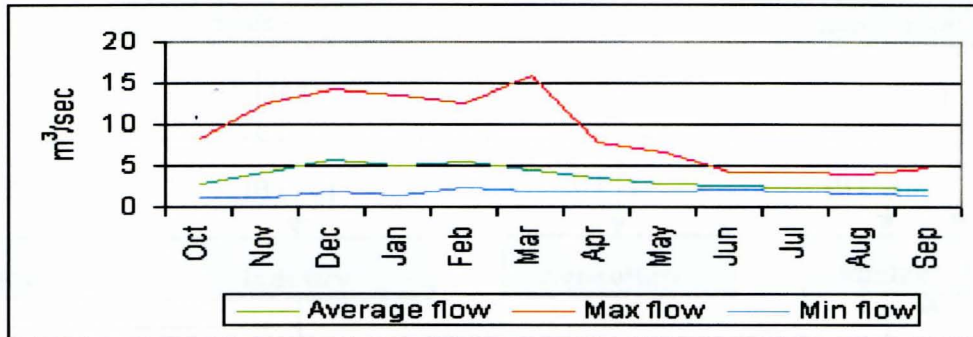


Figure 49: Monthly averaged minimum, maximum and average flow at C-R6 weir for the time period January 1992 to December 1999.

Inter Basin Transfers (IBT)

Rand Water, the bulk potable water supplier to the Rietspruit sub-catchment area obtains most of its raw water from the Vaal Dam reservoir. The IBT volume for the Rietspruit sub-catchment is 217×10^6 Ml/annum (Tavaras, 2002).

Return flows

In the context of the Rietspruit sub-catchment, return flows have been identified as those flows arising from wastewater treatment works (Figure 59) and ERPM mine (Figure 59) in the sub-catchment. The volumes from these discharges are 55×10^6 Ml/annum (Joubert, 2002) and 19×10^6 Ml/annum (van Jaarsveldt, 2001) respectively. The total return flow volume for the Rietspruit sub-catchment is 74×10^6 Ml/annum.

Figure 50 indicates the water balance for the Rietspruit sub-catchment.

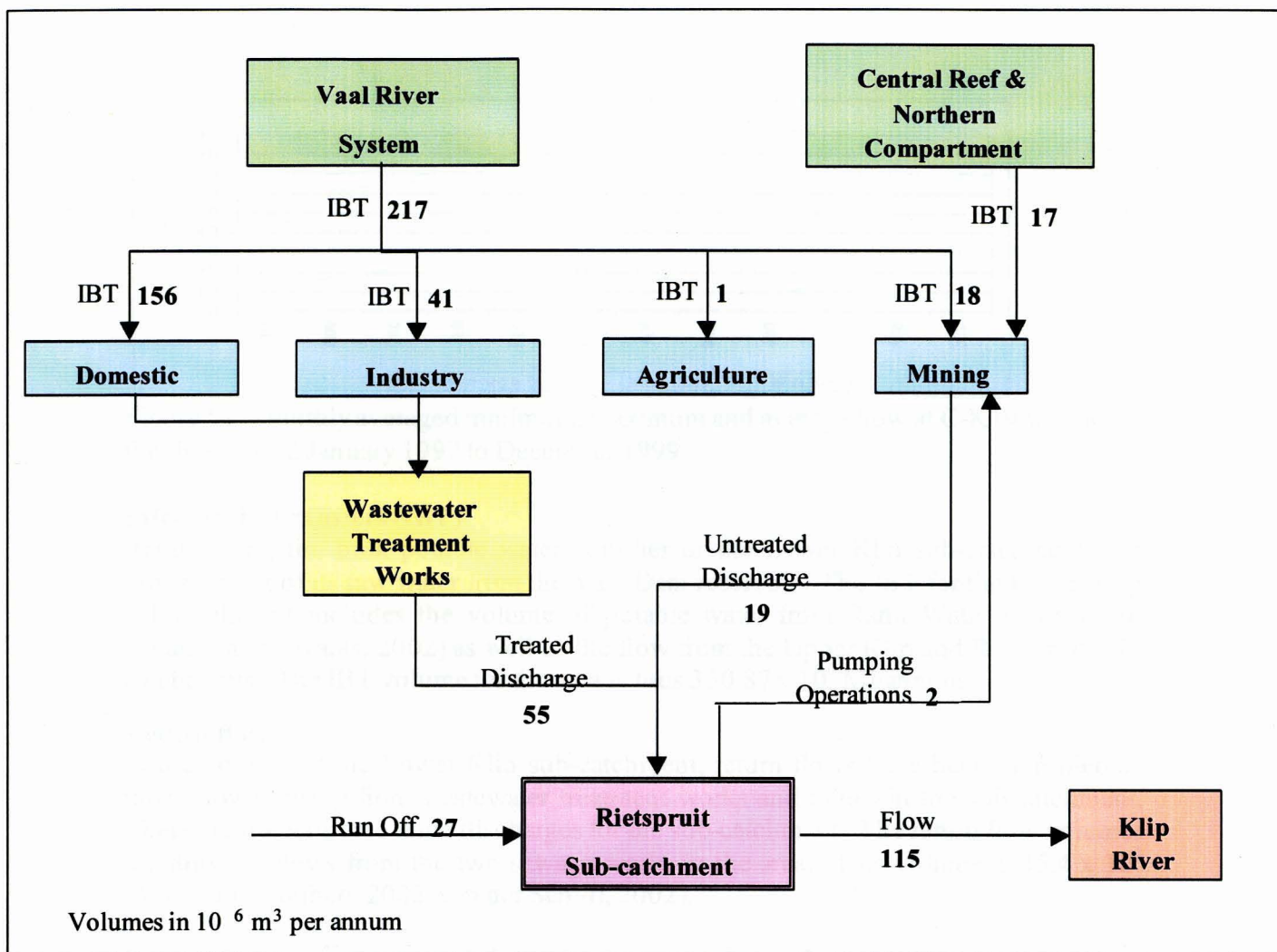


Figure 50: Water balance for the Rietspruit sub-catchment.

Lower Klip sub-catchment

Mean Annual Runoff (MAR)

As indicated in Figure 46, the mean annual runoff (MAR) in the Lower Klip is 24.3 – 30.7 mm (WRC, 1990 - 1994). The net MAR is $14.9 \times 10^6 \text{ m}^3$ (Midgley et al., 1994 a). Figure 51 is the monthly averaged minimum, maximum and average for the Lower Klip sub-catchment measured at Rand Water's C-K19 (indicated on Figure 59) weir for the time period January 1992 to December 1999.

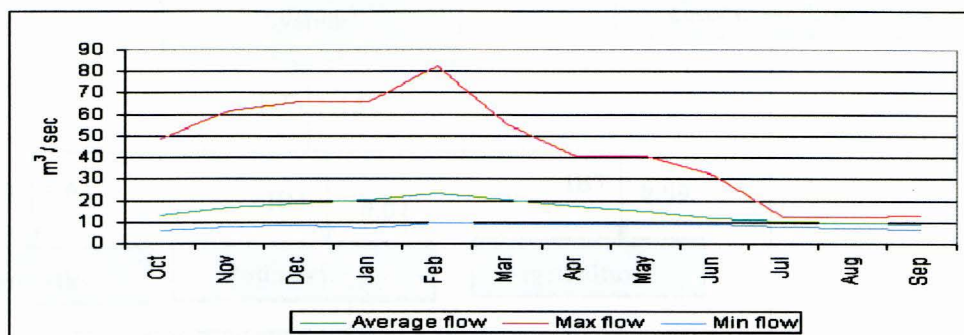


Figure 51: Monthly averaged minimum, maximum and average flow at C-K19 weir for the time period January 1992 to December 1999.

Inter Basin Transfers (IBT)

Rand Water, the bulk potable water supplier to the Lower Klip sub-catchment area obtains most of its raw water from the Vaal Dam reservoir. The IBT for the Lower Klip sub-catchment includes the volume of potable water from Rand Water (1.15×10^6 Ml/annum) (Tavaras, 2002) as well as the flow from the Upper Klip and Rietspruit sub-catchments. The IBT volume for the area is thus 350.87×10^6 Ml/annum.

Return flows

In the context of the Lower Klip sub-catchment, return flows have been identified as those flows arising from wastewater treatment works and mines in the sub-catchment. There are no permitted mine discharges for the sub-catchment. The return flow volumes are thus the flows from the two sewage works in the area. This volume is 35.4×10^6 Ml/annum (Joubert, 2002, van der Schyff, 2002).

Figure 52 indicates the water balance for the Lower Klip sub-catchment.

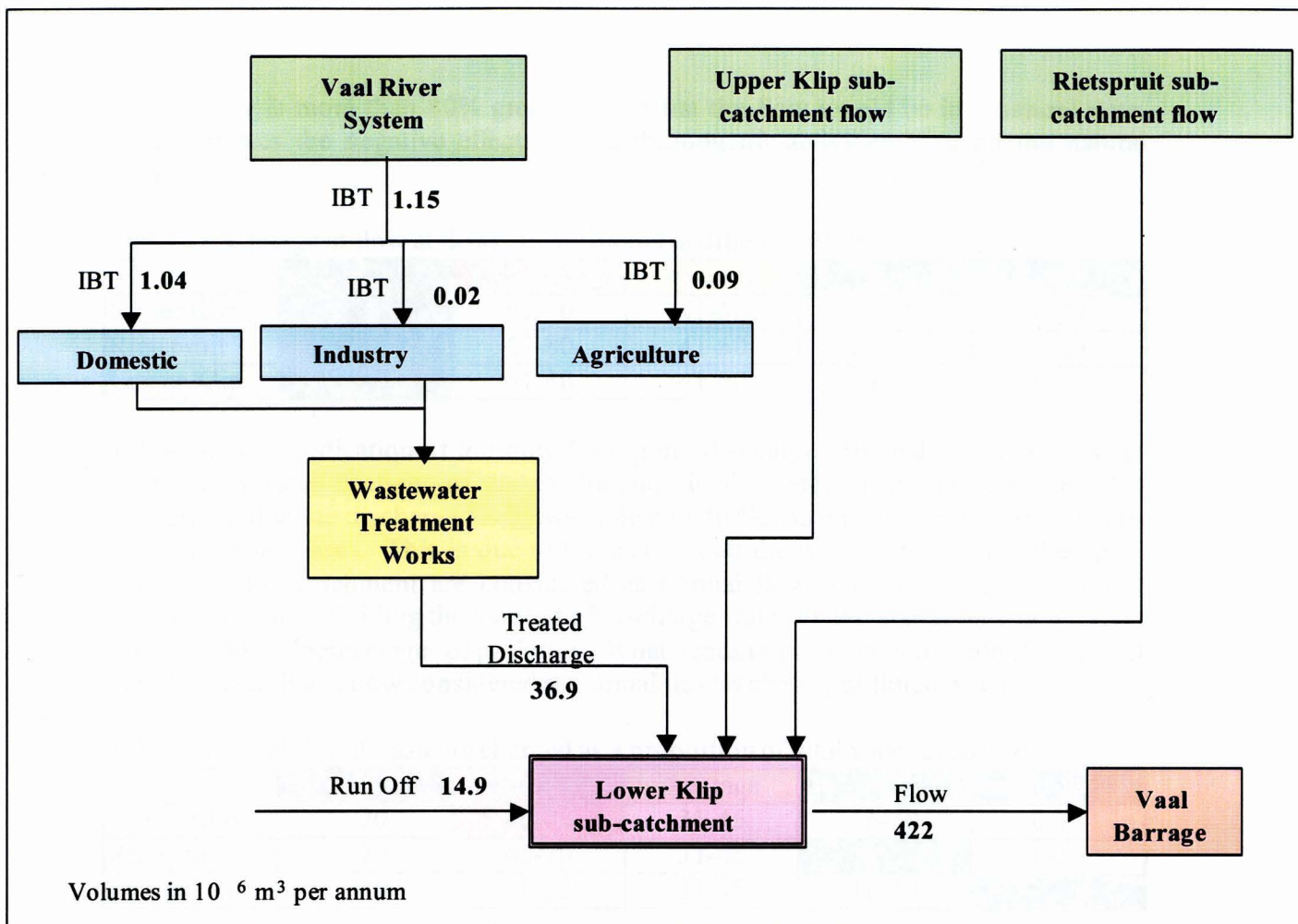


Figure 52: Water balance for the Lower Klip sub-catchment.

Discussion

From the above information, it can be seen that the amount of water within the Klip River increases as one moves downstream. Table 12 indicates the ratio of water from return flows and IBT's compared with the total amount of water within the system. As can clearly be seen more than 80 % of the water in the system is contributed from return flows and IBT's. Of this 80%, the majority of the water not natural to the system is from IBT's. This indicates that the catchment relies heavily on water from IBT's and this catchment cannot be considered as sustainable in its natural state.

Table 12: Anthropogenic supply as a proportion of total supply (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	> 80	61-80	41-60	21-40	0-20
Rietspruit	> 80	61-80	41-60	21-40	0-20
Lower Klip	> 80	61-80	41-60	21-40	0-20

Table 13 indicates how the current flow at a downstream point differs from what would be considered as the natural flow as represented by the MAR. It is obvious that the

current flow is more than 80% greater than what the flow would be in a natural state. This indicates the negative effects that anthropogenic activities have on the natural system.

Table 13: Change in flow at downstream point (% difference from MAR)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	> 80	61-80	41-60	21-40	0-20
Rietspruit	> 80	61-80	41-60	21-40	0-20
Lower Klip	> 80	61-80	41-60	21-40	0-20

Table 14 is an indication of the flow from point discharges divided by the total water supply in various sections of the catchment. In the Upper Klip sub-catchment the proportion of waste discharged is between 46 and 70 %. As one moves downstream this percentage decreases. This is due to the fact that all the water coming from the upper regions of the catchment are considered as normal flow once they reach the lower catchment. Thus dividing the amount of discharge water by the actual flow in the river gives one lower percentages of pollution. What needs to be taken into account is the fact that the water that is now considered as normal flow is already polluted water.

Table 14: Total liquid waste discharged as a proportion of total water available (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>70	46-70	31-45	16-30	0-15
Rietspruit	>70	46-70	31-45	16-30	0-15
Lower Klip	>70	46-70	31-45	16-30	0-15

2.4.2 Water demand

Domestic users

Rand Water supplies potable water for domestic use in the Klip river catchment. Some communities in the Lower Klip sub-catchment do extract water from boreholes. Many inhabitants of informal settlements in the area still use river water as their main source of drinking water (Bohlweki, 1999).

Industrial users

Industries mainly use water supplied by Rand Water. Some industries do abstract water directly from the Klip River.

Agriculture

Significant abstraction for irrigation purposes takes place in the catchment. The main use of the water is for crop irrigation and livestock watering. The main irrigated crops are maize, fodder crops, vegetables, instant lawns, nursery plants and private gardens. Livestock watering includes sheep, cattle and pigs (Bohlweki, 1999).

Recreational

Recreational activities include non-contact, intermediate contact and full contact activities such as riparian home ownership, fishing, bird watching, boating, swimming, windsurfing and water-skiing. These activities occur mainly on dams in the area. Certain cultural activities of township dwellers, such as baptism and use of water for traditional medicines, rely on the river system (Bohlweki, 1999).

Aquatic ecosystems

None of the rivers in the Klip River catchment can be considered pristine or sensitive. Exotic plants are well established in the area. Wetlands are common in the Upper Klip and Rietspruit sub-catchments. They sustain diversity, improve water quality, provide recreational opportunities and create a sanctuary for bird life, small animals and aquatic life (Bohlweki, 1999).

Upper Klip sub-catchment

Figure 53 indicates the sectoral supply of potable water by Rand Water in the Upper Klip sub-catchment (Tavaras, 2002).

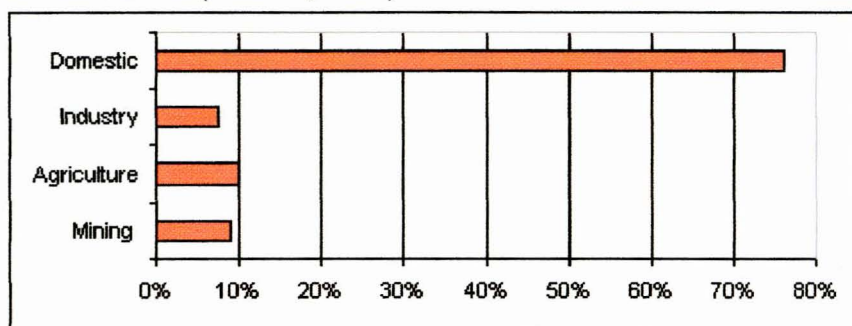


Figure 53: Sectoral use of potable water in the Upper Klip sub-catchment (Tavaras, 2002).

Rietspruit sub-catchment

Figure 54 indicates the sectoral supply of potable water by Rand Water in the Rietspruit sub-catchment (Tavaras, 2002).

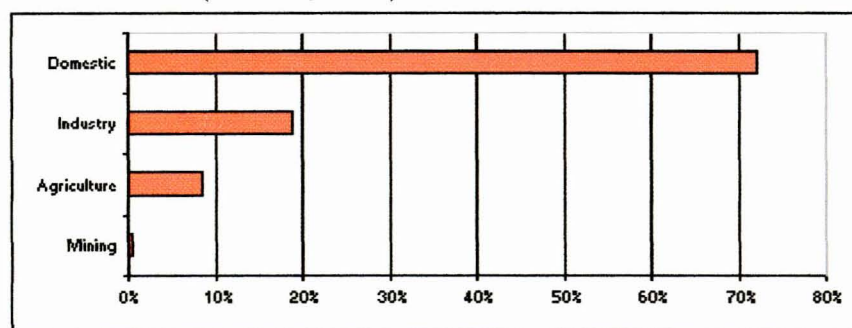


Figure 54: Sectoral use of potable water in the Rietspruit sub-catchment (Tavaras, 2002).

Lower Klip sub-catchment

Figure 55 indicates the sectoral supply of potable water by Rand Water in the Lower Klip sub-catchment (Tavaras, 2002).

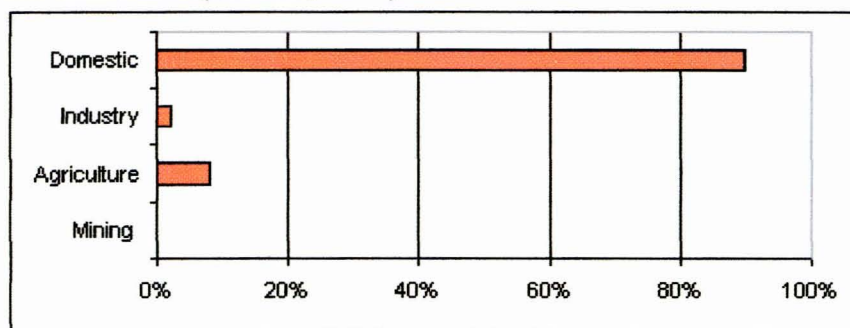


Figure 55: Sectoral use of potable water in the Lower Klip sub-catchment (Tavaras, 2002).

2.4.3 Projections of supply and demand

Upper Klip sub-catchment

Figure 56 indicates actual and projected annual average daily demand for potable water in the Upper Klip sub-catchment (Tavaras, 2002). The data prior to 1998 is actual data and after 1998 is projected data.

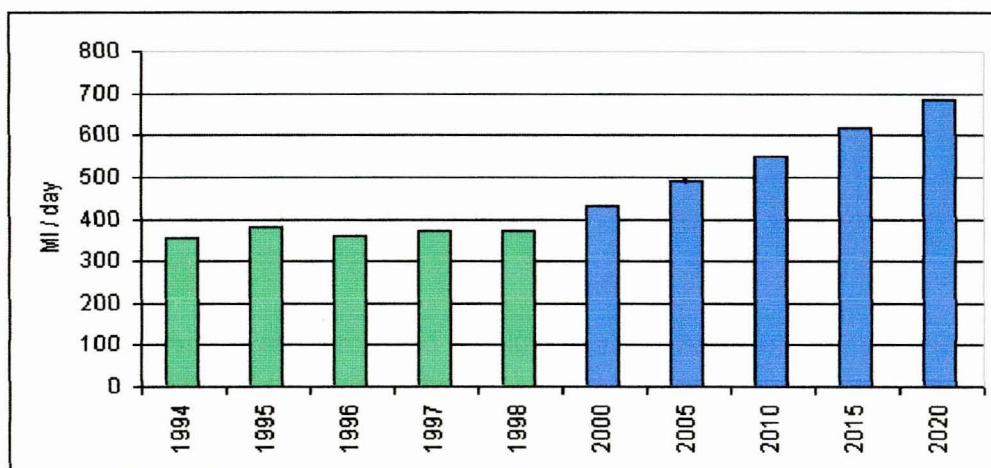


Figure 56: Actual and projected average daily demand for potable water in the Upper Klip sub-catchment (Tavaras, 2002).

Rietspruit sub-catchment

Figure 57 indicates actual and projected annual average daily demand for potable water in the Rietspruit sub-catchment (Tavaras, 2002). The data prior to 1998 is actual data and after 1998 is projected data.

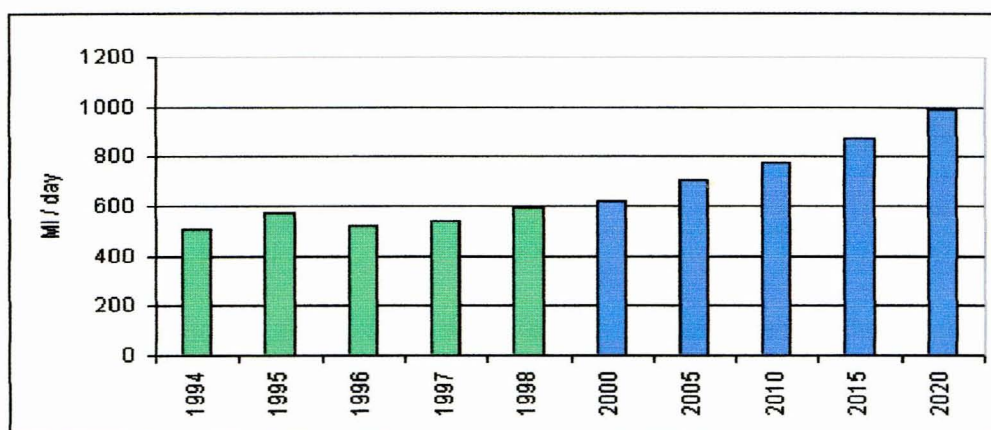


Figure 57: Actual and projected average daily demand for potable water in the Rietspruit sub-catchment (Tavaras, 2002).

Lower Klip sub-catchment

Figure 58 indicates actual and projected annual average daily demand for potable water in the Lower Klip sub-catchment (Tavaras, 2002). The data prior to 1998 is actual data and after 1998 is projected data.

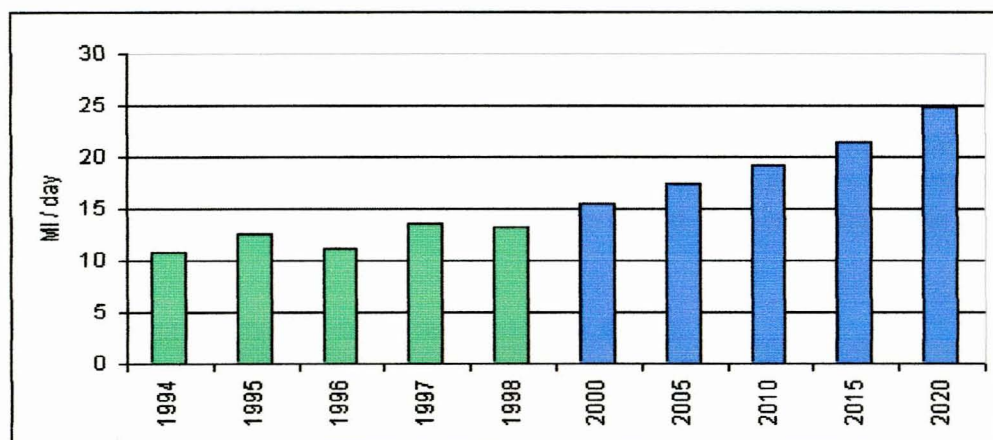


Figure 58: Actual and projected average daily demand for potable water in the Lower Klip sub-catchment (Tavaras, 2002).

Discussion

There is an increase in the demand for potable water over the next 20 years. This value is based upon the figures for the population increase within Southern Africa over the next 20 years and does not take factors such as AIDS into consideration (Tavaras, 2002).

Table 15 indicates the volume of water in natural streams that is available per capita. In the Upper Klip and Rietspruit sub-catchments there is less than 500 m³ of water available per capita per year. This implies that there is not enough naturally occurring water in these sub-catchments to provide for the needs of all the people. Only in the Lower Klip is there enough water to provide for the needs of the people. The reason there is enough water in this catchment is due to the large return flow volumes from the upper catchments

as well as the smaller population.

Table 15: Total water available per capita (m³/cap/annum)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0-500	501-1000	1001-1500	1501-2000	>2000
Rietspruit	0-500	501-1000	1001-1500	1501-2000	>2000
Lower Klip	0-500	501-1000	1001-1500	1501-2000	>2000

Table 16 indicates the potable water quality at reservoirs within each sub-catchment. Rand Water monitors the quality of its potable water before it reaches the end consumers. The potable water within the area falls within the Above Average and Excellent ranges. The reason that the quality in the Rietspruit sub-catchment does not fall within the Excellent range is due to high Standard Plate Count (SPC) measurements. SPC is a measurement of the total number of all organisms within a sample. Faecal coliforms is a measurement of faecal related organisms.

Table 16: Health-Related Index for potable water (% score)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	≤ 60	61-70	71-80	81-90	91-100
Rietspruit	≤ 60	61-70	71-80	81-90	91-100
Lower Klip	≤ 60	61-70	71-80	81-90	91-100

Table 17 indicates the recreational health risk of raw water within the areas. The water at the downstream points of the Upper Klip and Rietspruit sub-catchments is Below Average. This is due to the high Faecal coliform and dissolved chemicals in the water at these points.

Table 17: Recreational Index for raw water (% score)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	≤ 60	61-70	71-80	81-90	91-100
Rietspruit	≤ 60	61-70	71-80	81-90	91-100
Lower Klip	≤ 60	61-70	71-80	81-90	91-100

2.4.4 Reserve

Reserve means the quantity and quality of water required:

- to satisfy basic human needs for all people who are or who may be supplied from the relevant water resource and
- to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource (DWAF, 1999).

As yet, no reserve has been determined for the area.

2.5 Waste and pollution

2.5.1 Sources and types of waste generated

Tables 50, 51 and 52 in Appendix 3 are based on a query of the Witwatersrand Industry Database for the Upper Klip, Rietspruit and Lower Klip sub-catchments respectively. This database gives an indication of the types and number of industries in an area and the potential contaminants that could be produced by each type of industry. The data in the table should therefore not be interpreted as indicating actual or quantitative information on the sub-catchment. The information must be ground-truthed. As noted by the tables, a wide range of types of waste can be generated by industries within the sub-catchments.

2.5.2 Sources and types of waste discharged

The effluent from sewage works should comply with certain criteria. These criteria are found in Table 18.

Table 18: Effluent discharge criteria

Variable	Criteria
COD (mg/l)	< 75
SS (mg/l)	< 25
PO ₄ (mg/l)	< 1
NH ₃ (mg/l)	< 10
NO ₃ (mg/l)	< 15
Faecal Coliforms (/100ml)	0

Upper Klip sub-catchment

In the Upper Klip sub-catchment there are no permitted discharges from mines. This does not however mean that no discharge is occurring. Permitted discharges occur from Johannesburg's three southern sewage works (Bushkoppies, Goudkoppies and Olifantsvlei) (Figure 59). Table 19 indicates the organic load from the three works from October 1998 to September 1999. The Organic Load Index is calculated by dividing the operating COD capacity by the design COD capacity. What can be seen is that Olifantsvlei is still able to treat more COD than the other two works within the sub-catchment. Bushkoppies and Goudkoppies are using 86% and 78% of their COD treating capacity. Table 20 indicates the hydraulic capacity of the works for the same time period. The Hydraulic Capacity Index is calculated by dividing the operating hydraulic capacity by the design hydraulic capacity. What can be seen is that Olifantsvlei is still able to treat higher volumes of effluent than the other two works within the sub-catchment. Bushkoppies and Goudkoppies are using 88% and 78% of their volume capacity. Table 21 indicates the final effluent quality from the works. All three the works have above 80 % rating. This indicates that the amount of sewage pollution occurring directly from the works is kept at a minimum.

There are many sewage leaks within the Soweto and Johannesburg areas – both from formal and informal settlements. In the formal areas many breakages or vandalism of sewage lines occur. In the informal areas there is no adequate sewage system and a lack of education on proper sanitation. The sewage system in the central Johannesburg area is currently overloaded. These spillages would thus account for levels of sewage pollution that are detected within the Upper Klip River sub-catchment.

Table 19: Organic load and rating (OLI_{wcw}) of sewage works in the Upper Klip sub-catchment (Pitman, 2002).

	Bushkoppies	Goudkoppies	Olifantsvlei
Design COD capacity (tonnes/day)	170	83	110
Operating COD capacity (tonnes/day)	142	64.5	66.6
OLI_{wcw}	0.86	0.78	0.61

Table 20: Hydraulic capacity and rating (HCI_{wcw}) of the sewage works in the Upper Klip sub-catchment (Pitman, 2002).

	Bushkoppies	Goudkoppies	Olifantsvlei
Total Hydraulic capacity (Ml/day)	200	150	220
Total volume of effluent treated per day (Ml/day)	176	117	148
HCI_{wcw}	0.88	0.78	0.67

Table 21: Final effluent quality and rating (ECI (%)) of the sewage works in the Upper Klip sub-catchment (Pitman, 2002).

Variable	Averaged Effluent data			Compliance rating		
	Bush-koppies	Goud-koppies	Olifants-vlei	Bush-koppies	Goud-koppies	Olifants-vlei
COD (mg/l)	66	38	32	2	2	2
SS (mg/l)	4	12	5	2	2	2
PO ₄ (mg/l)	0.8	0.7	0.7	2	2	2
NH ₃ (mg/l)	1.4	2.9	0.7	2	2	2
NO ₃ (mg/l)	7.0	3.7	5.6	2	2	2
Faecal Coli (/100ml)	1000	48700	163	1	0	1
ECI (%)				91.67	83.33	91.67

Rietspruit sub-catchment

In the Rietspruit sub-catchment there are two permitted discharges from mines. The main mining concerns are East Rand Proprietary Mines (ERPM) and East Rand Gold Operations (ERGO). ERGO is involved in mine dump reclamation and has operations at various old mine dumps. There are two mine effluent discharge points from the ERPM

gold mine:

1. Water from the South West vertical shaft that is pumped to a plant where it is reused and some overflow is discharged to the Elsburgspruit.
2. Overflow water from the Hercules shaft is discharged into Angelo Pan (van Jaarsveldt, 2001). No water quality data was obtainable for the mine discharges in the area.

Permitted discharges occur from ERWAT's three sewage works, namely, Rondebult, Dekema and Vlakplaats (Figure 59). Table 22 indicates the organic load from the three works from October 1998 to September 1999. What can be seen is that Vlakplaats is still able to treat more COD than the other two works within the sub-catchment. Dekema is currently treating the maximum amount of COD that it has been designed for. This means that extensions may have to be built or COD needs to be diverted to one of the other treatment works within the area. Table 23 indicates the hydraulic capacity of the works for the same time period. Vlakplaats may currently not treat all the effluent as greater volumes of effluent are coming into the works than what the works was designed for. Table 24 indicates the final effluent quality from the works. This indicates that the works is only treating sewage to 50% compliance. Of concern are the high COD and Faecal coliform values. Figure 59 shows the locations of Rand Water's sampling points as well as the location of sewage works in the Klip River catchment.

Table 22: Organic load and rating (OLI_{wcw}) of sewage works in the Rietspruit sub-catchment (Joubert, 2002).

	Dekema	Rondebult	Vlakplaats
Design COD capacity (tonnes/day)	16.8	36	66
Operating COD capacity (tonnes/day)	16.8	27.4	45
OLI_{wcw}	1	0.76	0.68

Table 23: Hydraulic capacity and rating (HCI_{wcw}) of the sewage works in the Rietspruit sub-catchment (Joubert, 2002).

	Dekema	Rondebult	Vlakplaats
Total Hydraulic capacity (Ml/day)	36	36	83
Total volume of effluent treated per day (Ml/day)	32	26.7	92
HCI_{wcw}	0.89	0.74	1.11

Table 24: Final effluent quality (ECI (%)) of the sewage works in the Rietspruit sub-catchment (Joubert, 2002).

Variable	Averaged Effluent data			Compliance rating		
	Dekema	Rondebult	Vlakplaats	Dekema	Rondebult	Vlakplaats
COD (mg/l)	130	180	135	0	0	0
SS (mg/l)	41	60	27	0	0	1
PO4 (mg/l)	1.2	0.97	2	1	2	0
NH3 (mg/l)	8.6	10	10	2	2	2
NO3 (mg/l)	11	8.9	15.9	2	2	1
Faecal Coli (/100ml)	4425000	6885000	6220	0	0	1
ECI (%)				41.67	50	41.67

Lower Klip sub-catchment

In the Lower Klip sub-catchment there are no permitted discharges from mines. This does not however mean that no discharge is occurring. Permitted discharges occur from the Meyerton sewage works and ERWAT's Waterval sewage works. Table 25 indicates the organic load from the three works from October 1998 to September 1999. Meyerton works is currently not able to treat any of the COD entering the works; the works thus gets a Poor rating in terms of treating its COD loading. Waterval sewage works can still handle 18 % more COD loading. Table 26 indicates the hydraulic capacity of the works for the same time period. Meyerton works is getting more effluent in than what it can treat effectively. Waterval sewage works is currently using 89% of its hydraulic capacity. Table 27 indicates the final effluent quality from the works. Currently Meyerton is discharging effluent that is below standard. The only variable within the discharge standards is NO₃. Meyerton works is currently being looked at to try and upgrade the facilities and get the final effluent to acceptable qualities. Waterval effluent is within standards most of the time. The only problem variable is Faecal coliforms. Waterval sewage works is in the process of adding a chlorination zone to their works to deal with the high Faecal values within the final discharge effluent.

Figure 59 shows the locations of Rand Water's sampling points as well as the location of sewage works in the Klip River catchment.

Table 25: Organic load and rating (OLI_{wcw}) of sewage works in the Lower Klip sub-catchment (Joubert, 2002, van der Schyff, 2002).

	Waterval	Meyerton
Design COD capacity (tonnes/day)	114	0
Operating COD capacity (tonnes/day)	94	6.48
OLI _{wcw}	0.82	6.48

Table 26: Hydraulic capacity and rating (HCI_{WCW}) of the sewage works in the Lower Klip sub-catchment (Joubert, 2002, van der Schyff, 2002).

	Waterval	Meyerton
Total Hydraulic capacity (Ml/day)	105	5
Total volume of effluent treated per day (Ml/day)	93	7
HCI_{WCW}	0.89	1.4

Table 27: Final effluent quality (ECI (%)) of the sewage works in the Lower Klip sub-catchment (Joubert, 2002, van der Schyff, 2002).

Variable	Averaged Effluent data		Compliance rating	
	Waterval	Meyerton	Waterval	Meyerton
COD (mg/l)	44	138.44	2	0
SS (mg/l)	24.9	106.05	2	0
PO4 (mg/l)	1.1	2.91	1	0
NH3 (mg/l)	2.3	20.28	2	0
NO3 (mg/l)	2.4	2.1	2	2
Faecal Coli (/100ml)	764975	5159400	0	0
ECI (%)			75	33

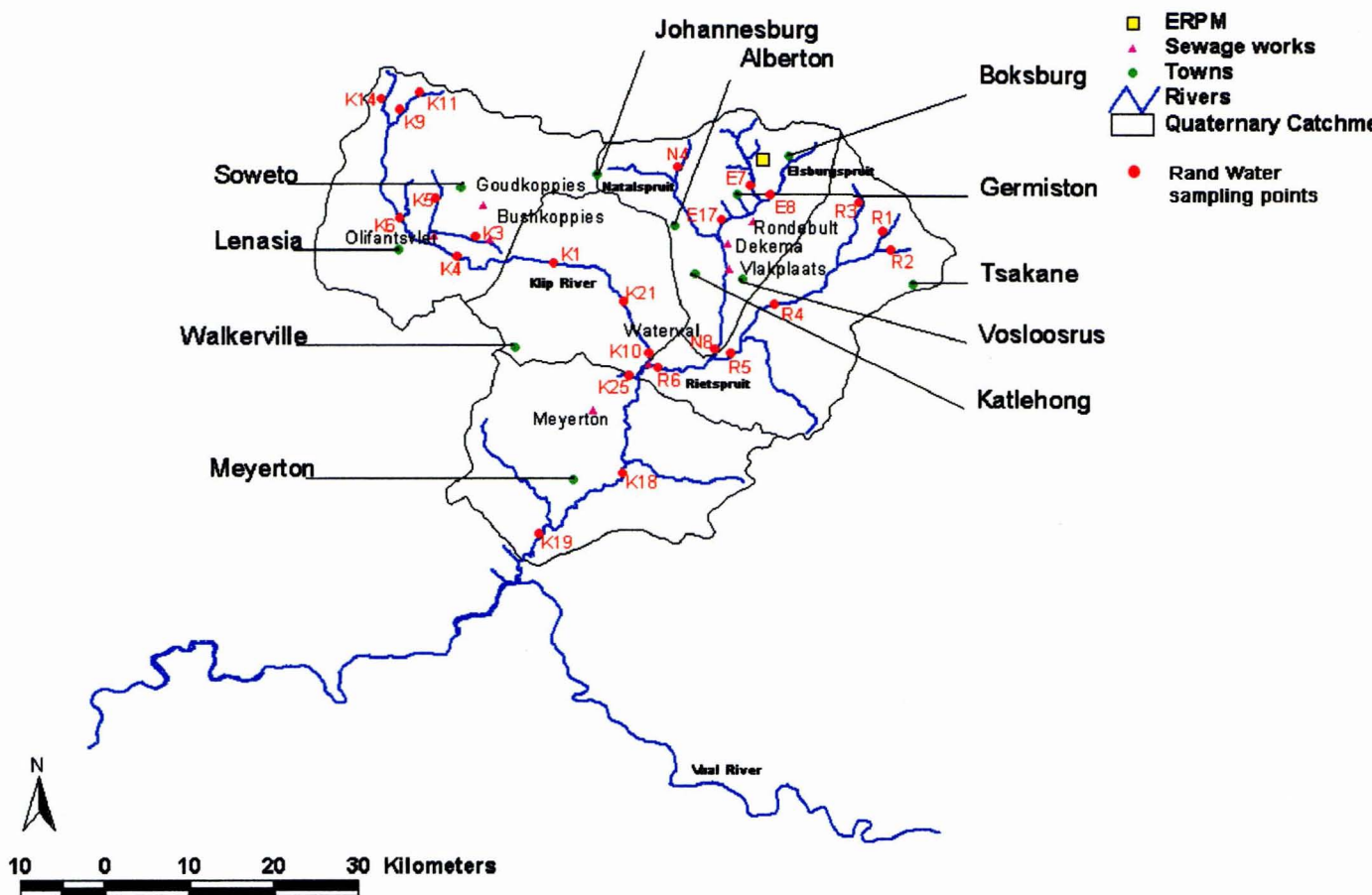


Figure 59: Location of Rand Water's sampling points and sewage works in the Klip River catchment.

Discussion

Figure 60 shows a bubble graph for the sewage works in the Upper Klip sub-catchment. Organic load is indicated on the y-axis and Hydraulic load on the x-axis. An ideal situation would be for the bubble of the works to fall in the lower left quadrant. This implies that the works is not utilizing its full COD or hydraulic capacity and can thus treat more effluent. The worst situation is when the bubble occurs in the top right quadrant. This shows that both the organic and hydraulic loads of the works are above 100% indicating a problem within the works. The top left quadrant will indicate a works with a high COD load and the bottom right a works with high hydraulic load.

As can be seen from Figure 60, all three the wastewater works in the area fall within the lower left quadrant. Bushkoppies and Goudkoppies both fall near the axis for high COD loads and Bushkoppies is approaching the axis for high hydraulic loading.

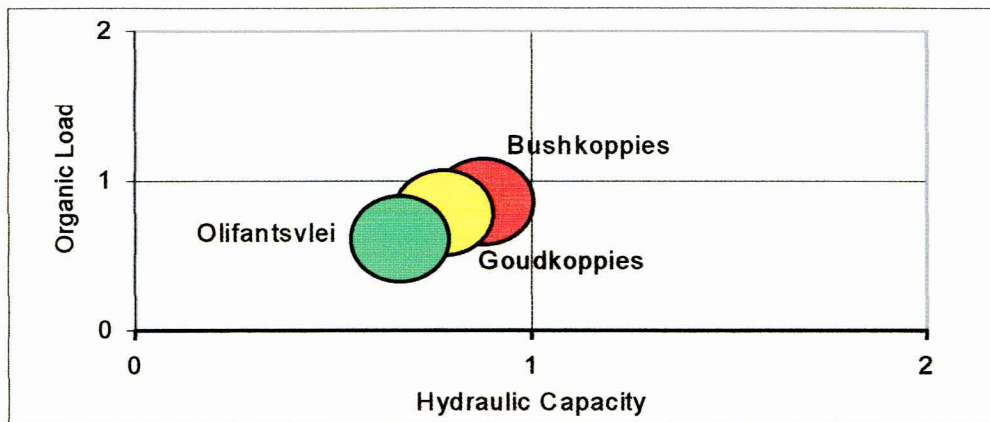


Figure 60: Water Care Works Bubble Graph for the Upper Klip sub-catchment

Figure 61 shows the bubble graph for the sewage works in the Rietspruit sub-catchment. Dekema works has a high COD loading and Vlakplaats already has to treat more effluent than what it was designed for.

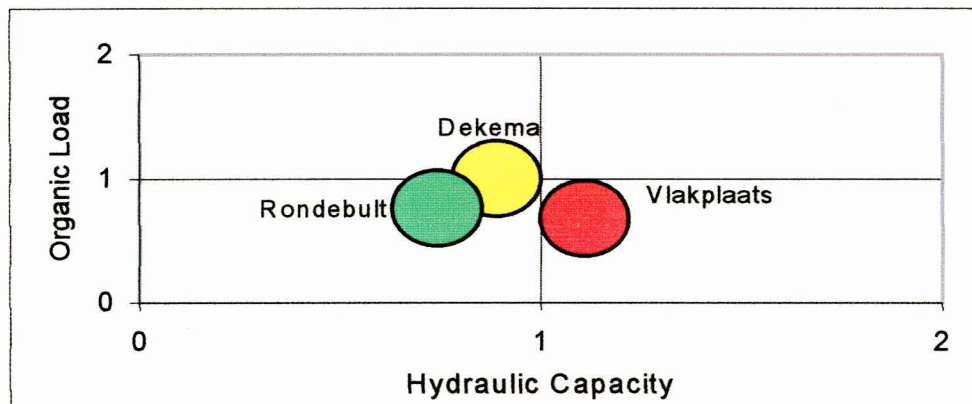


Figure 61: Water Care Works Bubble Graph for the Rietspruit sub-catchment.

Figure 62 shows the bubble graph for the sewage works in the Lower Klip sub-catchment. It is clear that Meyerton works is not able to treat the volume of effluent or the amount of COD entering the works. Waterval sewage works is still within the ideal quadrant but has a high COD and hydraulic capacity ratio.

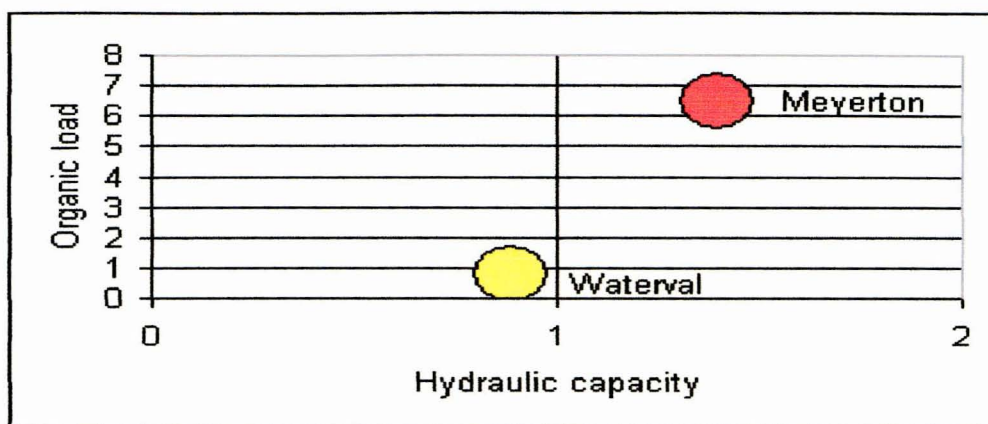


Figure 62: Water Care Works Bubble Graph for the Lower Klip sub-catchment

Tables 28, 29 and 30 are summary tables for the Organic Load Capacity (COD load), Hydraulic capacity and Effluent compliance indices for the three sub-catchments. The Organic load and hydraulic capacity for the works in all three sub-catchments are below average. The Effluent compliance for the sewage works in the Rietspruit and Lower Klip sub-catchments are below average and above average in the Upper Klip sub-catchment.

Table 28: Organic Load Capacity of Water Care Works (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>100	>75 - 100	75	50 - <75	0-50
Rietspruit	>100	>75 - 100	75	50 - <75	0-50
Lower Klip	>100	>75 - 100	75	50 - <75	0-50

Table 29: Hydraulic Capacity Index of Water Care Works (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>100	>75 - 100	75	50 - <75	0-50
Rietspruit	>100	>75 - 100	75	50 - <75	0-50
Lower Klip	>100	>75 - 100	75	50 - <75	0-50

Table 30: Effluent Compliance Index of Water Care Works (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0	>0 - 33	>33 - 66	>66 - <100	100
Rietspruit	0	>0 - 33	>33 - 66	>66 - <100	100
Lower Klip	0	>0 - 33	>33 - 66	>66 - <100	100

Tables 31 and 32 are an indication of whether the number of hydrological monitoring stations and water quality monitoring stations within the catchment are adequate or not. Only the Rand Water stations have been taken into account. DWAF and local municipality monitoring stations do exist. There are at times duplications within the

various monitoring programs. The number of hydrological monitoring stations falls within the Average range. All the sub-catchments could have more flow measurement stations in order to gather adequate information for the area as the sub-catchments cover a large area. The Lower Klip has the least number of water quality monitoring stations for the area. The Upper Klip and Rietspruit have adequate water quality monitoring stations.

Table 31: Number of active hydrological monitoring stations (no./100km²)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60
Rietspruit	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60
Lower Klip	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60

Table 32. Number of water quality monitoring stations (no./100km²)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0	0.01-0.3	0.31-0.60	0.61-1.2	>1.2
Rietspruit	0	0.01-0.3	0.31-0.60	0.61-1.2	>1.2
Lower Klip	0	0.01-0.3	0.31-0.60	0.61-1.2	>1.2

2.5.3 State of water resources – Biological

A number of indicators to evaluate the biological quality of the water were drawn up for the CDF. These include chlorophyll a in dams, algal growth potential, fish assemblage integrity, aquatic invertebrates and daphnia toxicity. Chlorophyll a is measured as the amount of chlorophyll detected in a water sample. The amount of chlorophyll is an indication of the amount of algae in water as these algal cells contain chlorophyll that can be detected using laboratory tests. Daphnia (water fleas) are used in bioassays because they are sensitive to changes in water chemistry.

Table 33 indicates the chlorophyll a in DWAF dams exceeding 30 ug/l. As there are no DWAF regulated dams in the area, the three sub-catchments score Excellent status.

Table 33: Percentage of DWAF reservoirs with chlorophyll a exceeding 30ug/l (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	81 - 100	61 - 80	41 - 60	21 - 40	0-20
Rietspruit	> 80	61 - 80	41 - 60	21 - 40	0-20
Lower Klip	> 80	61 - 80	41 - 60	21 - 40	0-20

Table 34 indicates the algal growth potential at a downstream point within each sub-catchment. Very low counts of algae have been recorded at these points. Algae tends to grow in more stagnant water and thus the high flows in the rivers makes algal growth more difficult.

Table 34: Algal Growth Potential at the downstream point (mg/l)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0
Rietspruit	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0
Lower Klip	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0

The Fish Assemblage Integrity Index shows the degree to which a fish assemblage deviates from what would have been expected in the absence of human impacts (WRC, 2002). Fish, being longer lived, are good indicators of longer-term influences on a river reach and general habitat conditions. Table 35 shows that as one moves downstream the fish assemblage integrity index decreases, thus indicating the negative impact of the polluted water on aquatic life within the catchment.

Table 35: Integrity of the indigenous fish species assemblage (%)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	0-39	40-59	60-79	80-89	90-100
Rietspruit	0-39	40-59	60-79	80-89	90-100
Lower Klip	0-39	40-59	60-79	80-89	90-100

The South Africa Scoring System (SASS) index measures various information on aquatic invertebrates. Invertebrate organisms (insect larvae, snails, crabs, worms) require specific aquatic habitat types and water quality conditions. Changes in the composition and structure of aquatic invertebrate communities are signs of change in the overall river system (WRC, 2002). Table 36 shows that the SASS4 scores for all three sub-catchments are less than 60. This indicates that there is a severe impact on the invertebrate life within the rivers. ASPT is the average score per taxon and is calculated by dividing the SASS score by the number of taxa.

Table 36: SASS4 at the downstream point (SASS4 score; ASPT)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	SASS4<60 ASPT <3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT3-5	SASS4 100-140 ASPT 5-7	SASS4 >140 ASPT >7
Rietspruit	SASS4<60 ASPT <3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT3-5	SASS4 100-140 ASPT 5-7	SASS4>140 ASPT>7
Lower Klip	SASS4<60 ASPT <3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT3-5	SASS4 100-140 ASPT 5-7	SASS4>140 ASPT>7

Table 37 indicates the percentage Daphnia survival done on downstream samples points within the three sub-catchments. Daphnia tests determine whether there are any toxic elements present in the water and indicate the sum of all activities within a catchment (Walmsley, 2000). It is clear that the daphnia survival in the Lower Klip sub-catchment is below average and average in the Upper Klip sub-catchment. It is a bit unclear as to why the survival in the Rietspruit sub-catchment is between 91 and 100% as many industries do discharge within the sub-catchment.

Table 37: Daphnia toxicity test at the downstream point (% survival)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	<60	61-70	71-80	81-90	91-100
Rietspruit	<60	61-70	71-80	81-90	91-100
Lower Klip	<60	61-70	71-80	81-90	91-100

Discussion

The biota in the rivers of the Klip River catchment are clearly being affected by poor water quality or disturbed habitats caused through human activities.

2.5.4 State of water resources - Chemical

Chemical and Biological analysis have been done on a number of Rand Water sample points within the Klip River catchment. The data has been averaged for the year 1 October 1998 to 30 September 1999 and coloured coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4). Figures 63 – 73 are maps indicating the changes in water quality throughout the entire Klip River Catchment. These figures have been classified into the following major sources of contamination:

A: Mining (COD, Conductivity, Iron, Manganese, pH and Sulphates) and

B: Sewage works and Commercial Farming (Faecal coliforms, Nitrates, Phosphates, Ammonia and Sodium).

Tables 54 -56 (Appendix 5) are a summary of the water quality for the Rand Water Upper Klip, Rietspruit and Lower Klip river sample points for October 1998 to September 1999 (CIMDSS, 2002). Figures 75 – 137 in Appendix 6 are time and cumulative frequency graphs for the variables for the Klip River catchment listed in Tables 54 – 56. These graphs show the trends of the various constituents in the samples over the time period 1 October 1998 to 30 September 1999.

A: Mining

Chemical Oxygen Demand (COD)

Figure 63 represents the COD variance throughout the catchment (coloured coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). COD is the amount of oxygen required to degrade the organic compounds of water. The bigger the COD value of water and effluents, the more oxygen the discharges demand from water bodies. As can be seen the COD values are within the Ideal ranges at the headwaters of the Klip River in the Upper Klip sub-catchment due to very limited impacts and deteriorate to an Acceptable range as one moves downstream. This is due to a number of impacts in the area including mining, informal settlements and sewage works. The headwaters of the Rietspruit sub-catchment range from Acceptable to Tolerable, thus indicating that the water within the Rietspruit sub-catchment is of a lower quality. A number of mines, industries and sewage works occur within the upper regions of the Rietspruit sub-catchment and could be responsible for this. Possible sources of COD are the ERPM and ERGO mining operations as well as the large industrial areas of Germiston.

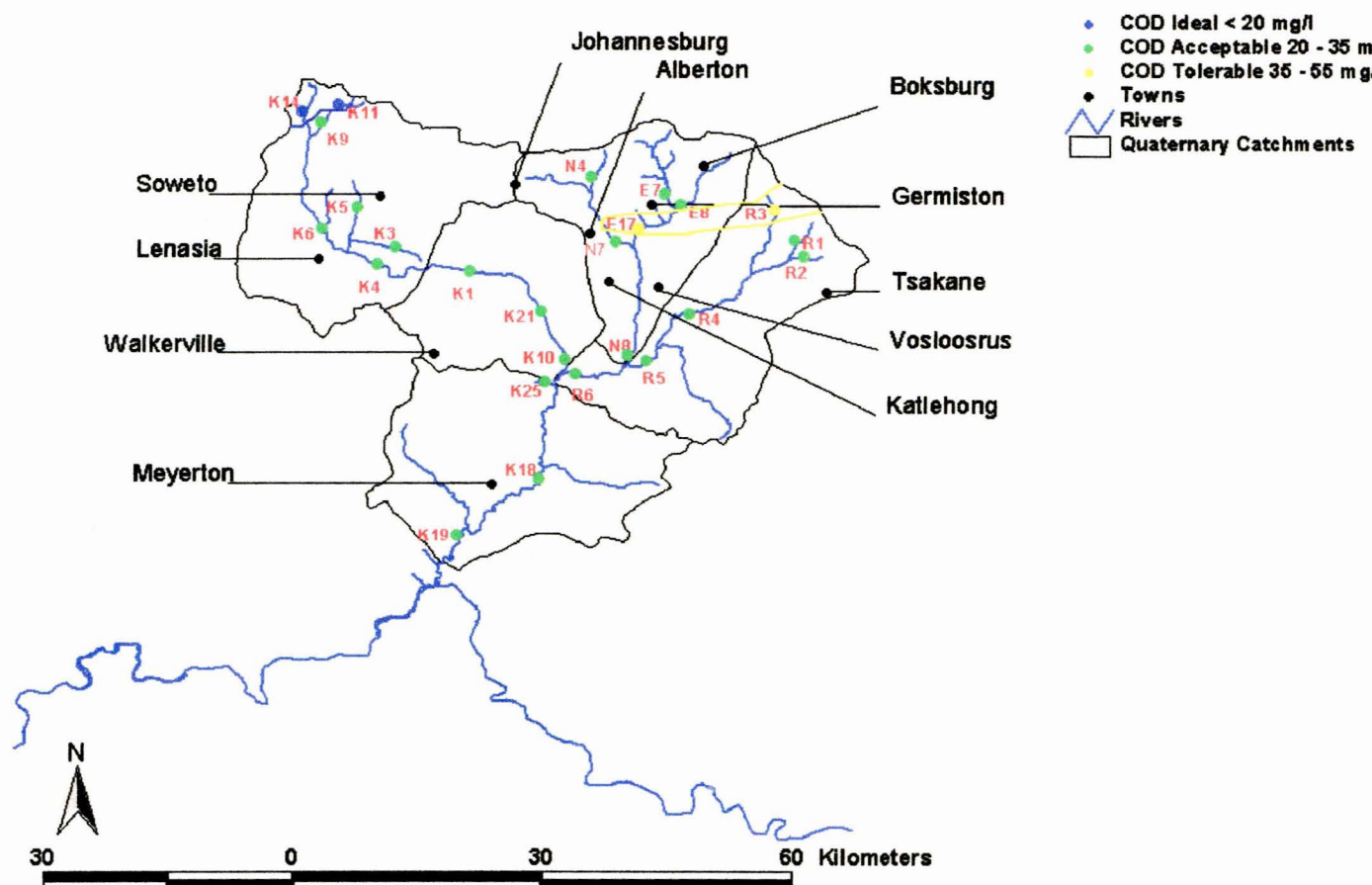


Figure 63: COD variance throughout the Klip River catchment.

Conductivity

Figure 64 represents the Conductivity variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). Conductivity estimates the amount of total dissolved salts or the total amount of dissolved ions in the water. Conductivity is controlled by geology, the size of the catchment relative to the area of the river or water body and other sources of ions to rivers such as sewage works, urban runoff, agricultural runoff and mining. As can be seen the only localities where the Conductivity values are within the Ideal ranges are at the headwaters of the Klip River in the Upper Klip sub-catchment as there are very limited impactors in this area. An Unacceptable value occurs at sample point K9 – this is due to runoff from the mining land in this area. The Conductivity at K6 and K5 is Tolerable. This is most likely due to mine runoff north of Soweto as well as sewage and urban runoff from Soweto and its associated informal settlements. The water quality then improves in terms of Conductivity as a large number of wetlands occur in the area. The

Conductivity in the Rietspruit sub-catchment is mostly Unacceptable. This is due to the large number of mines, informal settlements and industries in the area. The Conductivity in the Lower Klip sub-catchment is Tolerable – this is most likely due to the high Conductivity values originating from the Rietspruit sub-catchment. The conductivity generally decreases as one moves downstream. This is due to the wetlands in the areas purifying the water.

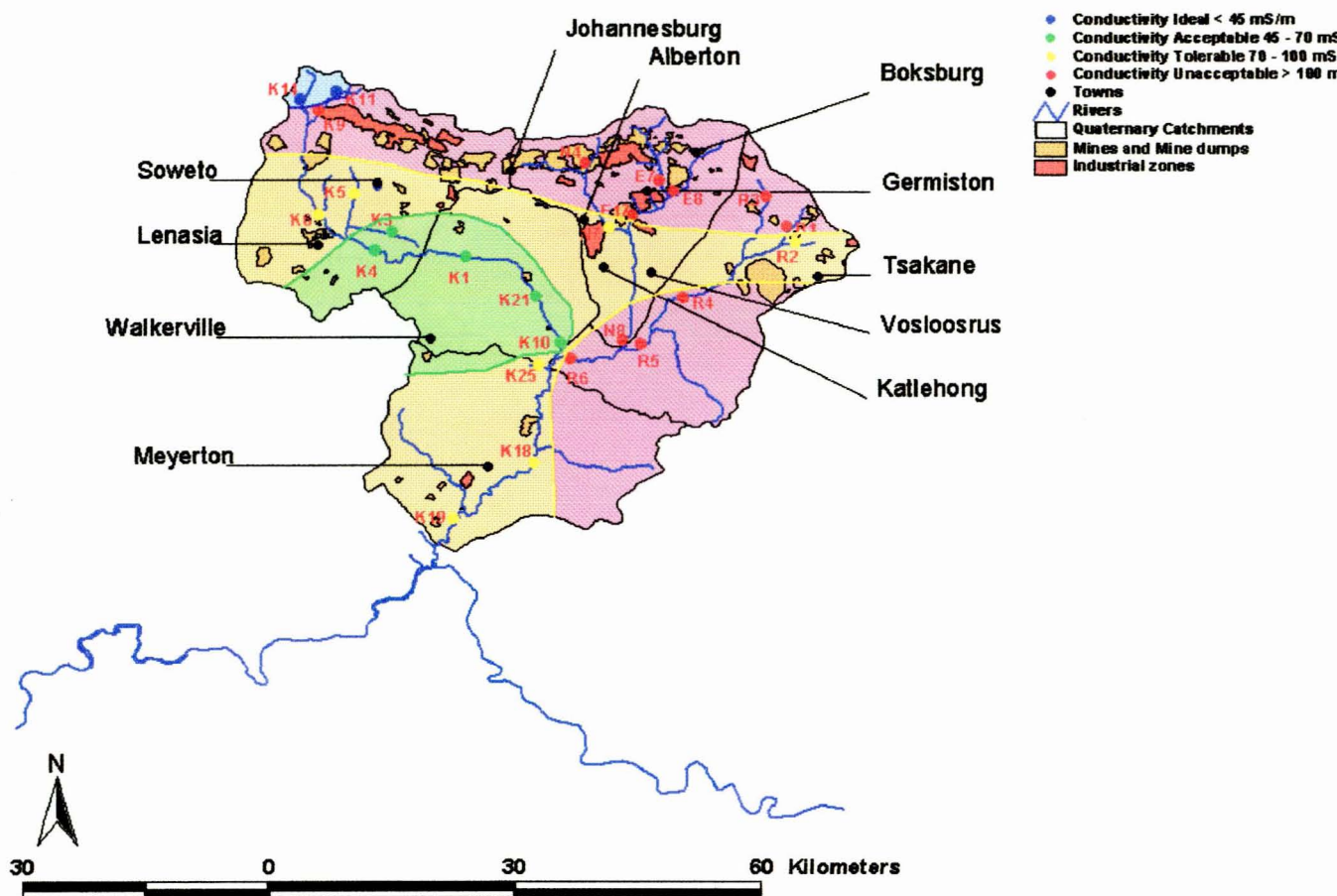


Figure 64: Conductivity variance throughout the Klip River catchment.

Iron (Fe)

Figure 65 represents the Fe variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). As can be seen the Fe values are Unacceptable at points K9, E8, R1 and N7 and Tolerable at point R3. These sample points are all within the Witwatersrand gold mining belt. Secondary oxidation of pyrite (efflorescence in the form of hydrous ferric and ferrous sulphates) on exposed tailings dams is water-soluble and is the main source of Acid Mine Drainage, TDS, Fe and SO_4 in the nearby streams. The rocks in this area contain pyrites

that in turn contain Fe. The soils in this area are Fe rich due to the breakdown of Iron sulphate (pyrite) bearing rocks. The Fe in the area is thus high due to mining as well as the naturally occurring Fe in soils. The pH of the water needs to be considered, as acidic pHs will cause the Fe in soils to be dissolved in water and transported further. At neutral pH (7), the Fe is precipitated out into sediments. As one moves south in the catchment and into the Malmani Dolomites, the Fe once again reaches Ideal ranges – either due to precipitation of Fe in water with more neutral pH's (perhaps generated by the dolomitic bedrock) or due to the take up of Fe by the extensive wetlands in the area.

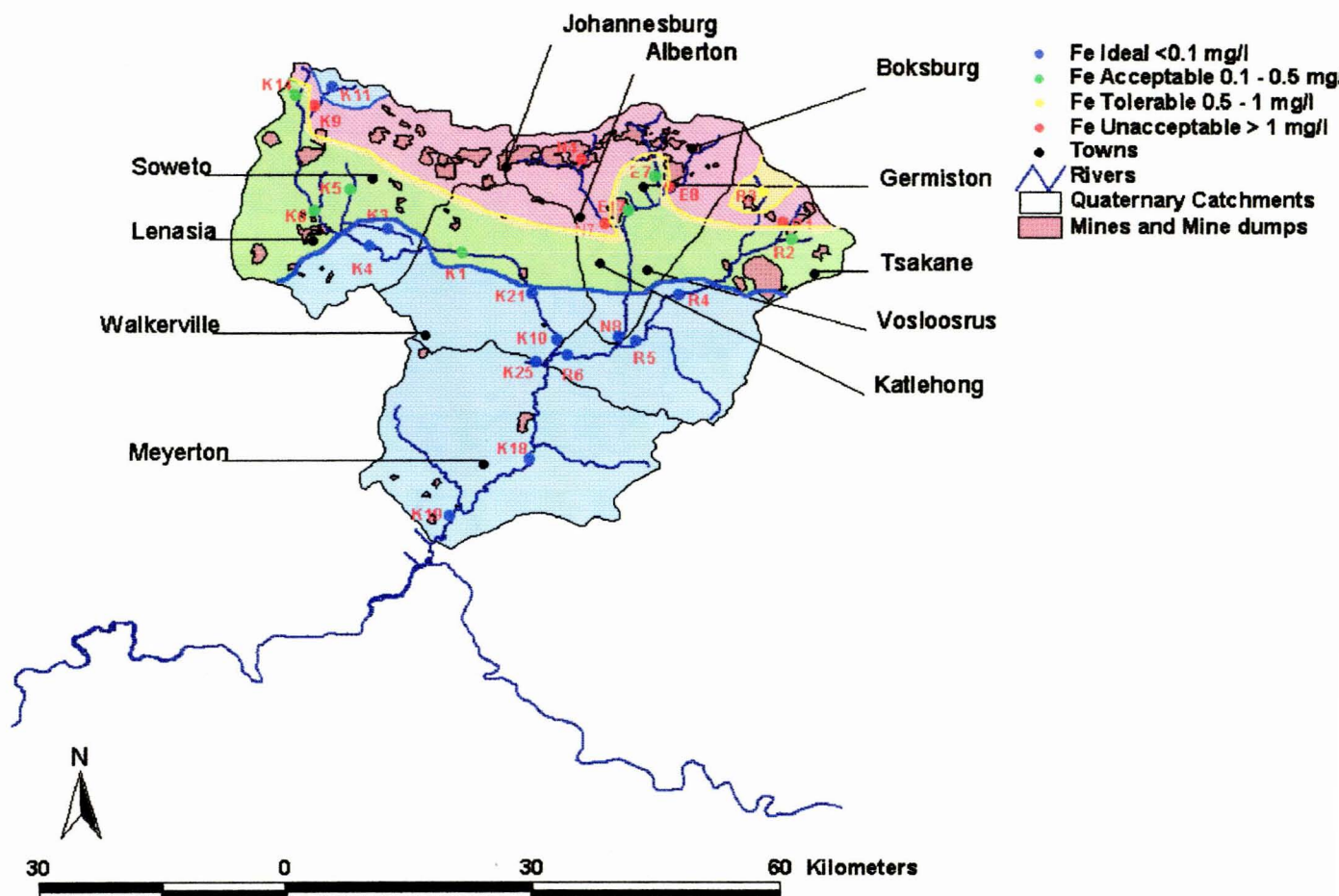


Figure 65: Fe variance throughout the Klip River catchment.

Manganese (Mn)

Figure 66 represents the Mn variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). The Mn values throughout the catchment are in the Tolerable and Unacceptable levels. It has been suggested that the criteria against which the Mn values are measured may be too

stringent. Mn is a naturally occurring element in the soils throughout the catchment in part due to the underlying dolomites in the area. The unacceptable levels within the Northern portion of the Klip River catchment are largely due to gold mining and industrial activities in the area. The Ideal range for Mn is below Rand Water's instrument detection limits.

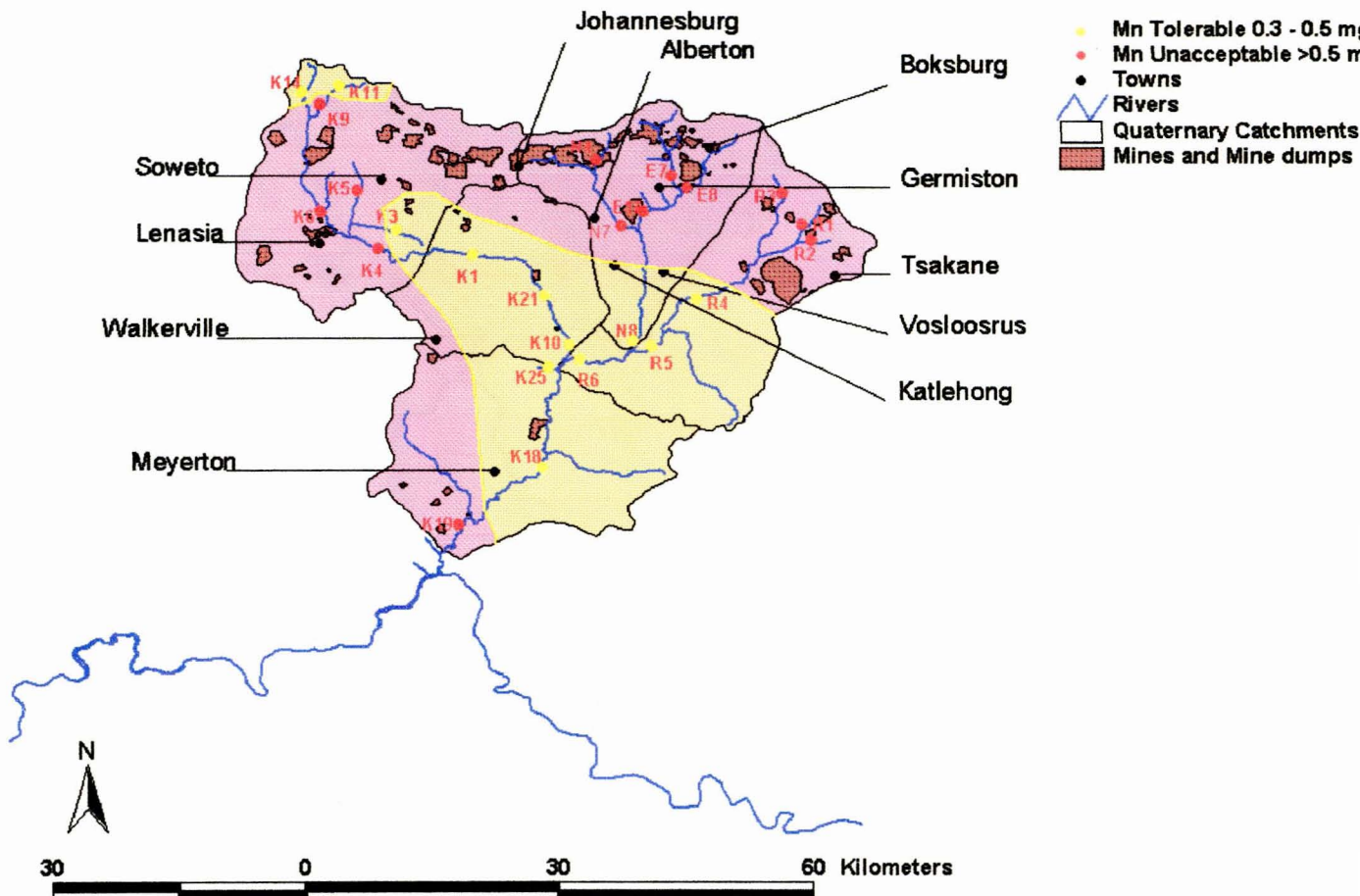


Figure 66: Mn variance throughout the Klip River catchment.

pH

Figure 67 represents the pH variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). As can be seen the pH values are generally within the Ideal range (6.5 – 8.5) throughout catchment. K9, R3, N4 and E17 all have pH values within the Unacceptable range (<6.5; >8.5) – In this case less than 6.5. This indicates acidic conditions and occurs in old mining areas. Acid Mine Drainage is thus a concern in the area.

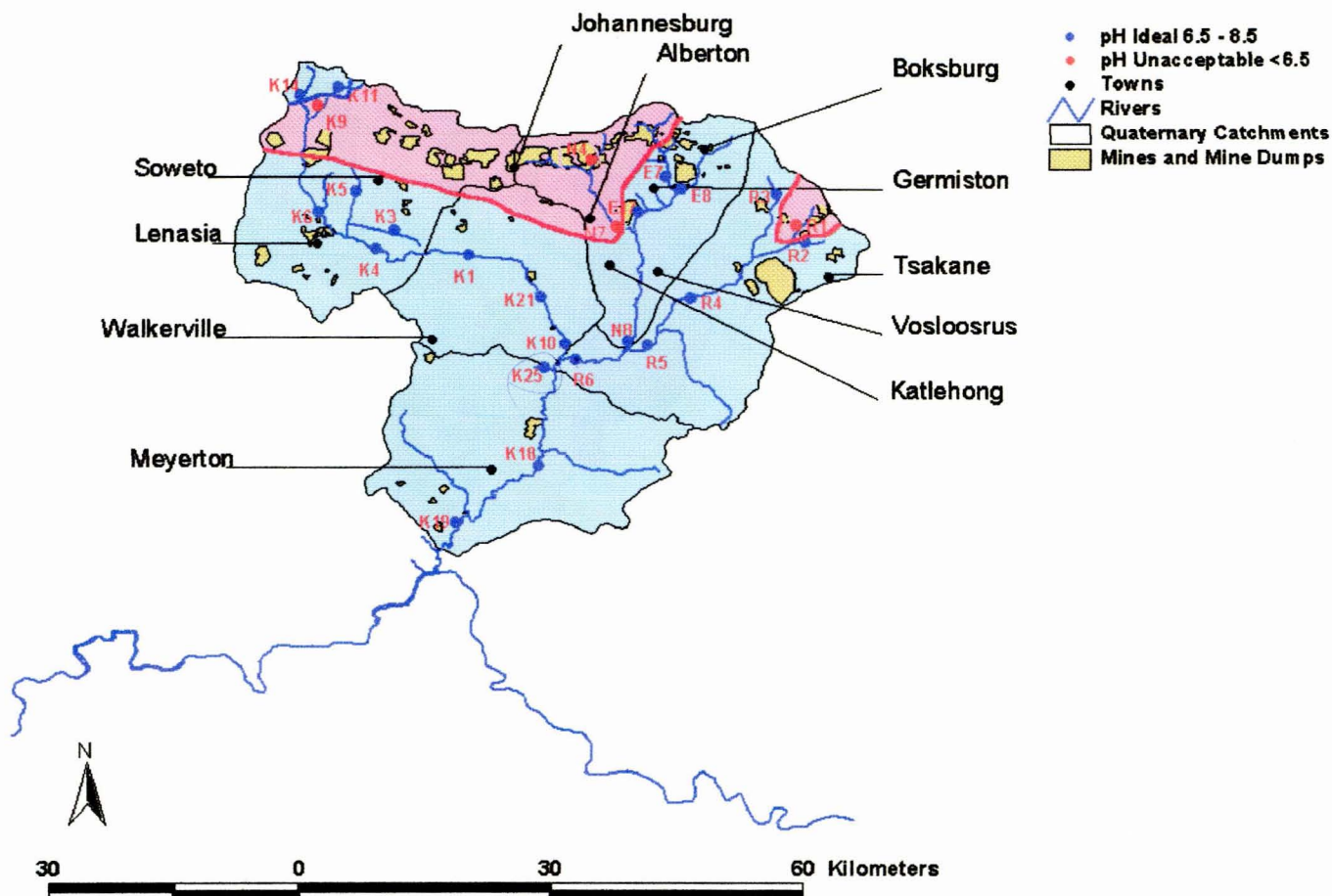


Figure 67: pH variance throughout the Klip River catchment.

Sulphate (SO₄)

Figure 68 represents the SO₄ variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). SO₄ is a component of pyrite – which is a widespread surface component from mining within the Upper Klip river catchment. As can be seen the SO₄ values are in the Unacceptable regions in the Rietspruit sub-catchment and at point K9 in the Upper Klip sub-catchment. This is due to the amount of mining occurring within these areas. The water quality improves as one moves downstream. This is most likely due to either dilution of the water by the addition of water from sewage works or the natural attenuation of the SO₄ as the water moves through the wetlands within the area.

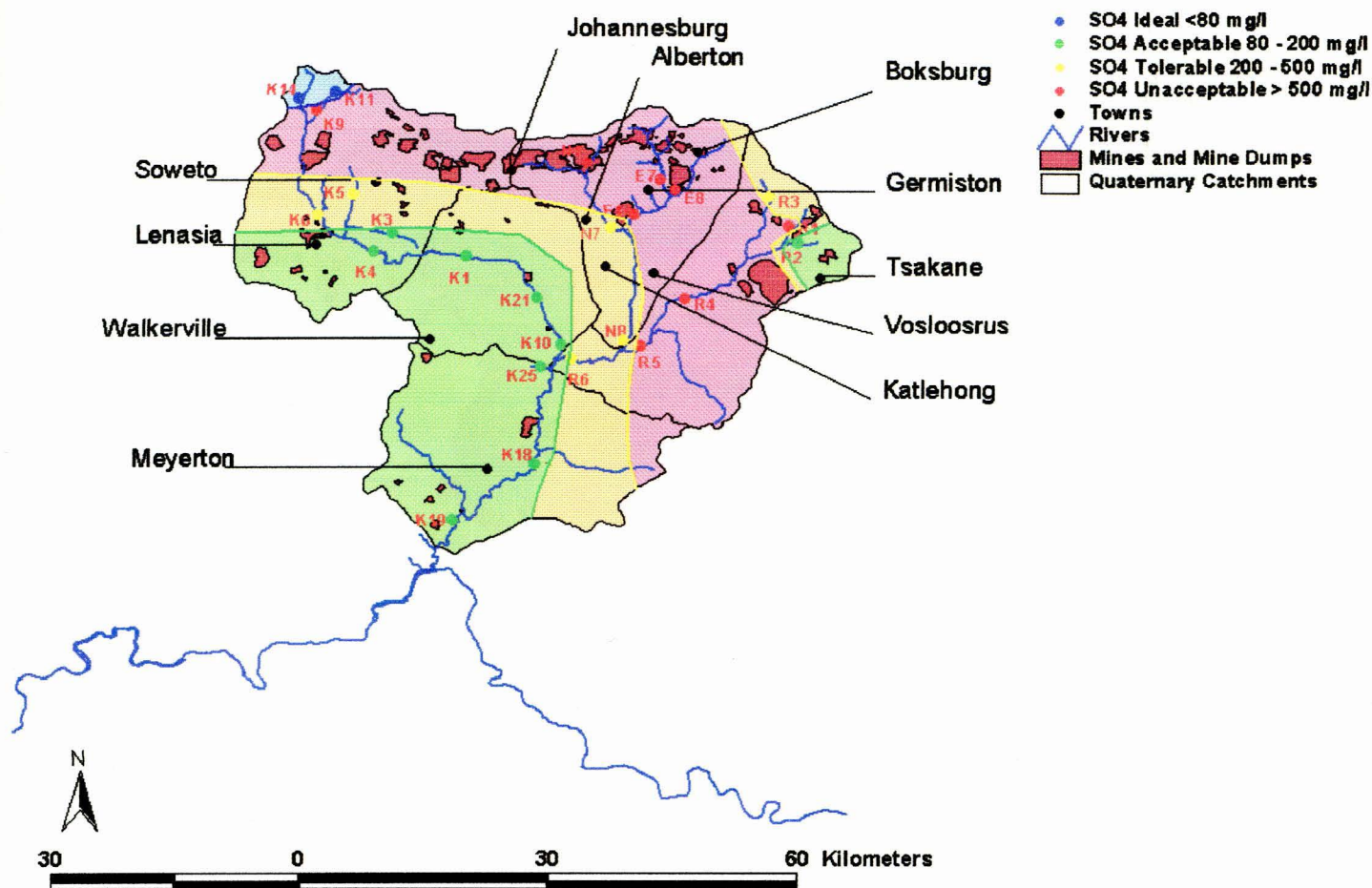


Figure 68:SO₄ variance throughout the Klip River catchment.

B: Sewage works and Commercial farming

Sodium (Na)

Figure 69 represents the Na variance throughout the catchment (coloured coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). Sodium compounds are found in certain fat soaps and fertilisers. As can be seen the Na values are within the Ideal ranges at the headwaters of the Klip River and deteriorate to an Acceptable and Tolerable ranges in the southeastern portions of the catchment. As Na is found in soaps as well as fertilisers, this increase in Na can be attributed to use of fertilisers on farms in the southern catchment as well as from wastewater effluent from treatment works.

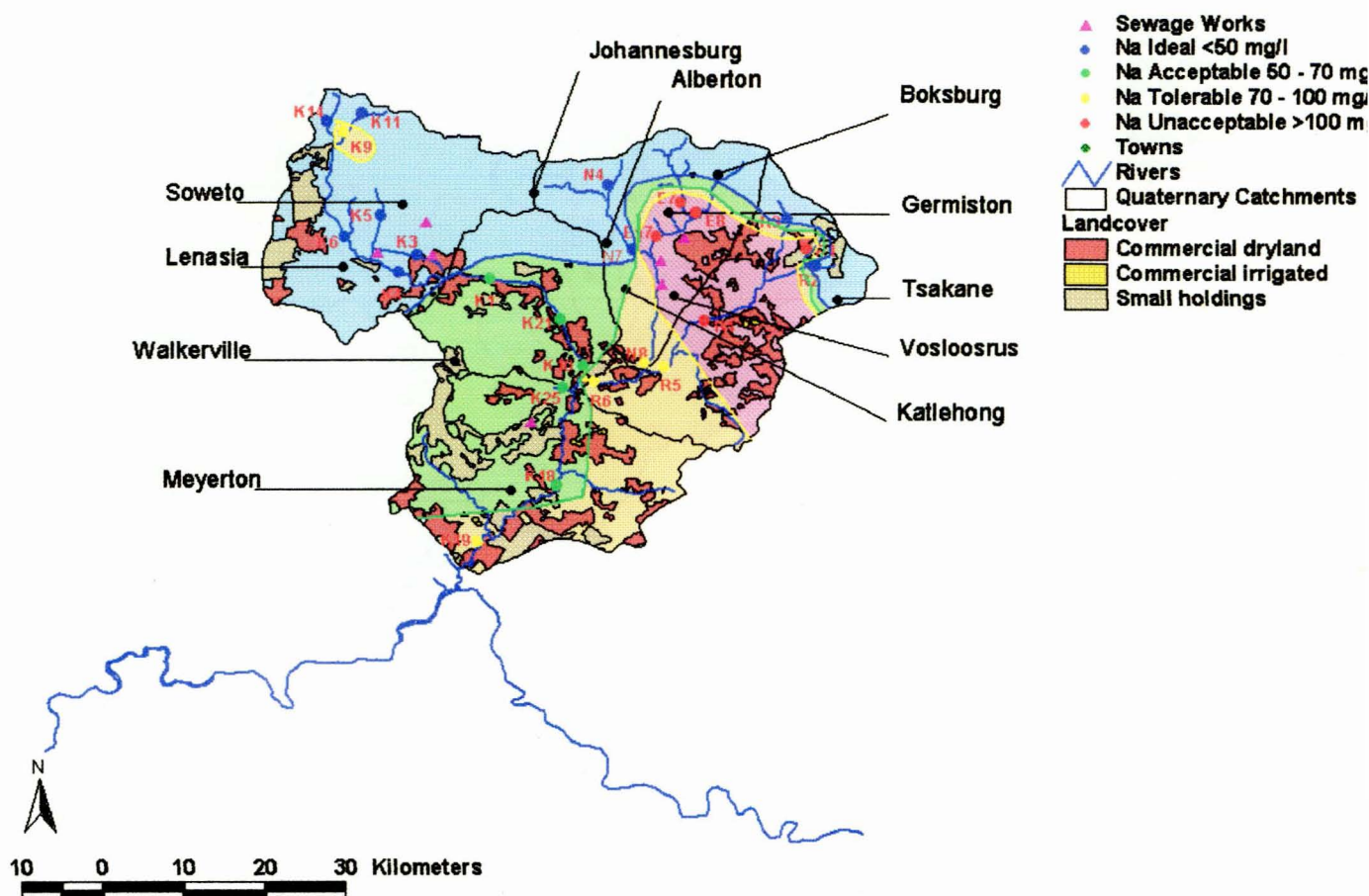


Figure 69: Na variance throughout the Klip River catchment.

Ammonia (NH_4)

Figure 70 represents the NH_4 variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). The largest amount of NH_4 is produced naturally in soil by bacteria, decaying plants and animals, and animal wastes. NH_4 is converted biologically to other forms of nitrogen (NO_3 or N_2). NH_4 thus provides a key building block for algae - nitrogen. The NH_4 values are within the Ideal and Acceptable ranges throughout most of the catchment. High NH_4 values occur at K9, R1 and R3 (mining and industrial areas). The cause of this is unclear and is being investigated.

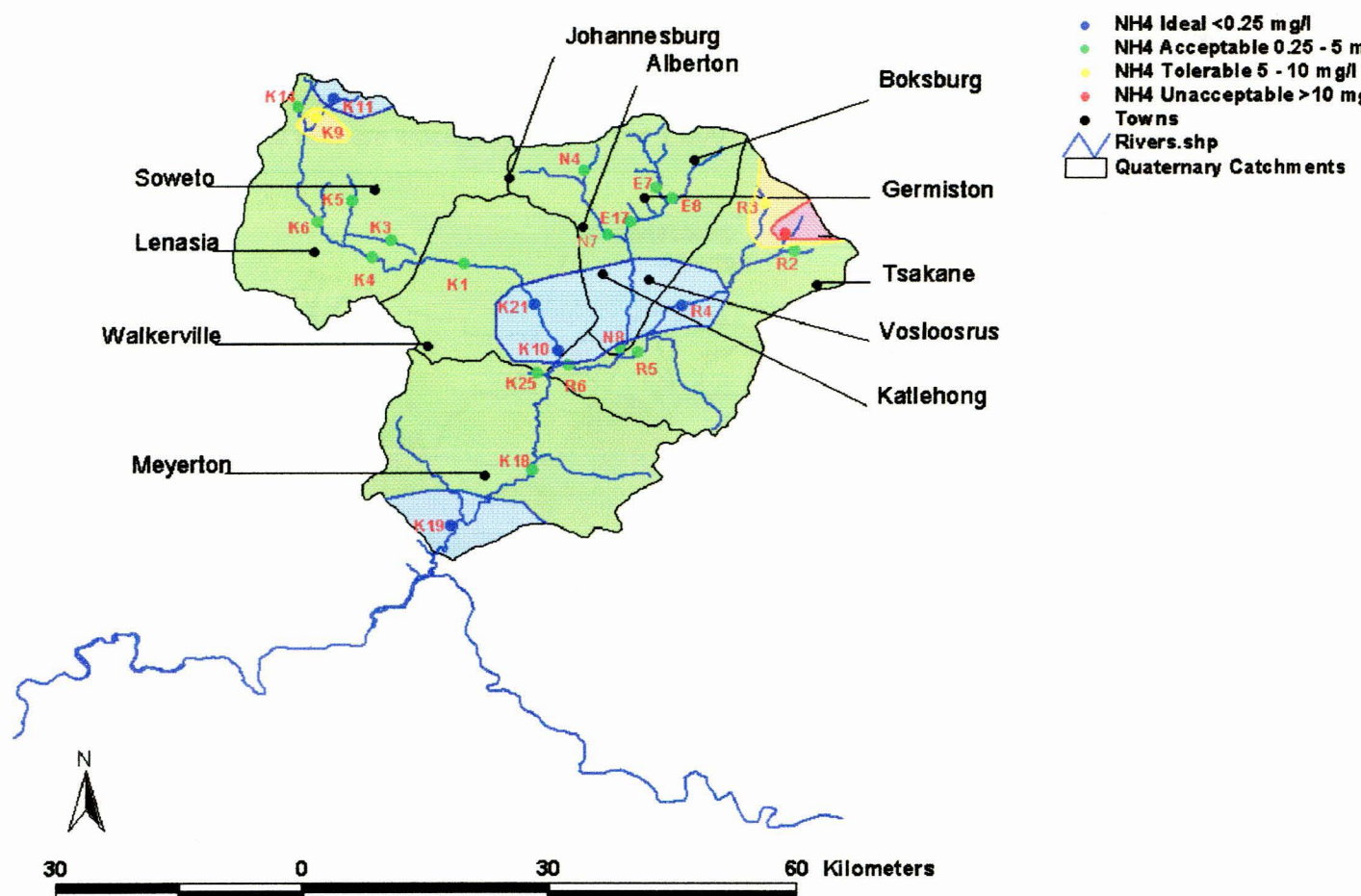


Figure 70: NH₄ variance throughout the Klip River catchment.

Faecal Coliforms

Figure 71 represents the Faecal Coliform variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). Faecal coliforms are bacteria mainly associated with the colon of animals (including humans) and which are excreted in faeces. Some of the bacteria and other pathogens associated with faecal coliforms can have serious implications for human health. Their presence in water is therefore used as a broad indicator of the extent of water contamination by faecal material. Faecal coliforms are not monitored at all of the Rand Water sample points as can be seen in the Figure 71. The reason for monitoring of Faecal coliforms not taking place at all the sample points is due to the high cost and time of analysis. Where Faecal coliforms are monitored however, the values are all in the Unacceptable range. This indicates either that the sewage works are not adequately removing Faecal contamination from wastewater or that a number of leaks are occurring

from sewage pipes and informal settlements in the area. It is known that sewage pipe manhole covers are being removed from the lines near sample point R5. As Faecal coliforms will never reach an Ideal range (< 10 counts/100ml) within nature, it may be a good idea to change the ranges to start at higher values and include a fifth range to indicate values that are extremely high (over 1 000 000 counts/100ml).

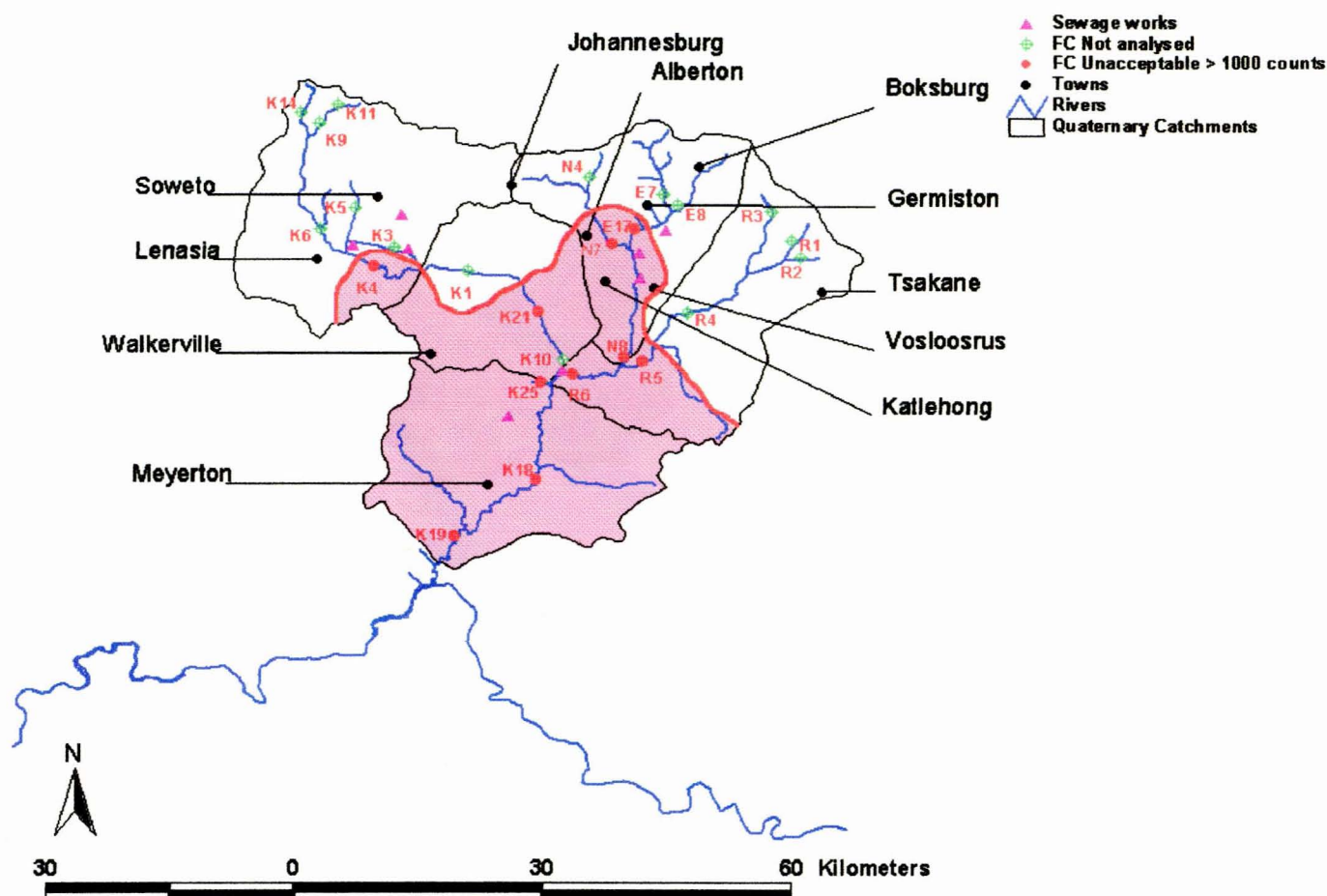


Figure 71: Faecal Coliform variance throughout the Klip River catchment.

Nitrate (NO₃)

Figure 72 represents the NO₃ variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). NO₃ enters rivers from sewage works as well as through over application of fertilisers. The principal harm caused by high NO₃ levels is that of 'eutrophication'- the over-enrichment of water resulting in undesirable ecological changes. As can be seen the NO₃ values are within the Ideal ranges at the headwaters of the Klip River and deteriorate to a Tolerable range as one moves downstream. This is due to a number of sewage works

along the Klip River as well as an increase in agricultural lands, which most likely use fertilizers, as one moves south along the river.

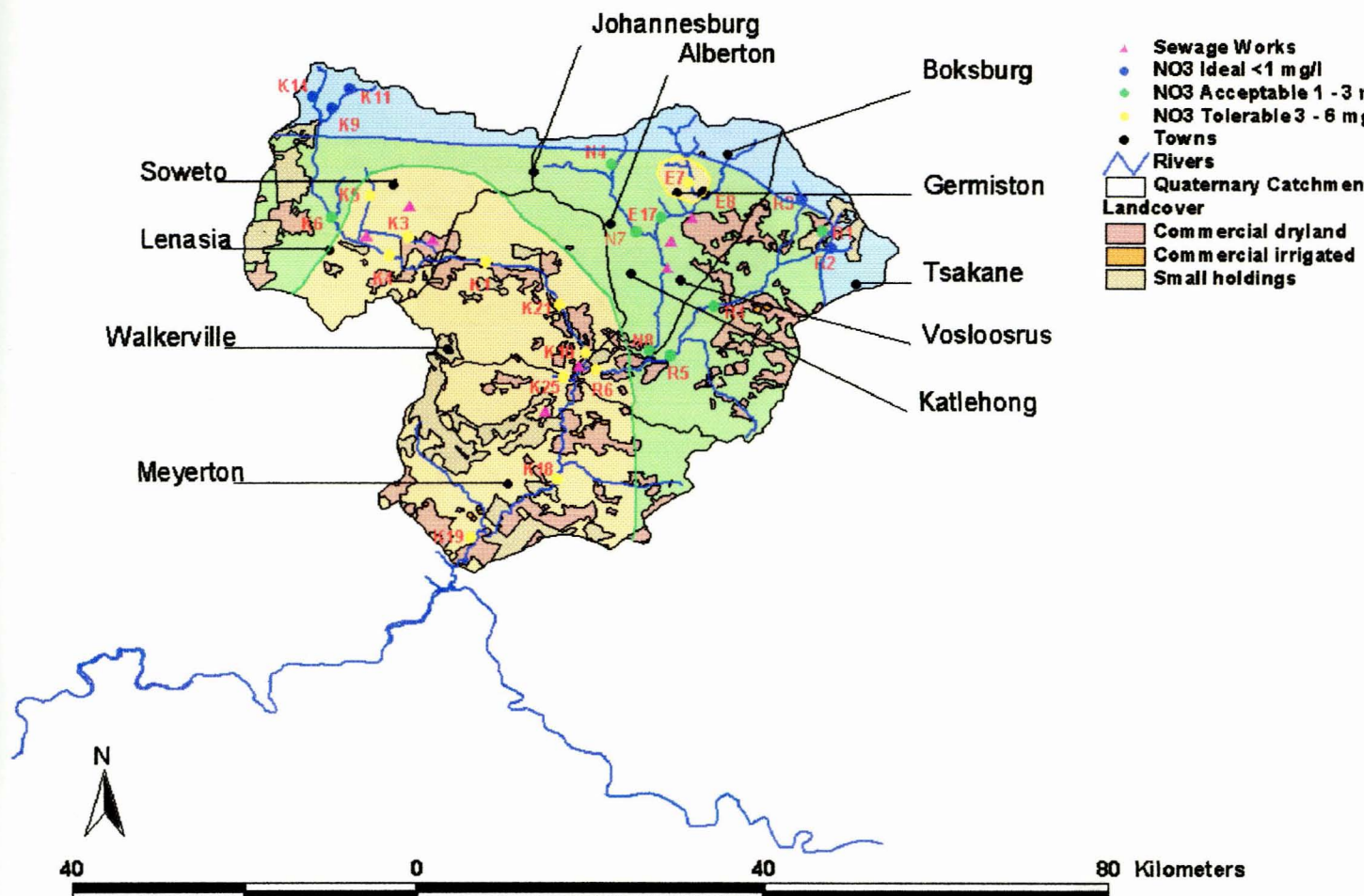


Figure 72: NO₃ variance throughout the Klip River catchment.

Phosphate (PO₄)

Figure 73 represents the PO₄ variance throughout the catchment (colour coded according to the water quality objectives as set up and used by the Klip River forum (Appendix 4)). High phosphate concentrations in surface waters may indicate fertilizer runoff, domestic waste discharge, or the presence of industrial effluents or detergents. As can be seen the PO₄ values are within the Ideal ranges at the headwaters of the Klip River and deteriorate as one moves downstream. The concentrations of PO₄ increase downstream of many of the sewage works within the area and within areas of commercial farming lands.

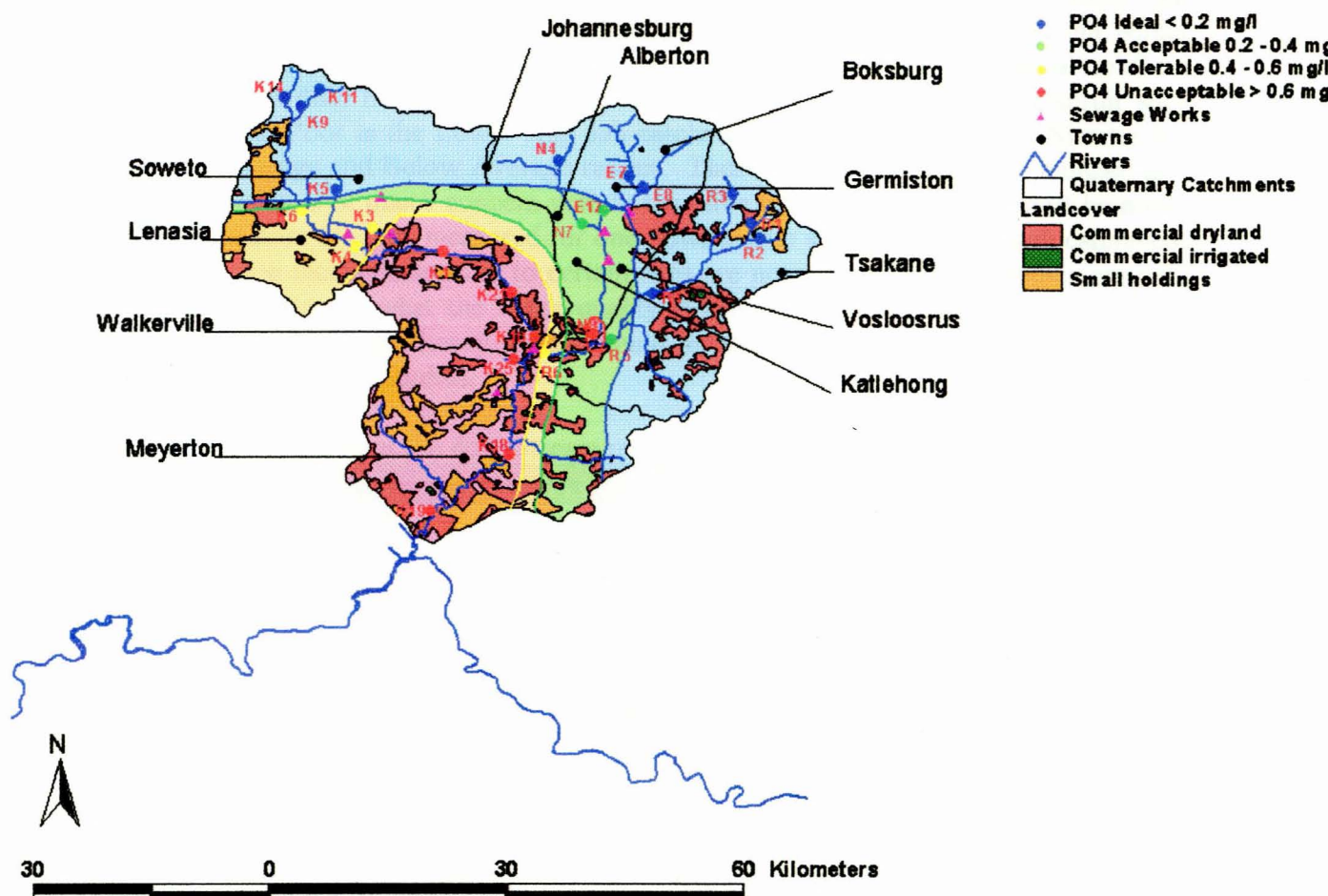


Figure 73: PO₄ variance throughout the Klip River catchment.

Discussion

From the preceding discussions and figures a few interesting points arise. K11 and K14 are almost always in the Ideal range – this is due to the fact that they are close to the headwaters of the Klip River and have as yet not received much contamination. K9 is almost always in the Unacceptable ranges. This sample point is situated in a run-off stream from old mining land and thus contains all pollutants commonly associated with mining.

It was decided by Mzuri Consultants that five water quality variables were to be used to rate a catchment. These are Conductivity (Table 38), Chemical Oxygen Demand (Table 39), Faecal Coliforms (Table 40), Phosphates (Table 41) and Nitrates (Table 42). The ranges on these tables do not compare with the reporting ranges as specified by the Klip

River Forum. What can be noted is that none of the variables for the sub-catchments fall within the Excellent range. The Conductivity and Chemical Oxygen demand fall within the Average or Above Average ranges in all three sub-catchments. The Faecal coliform pollution falls within the Below Average range in the Upper Klip and Rietspruit sub-catchments and Poor in the Lower Klip sub-catchment. The Phosphates and Nitrates fall within the Average and Below Average ranges. These last three variables all indicate that sewage pollution is of major concern with in the three sub-catchments. It must be noted that the indicators are only measured for one downstream sample point in each catchment – thus pollution incidents specific to certain sites are not picked up. The indicators only give a general idea of what the water quality is leaving each sub-catchment. Variables such as Sulphate, pH and heavy metals would indicate pollution from mining and could thus be included in later studies.

Table 38: Conductivity at the downstream point (mS/m)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>240	121-240	71-120	31-70	0-30
Rietspruit	>240	121-240	71-120	31-70	0-30
Lower Klip	>240	121-240	71-120	31-70	0-30

Table 39: Chemical Oxygen Demand at the downstream point (mg/l)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>75	51-75	31-50	11.0 - 30	0-10
Rietspruit	>75	51-75	31-50	11.0 - 30	0-10
Lower Klip	>75	51-75	31-50	11.0 - 30	0-10

Table 40: Faecal coliforms at the downstream point (counts/100ml)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>10000	4001-10000	1001-4000	131-1000	0-130
Rietspruit	>10000	4001-10000	1001-4000	131-1000	0-130
Lower Klip	>10000	4000-10000	1001-4000	131-1000	0-130

Table 41: Phosphates at the downstream point (mg/l)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10
Rietspruit	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10
Lower Klip	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10

Table 42: Nitrates at the downstream point (mg/l)

	Poor	Below Avg.	Average	Above Avg.	Excellent
Upper Klip	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0
Rietspruit	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0
Lower Klip	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0

2.6 Management and Institutional Status

2.6.1 Water management areas

The Klip River catchment falls within the Upper Vaal Management area (Government notice 1697, as published in the government gazette 19641, December 31, 1998). The Klip River Forum has been established for this area as part of the CMA structure. The forum meets quarterly and has a charter in place as part of the CMA requirements. The Klip River Forum Management Committee governs the activities of the forum and consists of elected members from the communities, industries, service providers and government institutions within the area. The Klip River Forum and its elected FMC fall under the Vaal Barrage catchment Executive Committee that in turn will lead to the formation of the Upper Vaal CMA. The CEC members are representatives from the various FMC's within the entire Vaal Barrage catchment area. The Upper Vaal CMA is not yet in existence but a Reference Group does exist for the area. The members of this Reference Group are representatives from the three CEC's in the entire Upper Vaal Catchment. Figure 74 is a diagrammatic representation of how the Klip River Forum and its associated FMC fit into the Upper Vaal Structure.

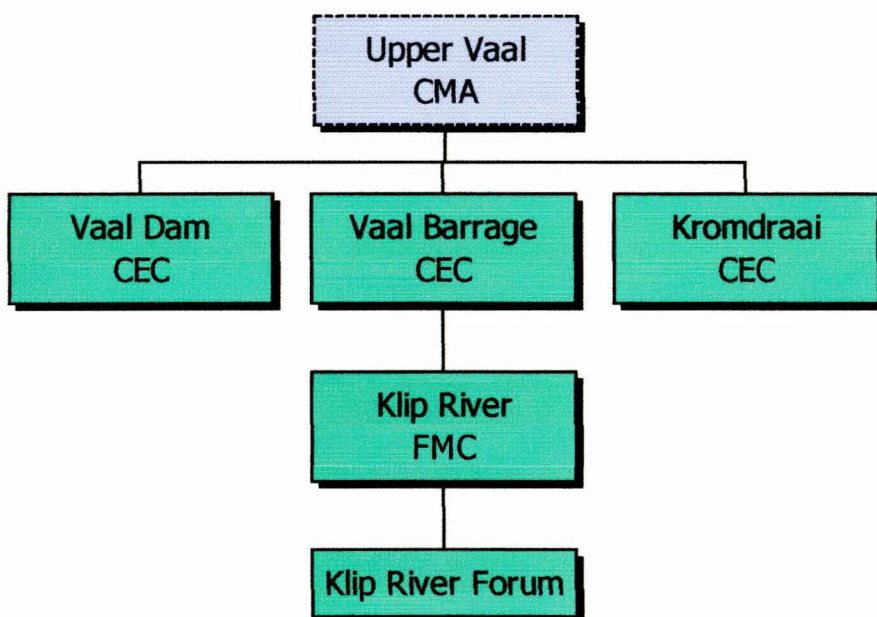


Figure 74: Diagrammatic representation of the Upper Vaal management structure.

2.6.2 Service providers

The service providers in the Klip river catchment include:

- ERWAT for bulk sanitation.
- Local municipalities such as Johannesburg and Meyerton for local potable water supply and sanitation.
- Rand Water for bulk potable water supply.

Government representatives include officials from Gauteng South Department of Water Affairs and Forestry (DWAF), Gauteng Department of Agriculture, Conservation, Environment and Land (GDACEL), Department of Environment and Tourism (DEAT) and Department of Minerals and Energy (DME).

3. CATCHMENT ANALYSIS AND MANAGEMENT RECOMMENDATIONS

3.1 Catchment analysis

The Klip River catchment is highly altered due to mining, urban, industrial and agricultural development. These developments have significantly altered the water level and flow regime of the Klip River as well as its water quality and stream morphology. All of these effects have impacts on the beneficial use of the Klip River itself and on the downstream users of the Vaal Barrage into which the Klip River flows. Summarised below are the Catchment Diagnostic Indicators for each of the three sub-catchments.

Upper Klip sub-catchment

Table 43 indicates that the CDIX Value for the Upper Klip sub-catchment is 62 out of a maximum possible score of 124. This gives a percentage score of 50. This percentage score can now be compared with other sub-catchment or catchment scores to find out how the sub-catchment compares. The value of 62 is obtained by adding the score for each indicator used. This score is the sum of multiplying the number of indicators that fall in the Excellent range by 4, Above Average by 3, Average by 2, Below Average by 1 and Poor by 0. This score is then divided by the maximum score – which would imply that all the indicators fell in the Excellent range (Total indicators x 4 = 31 x 4 = 124). Areas of concern are Water Quantity and Socio-Economics as they have more than half of the indicators falling in the zero (Poor) score category. Water Quality is also a concern as more than half of its indicators are within the one (Below Average) score category.

Table 43: Summarised CDIX values for the Upper Klip sub-catchment

Indicator	Rating					Total 1999
	Poor (0)	Below Average (1)	Average (2)	Above Average (3)	Excellent (4)	
Resource Condition						
7 Indicators	1		2		4	20
Socio-Economic						
10 Indicators	4	1			5	21
Water Quantity						
3 Indicators	3					0
Water Quality						
9 Indicators		5	1	3		16
Management						
2 Indicators			1	1		5
Total Score						62
Total Percentage (Total/124)						50%

Rietspruit sub-catchment

Table 44 indicates that the CDIX Value for the Rietspruit sub-catchment is 64 out of a maximum possible score of 124. This gives a percentage score of 51.61. The area of concern is Water Quantity as all the indicators fall in the zero (Poor) score category. Water Quality and Socio-Economics are also a concern as half of these indicators are within the one (Below Average) score and zero (Poor) score category.

Table 44: CDIX Value for the Rietspruit sub-catchment

Indicator	Rating					Total 1999
	Poor (0)	Below Average (1)	Average (2)	Above Average (3)	Excellent (4)	
Resource Condition						
7 Indicators	1	1			5	21
Socio-Economic						
10 Indicators	2	3		1	4	22
Water Quantity						
3 Indicators	3					0
Water Quality						
9 Indicators		4	4	1		15
Management						
2 Indicators			1		1	6
Total Score						64
Total Percentage (Total/124)						51.61%

Lower Klip sub-catchment

Table 45 indicates that the CDIX Value for the Lower Klip sub-Catchment is 62 out of a maximum possible score of 124. This gives a percentage score of 50. The areas of concern are Resource conditions Water Quantity as all the indicators fall in the zero (Poor) score category. Water Quality and Socio-Economics are also a concern as half of these indicators are within the one (Below Average) score and zero (Poor) score category.

Table 45: CDIX Value for the Lower Klip River Sub-Catchment

Indicator	Rating					Total 1999
	Poor (0)	Below Average (1)	Average (2)	Above Average (3)	Excellent (4)	
Resource Condition						
7 Indicators	2	2			3	14
Socio-Economic						
10 Indicators	1	3		2	4	25
Water Quantity						
3 Indicators	2				1	4
Water Quality						
9 Indicators	1	4	2	1	1	15
Management						
2 Indicators			2			4
Total Score						62
Total Percentage (Total/124)						50%

Mining

Mining has caused a number of impacts within the Klip River catchment. The reclamation of the mine dumps within the area causes water and dust pollution. Jets of water blast old tailings dams in order to make slurry, which can be processed. Water from this jetting process as well as from the slurry makes its way into nearby streams. This water is contaminated with heavy metals such as Iron and sulphates. The Suspended Solid concentrations in this water are extremely high and the pH is very low (acidic). The main variables indicating mining pollution within watercourses include pH, conductivity, Iron (Fe) and sulphates (SO₄). Acid Mine Drainage (AMD) is occurring throughout the area. AMD is found in areas close to tailing dams as hydrous ferric and ferrous sulphates salts (efflorescence) which are dissolved by water that flows over the surface of the tailing dams. Groundwater from old mine workings is also extremely polluted with sulphates, heavy metals and can be very acidic.

Particles blown by the wind off un-vegetated dumps in the area causes air pollution. Dust clouds over many of the dumps within the area are a common sight in windy months.

Other impacts include:

- radon gas released from bore holes and evaporation ponds
- failure of pipes and pond liners that cause spillages to soil and water.

Urban

Increased population growth leads to an increase in poverty, informal settlements and environmental degradation. Various pressures impact on the land, including the lack of services and a lack of space and housing, forcing more people to live within the 1:50 year flood line. This also means that more vegetation is removed for housing and cooking. The loss of protective vegetation through ploughing, overgrazing and fire makes soil vulnerable to being swept away by wind and water.

From the above discussions it can clearly be seen that humans have the greatest impact on the catchment area.

Urban run-off is another issue that impacts the catchment. This is when rainwater collects on paved surfaces in urban areas instead of sinking into the ground. This water is generally very polluted in terms of collected oil and litter. This polluted water enters storm-water drains and eventually ends up in rivers. The larger the paved urban areas, the greater the problem.

Sewage pollution

Associated with pollution from urban areas is sewage pollution. The sewage works within the area are not designed with adequate capacity to fully treat the raw sewage or they are not functioning properly. This then leads to the discharge of partially or untreated sewage entering the river systems.

There are also a large number of informal settlements with no sewage facilities at all. If chemical toilets are in use, these are often not cleaned regularly and the raw sewage ends up in rivers. In other areas, rivers are used for washing and as toilet facilities. These factors lead to the spreading of water borne diseases such as cholera. The main variables indicating sewage pollution include Faecal coliforms, NO_3 and PO_4 .

Agriculture

Agricultural practices can lead to a number of problems in the area. Erosion of exposed soil leads to the loss of nutrient-rich layers and few plants will grow in the soil again. Over-cultivation and over-irrigation can lead to either salinisation or water logging. If the irrigated area is subject to heavy soil-water losses through evapotranspiration, the salts in the water remain in the soil, causing salinisation. If infiltration of large volumes of water occurs, a rise in the water table may occur and the zone of saturation may be brought closer to the surface, causing the soil to be waterlogged. Excessive groundwater withdrawal for irrigation may lead to land subsidence.

Another issue is contamination of surface and ground water by the application of fertilizers. Fertilizers contain compounds such as Phosphates (PO_4), Nitrates (NO_3) and Ammonia (NH_4). These compounds enter the watercourses and lead to fish kills as well

as the proliferation of algae growth, which in turn leads to further pollution. These compounds can also increase the salinity of watercourses.

Industry

Currently there is very little monitoring of industrial effluent by authorities. Industries do however have to comply with standards laid out in discharge permits issued by Department of Water Affairs and Forestry. Of concern though are the electroplating industries that discharge heavy metals in their effluents. These heavy metals either end up in storm water channels and rivers or in sewage works where they can't be removed. It is believed that a large amount of unmonitored pollution is occurring within the catchment area.

Aquatic Ecosystems

The aquatic ecosystems within the Klip River catchment are severely impacted. The unnaturally high flow occurring all year is probably the most important negative impact on the physical habitat condition of the catchment. Effluents originating from the sewage works and urban runoff are responsible for this unnatural high flow. The unnatural high flow is also responsible for increased bank erosion and slight modification of the channel due to scouring of the banks. Informal housing and other human activities in the riparian zone are responsible for the removal of indigenous vegetation and the resulting encroachment by exotics. The poor water quality within the rivers also negatively affect the aquatic life.

3.2 Management Recommendations

Information gaps

Limited information is available of the groundwater status of the Klip river catchment. Detailed geohydrological information for the entire catchment is lacking and would be required to assess the current groundwater situation. No central borehole information source exists. This means that even though data may exist it can't be used, as it is not accessible.

There is no co-ordination between various role-players within the catchment that do monitoring of river water quality. Sampling frequency and analysis varies from organisation to organisation and duplication of monitoring points often occurs. Water quality and flow data is also not always available from organisations that do the monitoring.

The frequency of sampling and data collection should be as high as possible. Sampling and flow gauging stations should be extended to fill gaps in the existing information of the catchment. Industries, mines and sewage works should be required to provide monitoring data from their own compliance monitoring stations.

Indicator/CDF shortfalls

With the Health-related index for potable water, no Giardia or Total Residual chlorine values were available. These aspects need to be included in monitoring to get a correct indicator status.

Indicator results are calculated for downstream points only. The catchment may well score even lower if certain areas were looked at specifically. There is very poor water quality in the upper reaches of the Upper Klip, Klipspruit and Rietspruit due to mining activities but these impacts are not picked up by the indicators due to large volumes of water from sewage works diluting pollution further downstream.

Industries are not specifically looked at in the CDF indicators. Heavy metals are not incorporated in any of the indices. This needs to be looked at in future studies. Other issues that need to be dealt with in future studies are groundwater and the impact of agricultural chemicals on surface and groundwater quality.

General

Ranges of what is considered Ideal, Acceptable, Tolerable and Unacceptable need to be re-examined in order to obtain useful information from the classifications. Faecal coliform results always fall within the Unacceptable range. A fifth range can be added which indicate values that are extremely high (over 1 000 000 counts/100ml). As Faecal coliforms will never reach an Ideal range (< 10 counts/100ml) within nature, it may be a good idea to change the ranges to start at higher values.

For Mn, the Ideal and Acceptable ranges fall below detection limits on the analysis instruments. These limits thus need to be adjusted. The background concentrations of Mn within the Klip river catchment are already naturally high and this must also be taken into account when setting up standards and objectives.

The people living in the Klip River catchment should be educated and informed on how they can reduce their impact on the river. Authorities should react with more urgency and react with more power on human activities impacting on the river systems. The Klip River system should not be allowed to deteriorate further, and an attempt should be made to improve it where possible.

4. APPENDICES

Appendix 1

Tables 46 – 48 are a summary of the Indicators for the Upper Klip, Rietspruit and Lower Klip sub-catchments.

Table 46: Indicators included in the prototype CDIX for the Upper Klip sub-catchment.

INDICATOR	RATING SYSTEM				
	Poor	Below Avg.	Average	Above Avg.	Excellent
RESOURCE CONDITION					
1. DWAF Reservoir capacity as a percentage of total water available (%)	> 100	70 - 100	41 - 70	21 - 40	0 - 20
2. Integrity of the indigenous fish species assemblage (%)	0-39	40-59	60-79	80-89	90-100
3. TSS loading at the downstream point as a percentage of catchment sediment yield (%)	81-100	61-80	41-60	21-40	0-20
4. Percentage of DWAF reservoirs with chlorophyll a exceeding 30ug/l (%)	81 - 100	61 - 80	41 - 60	21 - 40	0-20
5. Algal Growth Potential at the downstream point (mg/l)	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0
6. SASS4 at the downstream point (SASS4 score; ASPT)	SASS4 < 60 ASPT < 3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT 3-5	SASS4 100-140 ASPT 5-7	SASS4 > 140 ASPT > 7
7. Daphnia toxicity test at the downstream point (% survival)	<60	61-70	71-80	81-90	91-100
SOCIO-ECONOMIC					
8. Population Density (no./km ²)	>200	101-200	51-100	11.0 - 50	0-10
9. Urbanisation (%)	80-100	61-80	31-60	11.0 - 30	0-10
10. Catchment population as a proportion of the maximum sustainable population (%)	0-20	21-40	41-60	61-80	>80

11. Proportions of households earning <R6 000 per annum (%)	56-100	41-55	31-40	21-30	0-20
12. Households without access to piped water on site (%)	51-100	31-50	21-30	11.0 - 20	0-10
13. Households without access to toilet facilities (%)	85-100	56-84	41-55	21-40	0-20
14. Water Services Index (score)	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
15. Sanitation Service Index (score)	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
16. Health-Related Index for potable water (% score)	≤ 60	61-70	71-80	81-90	91-100
17. Recreational Index for raw water (% score)	≤ 65	66-75	76-85	86-90	91-100
WATER QUANTITY					
18. Total water available per capita (m ³ /cap/annum)	0-500	501-1000	1001-1500	1501-2000	>2000
19. Anthropogenic supply as a proportion of total supply (%)	> 80	61-80	41-60	21-40	0-20
20. Change in flow at downstream point (% difference from MAR)	> 80	61-80	41-60	21-40	0-20
WATER QUALITY					
21. Conductivity at the downstream point (mS/m)	>240	121-240	71-120	31-70	0-30
22. Chemical Oxygen Demand at the downstream point (mg/l)	>75	51-75	31-50	11.0 - 30	0-10
23. Faecal coliforms at the downstream point (counts/100ml)	>10000	4001-10000	1001-4000	131-1000	0-130

24. Phosphates at the downstream point (mg/l)	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10
25. Nitrates at the downstream point (mg/l)	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0
26. Total liquid waste discharged as a proportion of total water available (%)	>70	46-70	31-45	16-30	0-15
27. Hydraulic Capacity Index of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
28. Organic Load Capacity of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
29. Effluent Compliance Index of Water Care Works (%)	0	>0 - 33	>33 - 66	>66 - <100	100
MANAGEMENT					
30. Number of active hydrological monitoring stations (no./100km ²)	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60
31. Number of water quality monitoring stations (no./100km ²)	0	0.01-0.3	0.31-0.60	0.61-1.2	>1.2

Table 47: Indicators included in the prototype CDIX for the Rietspruit sub-catchment.

INDICATOR	RATING SYSTEM				
	Poor	Below Avg.	Average	Above Avg.	Excellent
RESOURCE CONDITION					
1. DWAF Reservoir capacity as a percentage of total water available (%)	> 100	70 - 100	41 - 70	21 - 40	0 - 20
2. Integrity of the indigenous fish species assemblage (%)	0-39	40-59	60-79	80-89	90-100
3. TSS loading at the downstream point as a percentage of catchment sediment yield (%)	81-100	61-80	41-60	21-40	0-20

4. Percentage of DWAF reservoirs with chlorophyll a exceeding 30ug/l(%)	> 80	61 – 80	41 - 60	21 - 40	0-20
5. Algal Growth Potential at the downstream point (mg/l)	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0
6. SASS4 at the downstream point (SASS4 score; ASPT)	SASS4<60 ASPT <3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT3-5	SASS4 100-140 ASPT 5-7	SASS4>140 ASPT>7
7. Daphnia toxicity test at the downstream point (% survival)	<60	61-70	71-80	81-90	91-100
SOCIO-ECONOMIC					
8. Population Density (no./km ²)	>200	101-200	51-100	11.0 - 50	0-10
9. Urbanisation (%)	80-100	61-80	31-60	11.0 - 30	0-10
10. Catchment population as a proportion of the maximum sustainable population (%)	0-20	21-40	41-60	61-80	>80
11. Proportions of households earning <R6 000 per annum (%)	56-100	41-55	31-40	21-30	0-20
12. Households without access to piped water on site (%)	51-100	31-50	21-30	11.0 - 20	0-10
13. Households without access to toilet facilities (%)	85-100	56-84	41-55	21-40	0-20
14. Water Services Index (score)	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
15. Sanitation Services Index (score)	1 - 1.6	1.6 - 2.2	2.2 - 2.8	2.8 - 3.4	3.4 - 4.0
16. Health-Related Index for potable water (% score)	≤ 60	61-70	71-80	81-90	91-100
17. Recreational Index for raw water (% score)	≤ 65	66-75	76-85	86-90	91-100

WATER QUANTITY					
18. Total water available per capita (m ³ /cap/annum)	0-500	501-1000	1001-1500	1501-2000	>2000
19. Anthropogenic supply as a proportion of total supply (%)	> 80	61-80	41-60	21-40	0-20
20. Change in flow at downstream point (% difference from MAR)	> 80	61-80	41-60	21-40	0-20
WATER QUALITY					
21. Conductivity at the downstream point (mS/m)	>240	121-240	71-120	31-70	0-30
22. Chemical Oxygen Demand at the downstream point (mg/l)	>75	51-75	31-50	11-30	0-10
23. Faecal coliforms at the downstream point (counts/100ml)	>10000	4001-10000	1001-4000	131-1000	0-130
24. Phosphates at the downstream point (mg/l)	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10
25. Nitrates at the downstream point (mg/l)	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0
26. Total liquid waste discharged as a proportion of total water available (%)	>70	46-70	31-45	16-30	0-15
27. Hydraulic Capacity Index of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
28. Organic Load Capacity of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
29. Effluent Compliance Index of Water Care Works (%)	0	>0 - 33	>33 - 66	>66 - <100	100
MANAGEMENT					
30. Number of active hydrological monitoring stations (no./100km ²)	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60

31. Number of water quality monitoring stations (no./100km ²)	0	0.01-0.3	0.31-0.60	0.61-1.2	> 1.2
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Table 48: Indicators included in the prototype CDIX for the Lower Klip sub-catchment.

INDICATOR	RATING SYSTEM				
	Poor	Below Avg.	Average	Above Avg.	Excellent
RESOURCE CONDITION					
1. DWAF Reservoir capacity as a percentage of total water available (%)	> 100	70 - 100	41 - 70	21 - 40	0 - 20
2. Integrity of the indigenous fish species assemblage (%)	0-39	40-59	60-79	80-89	90-100
3. TSS loading at the downstream point as a percentage of catchment sediment yield (%)	81-100	61-80	41-60	21-40	0-20
4. Percentage of DWAF reservoirs with chlorophyll a exceeding 30ug/l(%)	> 80	61 - 80	41 - 60	21 - 40	0-20
5. Algal Growth Potential at the downstream point (mg/l)	>100.0	75.1-100.0	50.1-75.0	25.1-50.0	0-25.0
6. SASS4 at the downstream point (SASS4 score; ASPT)	SASS4 <60 ASPT <3	SASS4 60-80 ASPT 3-5	SASS4 80-100 ASPT3-5	SASS4 100-140 ASPT 5-7	SASS4>140 ASPT>7
7. Daphnia toxicity test at the downstream point (% survival)	<60	61-70	71-80	81-90	91-100
SOCIO-ECONOMIC					
8. Population Density (no./km ²)	>200	101-200	51-100	11.0 - 50	0-10
9. Urbanisation (%)	80-100	61-80	31-60	11.0 - 30	0-10
10. Catchment population as a proportion of the maximum sustainable population(%)	0-20	21-40	41-60	61-80	>80

11. Proportions of households earning <R6 000 per annum (%)	56-100	41-55	31-40	21-30	0-20
12. Households without access to piped water on site (%)	51-100	31-50	21-30	11.0-20	0-10
13. Households without access to toilet facilities (%)	85-100	56-84	41-55	21-40	0-20
14. Water Services Index (score)	1-1.6	1.6-2.2	2.2-2.8	2.8-3.4	3.4-4.0
15. Sanitation Services Index (score)	1-1.6	1.6-2.2	2.2-2.8	2.8-3.4	3.4-4.0
16. Health-Related Index for potable water (% score)	≤ 60	61-70	71-80	81-90	91-100
17. Recreational Index for raw water (% score)	≤ 65	66-75	76-85	86-90	91-100
WATER QUANTITY					
18. Total water available per capita (m ³ /cap/annum)	0-500	501-1000	1001-1500	1501-2000	>2000
19. Anthropogenic supply as a proportion of total supply (%)	> 80	61-80	41-60	21-40	0-20
20. Change in flow at downstream point (% difference from MAR)	> 80	61-80	41-60	21-40	0-20
WATER QUALITY					
21. Conductivity at the downstream point (mS/m)	>240	121-240	71-120	31-70	0-30
22. Chemical Oxygen Demand at the downstream point (mg/l)	>75	51-75	31-50	11-30	0-10
23. Faecal coliforms at the downstream point (counts/100ml)	>10000	4000-10000	1001-4000	131-1000	0-130

24. Phosphates at the downstream point (mg/l)	>1.00	0.61-1.00	0.26-0.60	0.11-0.25	0-0.10
25. Nitrates at the downstream point (mg/l)	>10.0	6.1-10.0	3.1-6.0	1.1-3.0	0-1.0
26. Total liquid waste discharged as a proportion of total water available (%)	>70	46-70	31-45	16-30	0-15
27. Hydraulic Capacity Index of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
28. Organic Load Capacity of Water Care Works (%)	>100	>75 - 100	75	50 - <75	0-50
29. Effluent Compliance Index of Water Care Works (%)	0	>0 - 33	>33 - 66	>66 - <100	100
MANAGEMENT					
30. Number of active hydrological monitoring stations (no./100km ²)	0	0.01-0.10	0.11-0.30	0.31-0.60	>0.60
31. Number of water quality monitoring stations (no./100km ²)	0	0.01-0.3	0.31-0.60	0.61-1.2	>1.2

Appendix 2

Table 49 is a summary of the calculations of the various indices used in the text.

Table 49: Calculation of indicators

RESOURCE CONDITION INDICATORS			
1.	DWAF reservoir capacity as a percentage of total water available (%)		
	Description:	Amount of water stored in DWAF-regulated reservoirs in the catchment, as a percentage of total availability of water (%).	
	Formulas:	I ₁ = RC _T / (IBT + MAR) x 100 Where: RC _T = Total reservoir capacity (sum of all DWAF-regulated reservoirs) IBT = Inter-basin transfer (m ³ / a) MAR = Mean annual runoff(m ³ / a).	
	Calculation Upper Klip:	There are no DWAF-regulated reservoirs in the catchment, thus RC _T and I ₁ = 0.	
	Calculation Rietspruit	There are no DWAF-regulated reservoirs in the catchment, thus RC _T and I ₁ = 0.	
	Calculation Lower Klip:	There are no DWAF-regulated reservoirs in the catchment, thus RC _T and I ₁ = 0.	
	Ranking:	0. >100%	
		1. 71-100%	
		2. 41-70%	
	3. 21-40%		
	4. 0-20%		
	Upper Klip	Rietspruit	Lower Klip
	4	4	4
References:	Statistics South Africa, 1999; Tavaras, 2002; Midgley et al., 1994a		
2	Integrity of the indigenous fish species assemblage (%)		
	Description:	The observed fish assemblage integrity (FAII) score as a portion of the expected FAII score expressed as a percentage	
	Formulas:	I ₂ = FAII _{obs} / FAII _{expect} x 100 Where: FAII _{expected} = (T + A + F + H)/4 T = Tolerance rating for individual species A = Expected abundance rating for individual species F = Expected frequency of occurrence rating for individual species H = Expected health of individual species FAII _{obs} = The same as above but obtained during a survey for the time period of the study.	

	Calculation Upper Klip:	$FAII_{expected} = (24.7 + 27 + 11 + 55)/4$ $= 29.43$ $FAII_{obs} = (13.6 + 20.5 + 7.5 + 31.5)/4$ $= 18.28$ $I_2 = FAII_{obs} / FAII_{expected} \times 100$ $= 18.28 / 29.43 \times 100$ $= 62.11$		
	Calculation Rietspruit:	$FAII_{expected} = (24.7 + 11 + 11 + 55)/4$ $= 25.43$ $FAII_{obs} = (10.5 + 8 + 5 + 23.8)/4$ $= 11.83$ $I_2 = FAII_{obs} / FAII_{expected} \times 100$ $= 46.52$		
	Calculation Lower Klip:	$FAII_{expected} = (24.7 + 19 + 11 + 55)/4$ $= 27.43$ $FAII_{obs} = (5.8 + 7 + 2.5 + 7.5)/4$ $= 5.7$ $I_2 = FAII_{obs} / FAII_{expected} \times 100$ $= 20.78$		
	Ranking:	0. 0 – 39% 1. 40 – 59% 2. 60 – 79% 3. 80 – 89% 4. 90 – 100%		
		Upper Klip	Rietspruit	Lower Klip
		2	1	0
	References:	du Preez, 2001; Kotze, 2002		
3	Total Suspended Solids loading at the downstream point as a percentage of catchment sediment yield (%)			
	Description:	Amount of sediment exiting a catchment as a proportion of the expected sediment yield for a pristine catchment (%).		
	Formulas:	$I_3 = L_{TSS} / Y_{se} \times 100$ $L_{TSS} = TSS \times Q_D$ Where: L_{TSS} = TSS loading at the downstream point ($t\ a^{-1}$) Y_{se} = Catchment sediment yield ($t\ a^{-1}$) Q_D = Average annual flow at the downstream point ($m^3\ a^{-1}$). $TSS = 1.2 \times \text{Turbidity}$		

Calculation Upper Klip:	$L_{TSS} = 21 \text{ mg/l} \times 216718020 \text{ m}^3/\text{a}$ $= 21000 \text{ mg/m}^3 \times 216718020 \text{ m}^3/\text{a}$ $= 4549.70 \text{ t/a}$ $TSS = 1.2 \times 17.5$ $= 21 \text{ mg/l}$ $Y_{se} = 32\,000 \text{ t/a}$ $I_3 = 4549.70 \text{ t/a} / 32000 \text{ t/a} \times 100$ $= 14.22$		
Calculation Rietspruit:	$L_{TSS} = 14.64 \text{ mg/l} \times 115106400 \text{ m}^3/\text{a}$ $= 14640 \text{ mg/m}^3 \times 115106400 \text{ m}^3/\text{a}$ $= 1685.16 \text{ t/a}$ $TSS = 1.2 \times 12.2$ $= 14.64 \text{ mg/l}$ $Y_{se} = 29\,000 \text{ t/a}$ $I_3 = 1685.16 \text{ t/a} / 29000 \text{ t/a} \times 100$ $= 5.81$		
Calculation Lower Klip:	$L_{TSS} = 25.2 \text{ mg/l} \times 422582400 \text{ m}^3/\text{a}$ $= 25200 \text{ mg/m}^3 \times 422582400 \text{ m}^3/\text{a}$ $= 10649.08 \text{ t/a}$ $TSS = 1.2 \times 21$ $= 25.2 \text{ mg/l}$ $Y_{se} = 17\,000 \text{ t/a}$ $I_3 = 10649.08 \text{ t/a} / 17000 \text{ t/a} \times 100$ $= 62.64$		
Ranking:	0. 81-100% increase or decrease 1. 61-80% increase or decrease 2. 41-60% increase or decrease 3. 21-40% increase or decrease 4. 0-20% increase or decrease		
	Upper Klip	Rietspruit	Lower Klip
	4	4	1
References:	Midgley et al., 1994a; Rand Water, 2002; CIMDSS, 2002		
4	Percentage of DWAF regulated reservoirs with chlorophyll a exceeding 30 µg/l (%)		
Description:	Proportion of DWAF-regulated reservoirs in a catchment that are unsuitable for any period of the time due to eutrophication (%).		
Formulas:	$I_4 = R_{>30} / R_T \times 100$ Where: $R_{>30}$ = Reservoirs with chl a > 30 µg/ for any period of time. R_T = Total number of reservoirs.		
Calculation Upper Klip:	There are no DWAF-regulated reservoirs in the catchment, thus $R_{>30}$ and $I_4 = 0$.		
Calculation Rietspruit:	There are no DWAF-regulated reservoirs in the catchment, thus $R_{>30}$ and $I_4 = 0$.		

	Calculation Lower Klip:	There are no DWAF-regulated reservoirs in the catchment, thus $R_{>30}$ and $I_4 = 0$.		
	Ranking:	0. 81-100% 1. 61-80% 2. 41-60% 3. 21-40% 4. 0-20%.		
		Upper Klip	Rietspruit	Lower Klip
		4	4	4
	References:	Statistics South Africa, 1999		
5	Algal Growth Potential at the downstream point (mg/l)			
	Description:	Mean algal growth potential (AGP) at the downstream point, measured over a year (mg/l).		
	Formulas:	Standard methods are used to determine the AGP of a sample. These are expressed as a dry weight, mg/l. The number of algal cells can be expressed as dry mass (mg) by using the following expression: Dry mass (mg) of one cell (Euglena) = 8.27×10^{-7}		
	Calculation Upper Klip:	$8190.8 \text{ cells} \times 8.27 \times 10^{-7}$ = 0.07		
	Calculation Rietspruit:	$1440 \text{ cells} \times 8.27 \times 10^{-7}$ = 0.01		
	Calculation Lower Klip:	$6605.4 \text{ cells} \times 8.27 \times 10^{-7}$ = 0.05		
	Ranking:	0. > 100 mg/l 1. 75,1-100 mg/l 2. 50,1-75 mg/l 3. 25,1-50 mg/l 4. > 25 mg/l		
		Upper Klip	Rietspruit	Lower Klip
		4	4	4
	References:	du Preez, 2001; Kotze, 2002		
6	SASS4 at the downstream point (SASS4 score; ASPT)			
	Description:	Invertebrate fauna measured using the South African Scoring System (Version 4) (SASS4 and ASPT, average score per taxon) at the downstream point.		
	Formulas:	The data collected are presented as two scores, the SASS score which reflects the sum of the values assigned to the invertebrate families present, and the ASPT (average score per taxon), which is calculated by dividing the SASS score by the number of taxa.		
	Calculation Upper Klip:	SASS4 average = 53.25 ASPT average = 4.43		

Calculation Rietspruit:	SASS4 average = 43 ASPT average = 4.3		
Calculation Lower Klip:	SASS4 average = 16 ASPT average = 3.54		
Ranking:	Non-acidic streams 0. SASS4 <60; ASPT <3 1. SASS4 60-80; ASPT 3-5 2. SASS4 80-100; ASPT 3-5 3. SASS4 100-140; ASPT 5-7 4. SASS4 >140; ASPT >7		
	Upper Klip	Rietspruit	Lower Klip
	0	0	0
References:	du Preez, 2001; Kotze, 2002		

7	Daphnia toxicity test at the downstream point (% survival)		
Description:	Toxicity test for the survival of Daphnia spp. at the downstream point.		
Formulas:	The acute 48-hour definitive toxicity test will be used for this indicator. The final results are presented as % survival after 48 hours.		
Calculation Upper Klip:	77.17		
Calculation Rietspruit:	97.5		
Calculation Lower Klip:	68		
Ranking:	0. <60% 1. 61-70% 2. 71-80% 3. 81-90% 4. 91-100%.		
	Upper Klip	Rietspruit	Lower Klip
	2	4	1
References:	du Preez, 2001; Kotze, 2002		

SOCIOECONOMIC INDICATORS

8	Population Density		
Description:	Total population size of the catchment divided by its surface area		
Formulas:	$I_8 = P_T / A$ Where: P_T = Total catchment population (number) A = Total surface area (km ²).		
Calculation Upper Klip:	= 1626465 / 893 km ² = 1821.3		

	Calculation	= 1099085 / 856 km ²		
	Rietspruit:	= 1284.0		
	Calculation	= 63740 / 532		
	Lower Klip:	= 119.8		
	Ranking:	0. >200 people/km ² 1. 101-200 people/km ² 2. 51-100 people/km ² 3. 11-50 people/km ² 4. 0-10 people/km ²		
		Upper Klip	Rietspruit	Lower Klip
0		0	1	
References:	Statistics South Africa, 1999			
9	Urbanisation (%)			
	Description:	The percentage of the catchment population living in semi-formal and formal urban areas as defined by the Census (%).		
	Formulas:	$I_u = P_U / P_T \times 100$ Where: P_U = Urban population (number) P_T = Total catchment population (number).		
	Calculation	= 1618309 / 1626465 x 100		
	Upper Klip:	= 99.50		
	Calculation	= 1092239 / 1099085 x 100		
	Rietspruit:	= 99.38		
	Calculation	= 54609 / 63740 x 100		
	Lower Klip:	= 85.67		
	Ranking:	0. 80-100% 1. 61-80% 2. 31-60% 3. 11-30% 4. 0-10%.		
		Upper Klip	Rietspruit	Lower Klip
		0	0	0
	References:	Statistics South Africa, 1999		
10	Catchment population as a proportion of the maximum sustainable population (%)			
	Description:	Catchment population as a proportion of the maximum population that the water resource is able to support, whilst still allowing development(%).		

Formulas:	$I_{10} = P_{MS} / P_T \times 100$ $P_{MS} = MAR / Q_s$ Where: P_{MS} = Maximum sustainable population MAR = Mean annual runoff (m^3/a) IBT = Inter-basin transfer volume (m^3/a) Q_s = Water required to ensure sustainable development = ($100 m^3/cap/a$) (based on 250 l/day/capita) P_T = Total catchment population (number).		
Calculation Upper Klip:	$P_{MS} = MAR / Q_s$ = $28.6 \times 10^6 / 100$ = 286000 $I_{10} = P_{MS} / 1626465 \times 100$ = $286000 / 1626465 \times 100$ = 17.58		
Calculation Rietspruit:	$P_{MS} = MAR / Q_s$ = $26.7 \times 10^6 / 100$ = 267000 $I_{10} = P_{MS} / 1099085 \times 100$ = $267000 / 1099085 \times 100$ = 24.29		
Calculation Lower Klip:	$P_{MS} = MAR / Q_s$ = $14.9 \times 10^6 / 100$ = 149000 $I_{10} = P_{MS} / 63740 \times 100$ = $149000 / 63740 \times 100$ = 233.8		
Ranking:	0. 0-20% 1. 21-40% 2. 41-60% 3. 61-80% 4. >80%.		
	Upper Klip	Rietspruit	Lower Klip
	0	1	4
References:	Statistics South Africa, 1999; Tavaras, 2002; Walmsley, 2000		
11	Proportion of households earning less than R6 000 per annum (%)		
Description:	Percentage of households in the catchment that are earning less than R6 000 per year (1996 Rands).		
Formulas:	$I_{11} = H_{<6000} / H_T \times 100$ Where: $H_{<6000}$ = Households earning less than R 6 000 (1996) per annum. H_T = Total number of households in the catchment.		
Calculation Upper Klip:	$908107 / 1626441 \times 100$ = 55.83		

	Calculation Rietspruit:	595541 / 1099098 x 100 = 54.18		
	Calculation Lower Klip	33495 / 63734 x 100 = 52.55		
	Ranking:	0. 55-100% 1. 41-54% 2. 31-40% 3. 21-30% 4. 0-20%.		
		Upper Klip	Rietspruit	Lower Klip
		0	1	1
	References:	Statistics South Africa, 1999		
12	Households without access to piped water on site (%)			
	Description:	Proportion of households without access to on-site piped water for domestic use (%). Piped water on site is defined as water provided on the property by at least a standpipe.		
	Formulas:	$I_{12} = P_{NW} / P_T \times 100$ Where: P_{NW} = Households that do not receive piped water on site (number) P_T = Total catchment households (number).		
	Calculation Upper Klip:	= 6764 / 400066 x 100 = 1.69		
	Calculation Rietspruit:	= 10016 / 293956 x 100 = 3.41		
	Calculation Lower Klip:	= 2966 / 20210 x 100 = 14.68		
	Ranking:	0. 51-100%. 1. 31-50% 2. 21-30% 3. 11-20% 4. 0-10%		
		Upper Klip	Rietspruit	Lower Klip
		4	4	3
	References:	Statistics South Africa, 1999		
13	Households without access to toilet facilities (%)			
	Description:	Proportion of households without access to any form of toilet facility (%).		
	Formulas:	$I_{13} = P_{NT} / P_T \times 100$ Where: P_{NT} = Households without any toilet facilities (number) P_T = Total catchment households (number).		

	Calculation	= 21701 / 400066 x 100		
	Upper Klip:	= 5.42		
	Calculation	= 20948 / 293956 x 100		
	Rietspruit:	= 7.13		
	Calculation	= 891 / 20210 x 100		
	Lower Klip:	= 4.41		
	Ranking:	0. >85% 1. 56-85% 2. 41-55% 3. 21-40% 4. 0-20%.		
		Upper Klip	Rietspruit	Lower Klip
		4	4	4
	References:	Statistics South Africa, 1999		
14	Water Services Index (WSI)			
	Description:	Level of water services supplied to households in the catchment.		
	Formulas:	$I_{14} = ((\% HH_M \times 1) + (\% HH_B \times 2) + (\% HH_I \times 3) + (\% HH_F \times 4)) / 100$ Where: % HH _M = % Households with Minimal service level; % HH _B = % Households with Basic service levels; % HH _I = % Households with Intermediate service levels; and % HH _F = % Households with Full service levels.		
		Water service level		
		Minimal (1)	Basic (2)	Intermediate (3)
		Dam/River, Carrier/ borehole/tank	Public Tap	Water on site
				Piped water in dwelling
	Calculation	= ((1.7 x 1) + (9.8 x 2) + (29.4 x 3) + (63.3 x 4))/100		
	Upper Klip:	= 3.62		
	Calculation	= ((3.4 x 1) + (12 x 2) + (17 x 3) + (68 x 4))/ 100		
	Rietspruit:	= 3.70		
	Calculation	= ((14.6 x 1) + (0.5 x 2) + (16 x 3) + (69 x 4))/100		
	Lower Klip:	= 3.39		
	Ranking:	0. 1 – 1.6 1. 1.6 – 2.2 2. 2.2 – 2.8 3. 2.8 – 3.4 4. 3.4 – 4.0		
		Upper Klip	Rietspruit	Lower Klip
		4	4	3
	References:	CSIR, 1995; Statistics South Africa, 1999; van der Walt, 1999		

15

Sanitation Service Index (SSI)

Description:

Level of sanitation services to households in the catchment.

Formulas:

$$I_{15} = ((\% HH_M \times 1) + (\% HH_B \times 2) + (\% HH_I \times 3) + (\% HH_F \times 4)) / 100$$

Where:

% HH_M = % of Households with minimal service level;

% HH_B = % of Households with Basic service level;

% HH_I = % of Households with intermediary service level; and

% HH_F = % of Households with full service level.

Minimal (1)	Basic (2)	Intermediate (3)	Full (4)
None of the above	Unspecified/ Bucket latrine	Pit latrine	Flush or Chemical toilet

Calculation Upper Klip:

$$I_{15} = ((1.93 \times 1) + (3.49 \times 2) + (2.6 \times 3) + (91.98 \times 4)) / 100 = 3.84$$

Calculation Rietspruit:

$$I_{15} = ((6 \times 1) + (1 \times 2) + (7 \times 3) + (86 \times 4)) / 100 = 3.73$$

Calculation Lower Klip:

$$I_{15} = ((3.3 \times 1) + (1.7 \times 2) + (16 \times 3) + (79 \times 4)) / 100 = 3.71$$

Ranking:

0. 1 – 1.6

1. 1.6 – 2.2

2. 2.2 – 2.8

3. 2.8 – 3.4

4. 3.4 – 4.0

Upper Klip	Rietspruit	Lower Klip
4	4	4

References:

CSIR, 1995; Statistics South Africa, 1999; van der Walt, 1999

16

Health-related index for potable water (% score)

Description:

Index of water-related health hazards for potable water developed by Rand Water

Formulas:

$$I_{16} = (4.FC + 4.G + 2.TC + 2.SPC + 1.NTU + 1.TRC) / 56 \times 100$$

	Ideal (4)	Acceptable (3)	Tolerable (2)	Unacceptable (1)
FC: Faecal coliforms (/100 ml)	0-1	2.0 – 5	6.0 – 10	>10
G: Giardia	0			> 0
TC: Total coliforms (/100 ml)	0-1	2.0 – 5	6-100	>100

	SPC: Standard Plate Counts (/ 100 ml)	0-100	101-1 000	1 001 - 10 000	>10 000
	NTU: Turbidity (NTU)	0-1.00	1.01-3.00	3.01-5.00	>5.00
	TRC: Total Residual Chlorine (mg/l)	> 0.60	0.41 – 0.60	0.21 – 0.40	< 0.20
Calculation Upper Klip:	FC	0		4	
	G	Not measured			
	TC	0.12		4	
	SPC	383		3	
	NTU	0.62		4	
	TRC	Not measured			
	$I_{16} = (4.4 + 2.4 + 2.3 + 1.4) / 36 \times 100$ = 94.44				
Calculation Rietspruit:	FC	0.02		4	
	G	Not measured			
	TC	0.06		4	
	SPC	1048.12		2	
	TRC	Not measured			
	NTU	Not measured			
	$I_{16} = (4.4 + 2.4 + 2.2) / 32 \times 100$ = 87.5				
Calculation Lower Klip	FC	0.02		4	
	G	Not measured			
	TC	0.12		4	
	SPC	55.53		4	
	NTU	0.65		4	
	TRC	Not measured			
	$I_{16} = (4.4 + 2.4 + 2.4 + 1.4) / 36 \times 100$ = 100				
Ranking:	0. = 60%				
	1. 61-70%				
	2. 71-80%				
	3. 81-90%				
	4. 91-100%.				
	Upper Klip	Rietspruit		Lower Klip	
	4	3		4	
References:	Rand Water, 2002				

17	Recreational index for Raw Water (% score)					
	Description:	Index of water-related health hazards for users of water for recreation.				
	Formulas:	I ₁₇ = (4.FC + 2.PTA + 2.API + 2.NTU + 1.Cond)/ 44 x 100 Where:				
			Ideal (4)	Acceptable (3)	Tolerable (2)	Unacceptable (1)
		FC: Faecal coliforms (per 100 ml)	0-130	131-4 000	4 001-10 000	>10000
		PTA: Toxic Algae	0	1.0 – 2000	2001-10 000	>10 000
		API: Algal Problem Index value	1.0 – 20	11.0 – 20	21-30	>30
		Turbidity (NTU)	0-75	76-150	151-200	>200
		Conductivity (mS/m)	0-30	31-70	71-100	>100
	Calculation Upper Klip:	Variable		Value	Rating	
		FC		7238.59	2	
		PTA		607	3	
		API		11 - 20	4	
		Turbidity		17.5	4	
		Conductivity		64.64	3	
		= (4.2 + 2.3 + 2.4 + 2.4 + 1.3)/ 44 x 100 =75				
	Calculation Rietspruit:	Variable		Value	Rating	
		FC		8523.7	2	
		PTA		Not measured		
		API		< 5	4	
		Turbidity		12	4	
		Conductivity		111.82	1	
		= (4.2 + 2.4 + 2.4 + 1.3)/ 36 x 100 =75				
	Calculation Lower Klip:	Variable		Value	Rating	
		FC		13409.44	1	
		PTA		Not measured		
		API		Not measured		
Turbidity		21	4			
Conductivity		83.52	2			
= (4.2 + 2.4 + 1.3)/ 28 x 100 = 67.86						

	Ranking:	0. = 65%		
		1. 66-75%		
		2. 76-85%		
		3. 86-90%		
		4. 91-100%		
		Upper Klip	Rietspruit	Lower Klip
		1	1	1
References:		Rand Water, 2002; CIMDSS, 2002		
WATER QUANTITY INDICATORS				
18	Total water available per capita (m³ /cap/ annum)			
	Description:	Amount of water available per person per year (m ³ /cap/a).		
	Formulas:	I ₁₈ = (MAR + IBT) / P _T Where: MAR = Mean annual runoff (m ³ /a) IBT = Inter-basin transfer volume (m ³ /a) P _T = Total catchment population (number).		
	Calculation Upper Klip:	=28.6 x 10 ⁶ + 135.5 x 10 ⁶ / 1626465 =100.98		
	Calculation Rietspruit:	= 26.7 x 10 ⁶ + 217 x 10 ⁶ / 1099085 = 221.73		
	Calculation Lower Klip:	= 14.9 x 10 ⁶ + 350.87 x 10 ⁶ / 63740 = 5738.47		
	Ranking:	0. 0-500 m ³ /cap/a		
		1. 501-1 000 m ³ /cap/ a		
		2. 1 001-1 500 m ³ /cap/a		
		3. 1 501-2 000 m ³ /cap/a		
4. >2 000 m ³ /cap/ a				
Upper Klip		Rietspruit	Lower Klip	
	0	0	4	
References:		Midgley et al., 1994a; Tavaras, 2002; Statistics South Africa, 1999		
19	Anthropogenic supply as a proportion of total supply (%)			
	Description:	Supply of water from return flows and IBTs as a percentage of total water available (anthropogenic and natural) for the catchment (%).		
	Formulas:	I ₁₉ = (IBT + RT) / (IBT + RT + MAR) x 100 Where: IBT = Inter-basin transfer volume (m3/a) RT = Return flow volume (m3/a) MAR = Mean annual runoff(m3/a).		
	Calculation Upper Klip:	= (135.50 x 10 ⁶ + 160.97 x 10 ⁶) / (135.50 x 10 ⁶ + 160.97 x 10 ⁶ + 28.6 x 10 ⁶) x 100 = 91.20		

Calculation Rietspruit:	$= (217 \times 10^6 + 74 \times 10^6) / (217 \times 10^6 + 74 \times 10^6 + 26.7 \times 10^6) \times 100$ $= 91.60$		
Calculation Lower Klip:	$= (350.87 \times 10^6 + 35.4 \times 10^6) / (350.87 \times 10^6 + 35.4 \times 10^6 + 14.9 \times 10^6) \times 100$ $= 96.29$		
Ranking:	0. 81-100% 1. 61-80% 2. 41-60% 3. 21-40% 4. 0-20%		
	Upper Klip	Rietspruit	Lower Klip
	0	0	0
References:	Tavaras, 2002; Pitman, 2002; Joubert, 2002; van Jaarsveldt, 2001; van der Schyff, 2002; Midgley et al., 1994a		

20	Change in flow at the downstream point (% difference from MAR)		
Description:	Measured amount of water flowing out of a management unit compared to MAR, expressed as a percentage difference (%).		
Formulas:	$I_{20} = Q_D / \text{MAR} \times 100$		
Calculation Upper Klip:	$= (216.65 \times 10^6 \text{ m}^3/\text{a} / 28.6 \times 10^6 \text{ m}^3/\text{a}) \times 100$ $= 757.53$		
Calculation Rietspruit:	$= (115.11 \times 10^6 \text{ m}^3/\text{a} / 26.7 \times 10^6 \text{ m}^3/\text{a}) \times 100$ $= 431.11$		
Calculation Lower Klip:	$= (422.58 \times 10^6 \text{ m}^3/\text{a} / 14.9 \times 10^6 \text{ m}^3/\text{a}) \times 100$ $= 2836.12$		
Ranking:	0. >80% increase or decrease 1. 61-80% increase or decrease 2. 41-60% increase or decrease 3. 21-40% increase or decrease 4. 0-20% increase or decrease.		
	Upper Klip	Rietspruit	Lower Klip
	0	0	0
References:	Rand Water, 2002; Midgley et al., 1994a		

WATER QUALITY INDICATORS

21	Conductivity at the downstream point (mS/m)		
Description:	Mean conductivity of the water exiting the catchment, measured over a year (mS/m).		
Formulas:	Average concentration of conductivity at downstream points for October 1998 – September 1999.		
Calculation Upper Klip:	64.64 mS/m		
Calculation Rietspruit:	111.82 mS/m		

	Calculation Lower Klip:	83.52 mS/m		
	Ranking:	0. > 240 mS/m 1. 121-240 mS/m 2. 71-120 mS/m 3. 31-70 mS/m 4. 0-30 mS/m		
		Upper Klip	Rietspruit	Lower Klip
		3	2	2
	References:	CIMDSS, 2002		
22	Chemical oxygen demand at the downstream point (mg/l)			
	Description:	Mean concentration of COD as the water exits the catchment, measured over a year (mg/l).		
	Formulas:	Average concentration of COD at downstream points for October 1998 – September 1999.		
	Calculation Upper Klip:	28.33 mg/l		
	Calculation Rietspruit:	30.80 mg/l		
	Calculation Lower Klip:	27.59 mg/l		
	Ranking:	0. >75 mg/l 1. 51-75 mg/l 2. 31-50 m/l 3. 11-30 mg/l 4. 0-10 mg/l		
		Upper Klip	Rietspruit	Lower Klip
		3	2	3
	References:	CIMDSS, 2002		
23	Faecal coliforms at the downstream point (counts / 100ml)			
	Description:	Mean concentration of Faecal Coliforms as the water exits the catchment, measured over a year (counts / 100ml).		
	Formulas:	Average concentration of Faecal Coliforms at downstream points for October 1998 – September 1999.		
	Calculation Upper Klip:	7238.59 counts/100ml		
	Calculation Rietspruit:	8523.70 counts/100 ml		
	Calculation Lower Klip:	13409.44 counts/100 ml		

	Ranking:	0. >10 000 / 100 ml 1. 4 001 – 10 000 / 100 ml 2. 1 001 – 4 000 / 100 ml 3. 131 – 1 000 / 100 ml 4. 0 – 130 / 100 ml		
		Upper Klip	Rietspruit	Lower Klip
		1	1	0
	References:	CIMDSS, 2002		
24	Phosphates at the downstream point (mg/l)			
	Description:	Mean concentration of organic phosphorus as the water exits the catchment, measured over a year (mg/l).		
	Formulas:	Average concentration of phosphates at downstream points for October 1998 – September 1999.		
	Calculation Upper Klip:	0.69 mg/l		
	Calculation Rietspruit:	0.57 mg/l		
	Calculation Lower Klip:	0.73 mg/l		
	Ranking:	0. >1,00 mg/l 1. 0,61- 1,00 mg/l 2. 0,26 - 0,60 mg/l 3. 0,11 - 0,25 mg/l 4. 0 - 0,10 mg/l		
		Upper Klip	Rietspruit	Lower Klip
		1	2	1
	References:	CIMDSS, 2002		
25	Nitrates at the downstream point (mg/l)			
	Description:	Mean concentration of nitrates as the water exits the catchment, measured over a year (mg/l).		
	Formulas:	Average concentration of nitrates at downstream points for October 1998 – September 1999.		
	Calculation Upper Klip:	3.99 mg/l		
	Calculation Rietspruit:	3.66 mg/l		
	Calculation Lower Klip:	4.53 mg/l		

Ranking:	0. >10,0 mg/l 1. 6,1 – 10,0 mg/l 2. 3,1 – 6,0 mg/l 3. 1,1 – 3,0 mg/l 4. 0 – 1,0 mg/l		
	Upper Klip	Rietspruit	Lower Klip
	2	2	2
References:	CIMDSS, 2002		

26	Total liquid waste discharged as a proportion of supply (%)		
Description:	Volume of return flows from point discharges (as an indicator of polluted water) divided by the total water supply (%).		
Formulas:	$I_{26} = RT / (RT + IBT + MAR) \times 100$ Where: RT = Return flow (m ³ /a) IBT = Inter-basin transfer volume (m ³ /a) MAR = Mean annual runoff(m ³ /a)		
Calculation Upper Klip:	= 160.97 x 10 ⁶ / (160.97 x 10 ⁶ + 135.50 x 10 ⁶ + 28.6 x 10 ⁶) x 100 = 49.52		
Calculation Rietspruit:	= 74 x 10 ⁶ / (74 x 10 ⁶ + 217 x 10 ⁶ + 26.7 x 10 ⁶) x 100 = 23.29		
Calculation Lower Klip:	= 35.4 x 10 ⁶ / (35.4 x 10 ⁶ + 350.87 x 10 ⁶ + 14.9 x 10 ⁶) x 100 = 8.82		
Ranking:	0. >70% 1. 46-70% 2. 31-45% 3. 16-30% 4. 0-15%.		
	Upper Klip	Rietspruit	Lower Klip
	1	3	4
References:	Tavaras, 002; Pitman, 2002; Joubert, 2002; van Jaarsveldt, 2001; van der Schyff, 2002; Midgley et al., 1994a		

27	Hydraulic capacity index of water care works (HCI_{wcw}) (%)		
Description:	The amount of sewage all the water care works in the catchment are treating hydraulically in comparison to their hydraulic design capacity (%).		
Formulas:	$I_{27} = Q_{Tr} / QC_T \times 100$ Where: Q _{Tr} = Total volume of water treated per day by all the water care works in the catchment (Ml/day) QC _T = Total hydraulic capacity of all the water care works in the catchment (Ml/day)		

	Calculation Upper Klip:	$= (441 / 570) \times 100$ $= 77.37$		
	Calculation Rietspruit:	$= (150.7 / 155) \times 100$ $= 97.23$		
	Calculation Lower Klip:	$= (101/110) \times 100$ $= 91.82$		
	Ranking:	0. >100% 1. >75 – 100% 2. 75% 3. 50 – <75% 4. 0 – 50%		
		Upper Klip	Rietspruit	Lower Klip
		1	1	1
	References:	Joubert, 2002; Pitman, 2002; van der Schyff, 2002		
28	Organic load capacity index of water care works (OLI_{wcw}) (%)			
	Description:	Amount of organic load (COD) treated by all the water care works in the catchment in comparison to their organic load design capacity (%).		
	Formulas:	$I_{28} = L_{Tr} / LC_T \times 100$ Where: L_{Tr} = Total COD Load Treated per day by all the water care works in the catchment (tonnes/day) LC_T = Total COD Load Capacity of all the water care works in the catchment (tonnes/day)		
	Calculation Upper Klip:	$= (273.10 / 363.00) \times 100$ $= 75.23$		
	Calculation Rietspruit:	$= (89.2 / 118.8) \times 100$ $= 75.08$		
	Calculation Lower Klip:	$= (100.48 / 114) \times 100$ $= 88.14$		
	Ranking:	0. >100% 1. >75 – 100% 2. 75% 3. 50 – <75% 4. 0 – 50%		
		Upper Klip	Rietspruit	Lower Klip
		1	1	1
	References:	Joubert, 2002; Pitman, 2002; van der Schyff, 2002		
29	Effluent compliance index of water care works (ECI_{wcw}) (%)			
	Description:	A measure of how the treated effluent discharged from water care works conforms to effluent standards in respect of COD, SS, NH ₃ , NO ₃ , PO ₄ and FC.		

Formulas:	Parameter	Ideal (2)	Tolerable (1)	Unacceptable (0)
	COD (mg/l)	=75	>75 = 93.75	>93.75
	SS (mg/l)	=25	>25 = 31.25	>31.25
	PO4 (mg/l)	=1	>1 = 1.25	>1.25
	NH ₃ (mg/l)	=10	>10 = 12.5	>12.5
	NO ₃ (mg/l)	=15	>15 = 18.75	>18.75
	FC (/100ml)	= 0	>0 = 10000	>10000
	$I_{29} = [\text{COD (rating)} + \text{SS (rating)} + \text{PO}_4 \text{ (rating)} + \text{NH}_3 \text{ (rating)} + \text{NO}_3 \text{ (rating)} + \text{FC (rating)}] / 12 \times 100$			
	Calculation Upper Klip:	Parameter	Average value	
COD (mg/l)		45		2
SS (mg/l)		7		2
PO4 (mg/l)		1		2
NH ₃ (mg/l)		2		2
NO ₃ (mg/l)		5		2
FC (FC/100ml)		16621		0
$= (2 + 2 + 2 + 2 + 2 + 0) / 12 \times 100$				
$= 75$				
Calculation Rietspruit:	Parameter	Average value		Rating
	COD (mg/l)	148.33		0
	SS (mg/l)	42.67		0
	PO4 (mg/l)	1.39		0
	NH ₃ (mg/l)	9.53		2
	NO ₃ (mg/l)	11.93		2
	FC (FC/100ml)	3772073.33		0
	$= (0 + 0 + 0 + 2 + 2 + 0) / 12 \times 100$			
	$= 33.33$			
Calculation Lower Klip:	Parameter	Average value		Rating
	COD (mg/l)	91.22		1
	SS (mg/l)	65.48		0
	PO4 (mg/l)	2.01		0
	NH ₃ (mg/l)	11.29		1
	NO ₃ (mg/l)	2.25		2
	FC (FC/100ml)	2962187.5		0
	$= (1 + 0 + 0 + 1 + 2 + 0) / 12 \times 100$			
	$= 33.33$			
Ranking:	0. 0%			
	1. >0 – 33%			
	2. >33 – 66%			
	3. >66 <100%			
	4. =100%			
	Upper Klip		Rietspruit	Lower Klip
	3		1	1
References:	Joubert, 2002; Pitman, 2002; van der Schyff, 2002			

MANAGEMENT INDICATORS

30	Number of active hydrological monitoring stations per 100 km²		
Description:	The density of active hydrological monitoring stations (number per 100 km ²)		
Formulas:	$I_{30} = S_H / A \times 100$ Where: S_H = Active hydrological monitoring stations in the catchment A = Total catchment area (km ²)		
Calculation Upper Klip:	$= 1 / 893 \times 100$ $= 0.11$		
Calculation Rietspruit:	$= 1 / 856 \times 100$ $= 0.12$		
Calculation Lower Klip:	$= 1 / 532 \times 100$ $= 0.19$		
Ranking:	0. 0 per 100 km ² 1. 0,01-0,1 per 100 km ² 2. 0,11-0,3 per 100 km ² 3. 0,31-0,6 per 100 km ² 4. >0,6 per 100 km ²		
	Upper Klip	Rietspruit	Lower Klip
	2	2	2
References:	Rand Water, 2002		

31	Number of water quality monitoring points per 100 km²		
Description:	Density of the water quality monitoring networks in the catchment (number per 100 km ²).		
Formulas:	$I_{31} = S_{WQ} / A \times 100$ Where: S_{WQ} = Active water quality monitoring stations in the catchment A = Total catchment area (km ²)		
Calculation Upper Klip:	$= 10 / 893 \times 100$ $= 1.12$		
Calculation Rietspruit:	$= 21 / 856 \times 100$ $= 2.45$		
Calculation Lower Klip:	$= 3 / 532 \times 100$ $= 0.56$		
Ranking:	0. 0 per 100 km ² 1. 0,01-0,30 per 100 km ² 2. 0,31-0,60 per 100 km ² 3. 0,61-1,2 per 100 km ² 4. >1,2 per 100 km ²		
	Upper Klip	Rietspruit	Lower Klip
	3	4	2
References:	Rand Water, 2002		

Appendix 3

Tables 50 – 52 are based on a query of the Witwatersrand Industry Database for the Upper Klip, Rietspruit and Lower Klip sub-catchments respectively as per Section 2.5.1 Sources and types of waste generated. This database gives an indication of the types and number of industries in an area and the potential contaminants that could be produced by each type of industry.

Table 50: Potential industrial pollution types in the Upper Klip sub-catchment (Witwatersrand Industry Database, 2001).

Manufacturing	Number	Potential contaminants					
Beverage							
1. Brewing sorghum beer	1	COD	EC	MnO ⁴⁺	Na	PO ₄	Settle
		SS	TDS	TOC			
2. Soft drinks and carbonated waters	1	COD	Na	PO ₄	SS	TDS	
Chemicals							
1. Alkalies, chlorine, inorganic chemicals, organic petrochemicals, paints	8	BOD	Cd	COD	Cr	Fe	Hg
		Na	NH ₄	NO ₂	NO ₃	NUT	Pb
		pH	PO ₄	PO ₄ ³⁻	Sn	SS	TDS
		TO	Zn				
Coating and Plating							
1. Plating, dipping and painting - i.e. metal finishing	2	Al ³⁺	Au	Cd	CN	COD	Cr
		Cu	Hg	Na	Ni	Pb	PO ₄
		PO ₄ ²⁻	Se	Sn	SO ₄ ²⁻	SS	TDS
		TO	Zn				
Detergents							
1. Soap and cleaning products	1	As	BOD	Cd	Cr	Cu	Fe
		Ni	SOG	Zn			
Food							
1. Dairy	3	BOD	Ca	COD	Colour	EC	FOG
		Na	NH ₄	NO ₂	NO ₃	NUT	OA
		pH	PO ₄	PO ₄ ³⁻	SOG	SS	TDS
		TKN	TOC				
Food processing							
1. Animal food	1	BOD	COD	Colour	pH	Se	SS
		Zn					
2. Baking, Confectionery and Food	3	BOD	COD	Colour	Na	pH	PO ₄
		Se	SS	TDS	Zn		
3. Fish processing: Seafood and Fish oil	1	BOD	COD	Colour	NH ₄	NO ₂	NO ₃
		NUT	pH	PO ₄ ³⁻	Se	SS	Zn
4. Fruit and Vegetables	1	BOD	COD	Colour	Na	OA	pH
		PO ₄	Salts	Se	SS	TDS	Zn

5. Grain	2	BOD	COD	Colour	Na	pH	PO ₄
		Se	SS	TDS	Zn		
6. Sugar	1	BOD	COD	Colour	NH ₄	NO ₂	NO ₃
		NUT	pH	PO ₄	PO ₄ ³⁺	Se	SS
		Temp	Zn				
Glass							
1. Glass and glass products	2	COD	Cr	Na	TDS		
Iron and steel							
1. Iron and Steel (steel works)	7	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Leather and leather products							
1. Tanning and leather	2	BOD	COD	Colour	Cr	FOG	Na
		pH	PO ₄	SS	TDS	TO	
Machinery							
1. Machinery (electrical and not electrical), Motor vehicles, parts, Transport equipment, specialist parts	24	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Medical							
1. Medical appliances	2	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Metal fabrication							
1. Fabricated Metal Products, general equipment, Recycling	13	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Non Ferrous Metals							
1. Nonferrous metal works and basic industry	2	Cd	Cr	Cu	Hg	Pb	Zn
Non Metallic Mineral Products							
1. Concrete, asbestos cement and Plaster products, Cement, Other	4	COD	Cr	TDS			
Non Metallic Mineral Products							
1. Porcelain, stoneware, ceramics and Recycling	2	BOD	COD	NH ₄	NO ₂	NO ₃	NUT
		pH	PO ₄ ³⁺	SS	TDS	TO	
Paper, Printing and Publishing							
1. Paper Products, Printing and Publishing	9	COD	Na	PO ₄	TDS		
Paper, Printing and Publishing							
1. Pulp and Paper mills, Paperboards	5	Al	B	BOD	Ca	Cl	Co
		COD	Colour	Cr	Cu	Hg	K

		Mg	Mn	Na	NH ₄	Ni	NO ₃
		Pb	pH	PO ₄	SO ₄	SS	TDS
		Temp	TO	Zn			
Petroleum and coal							
1. Petroleum refining and coal products	4	BOD	Cd	COD	Cr	Cu	Fe
		FOG	Ni	pH	Temp	TO	Zn
Rubber							
1. Rubber and Plastic Products	1	COD	Na	TDS			
Textiles							
1. Carpet and rug, cordage, rope and twine, Clothing (not leather), Made-up textile goods, knitting products, Wool, cotton, fibre, fabric yarn	14	BOD	Cd	COD	Colour	Cr	Cu
		Fe	Hg	Pb	pH	SO ₄	SS
		TDIS	TDS	Temp	TO	Zn	
Aluminium							
1. Manufacture of aluminium products	1	Al					
Mining	Number	Potential contaminants					
Copper	1	Cu					
Gold and Uranium	2	Au	Cd	Co	Cr	Cu	Fe
		Mn	Ni	Pb	pH	SO ₄	U
		Zn					
Agriculture	Number	Potential contaminants					
Growing Crops, Vegetables and Fruit							
1. Mushrooms, Nurseries, Flowers, shrubs and trees	1	Na	NH ₄	NO ₂	NO ₃	PO ₄	SO ₄
Construction	Number	Potential contaminants					
1. Construction of Buildings and other construction	7	COD	Cr	TDS			

Rietspruit sub-catchment

Table 51: Potential industrial pollution types in the Rietspruit sub-catchment (Witwatersrand Industry Database, 2001).

Manufacturing	Number	Potential contaminants					
Articles not yet described							
1. Aluminium	1	Al					
Beverage							
1. Brewing sorghum beer	1	COD	EC	MnO ⁴⁺	Na	PO ⁴⁺	Settle
		SS	TDS	TOC			
2. Soft drinks & carbonated waters	1	COD	Na	PO ⁴⁺	SS	TDS	
3. Spirits	1	COD	TDS				
Chemicals							
1. Alkalies, chlorine, inorganic chemicals, organic petrochemicals, paint	9	BOD	Cd	COD	Cr	Fe	Hg
		Na ⁺	NH ₄ ⁺	NO ₂	NO ₃	Nut	Pb
		pH	PO ⁴⁺	PO ₄ ³⁻	Sn	SS	TDS
		Tox	Zn				
Coating & Plating							
1. Plating, dipping & painting - i.e. metal finishing, Vehicle and aircraft plating	4	Ag	Al ³⁺	Au	Cd	CN ⁻	COD
		Cr	Cu	Hg	Na	Ni	Pb
		PO ⁴⁺	PO ₄ ³⁻	Se	Sn	SO ₄ ²⁻	SS
		TDS	To	Zn			
Copper							
1. Copper	1	Cu					
Detergents							
1. Soap & cleaning products	2	As	BOD	Cd	Cr	Cu	Fe
		Ni	SOG	Zn			
Food							
1. Dairy	2	BOD	Ca	COD	Colour	EC	FOG
		Na ⁺	NH ₄ ⁺	NO ₂	NO ₃	Nut	OA
		pH	PO ⁴⁺	PO ₄ ³⁻	SOG	SS	TDS
		TKN	TOC				
2. Red meat	1	BOD	COD	Colour	FOG	Na	NH ₄
		NO ₂	NO ₃	Nut	OA	pH	PO ⁴⁺
		PO ₄ ³⁻	SS	TDS	TKN		
Food processing							
1. Animal food	1	Ag	BOD	COD	Colour	pH	Se
		SS	Zn				
2. Baking, Confectionery & Food, grain	6	Ag	BOD	COD	Colour	Na	pH
		PO ⁴⁺	Se	SS	TDS	Zn	
3. Edible oil: Animal & vegetable oil	1	Ag	BOD	COD	Colour	Na	pH

		Se	SO ₄ ²⁻	SOG	SS	TDS	Zn
4. Fruit & Vegetables	1	Ag	BOD	COD	Colour	Na	OA
		pH	PO ₄ ³⁻	Salts	Se	SS	TDS
		Zn					
5. Sugar	2	Ag	BOD	COD	Colour	NH ₄	NO ₂
		NO ₃	Nut	pH	PO ₄ ³⁻	PO ₄ ³⁻	Se
		SS	Temp	Zn			
Glass							
1. Glass & glass products	2	COD	Cr	Na	TDS		
Iron & steel							
1. Iron and Steel (steel works)	8	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄ ³⁻	Se	Sn
		TDS	Zn				
Leather & - products							
1. Tanning and leather	2	BOD	COD	Colour	Cr	FOG	Na
		pH	PO ₄ ³⁻	SS	TDS	TO	
Machinery							
1. Machinery (electrical and not electrical), motor vehicle parts, Transport equipment, specialist parts	28	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄ ³⁻	Se	Sn
		TDS	Zn				
Medical							
1. Medical appliances	1	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄ ³⁻	Se	Sn
		TDS	Zn				
Metal fabrication							
1. Fabricated Metal Products, general equipment Ferro chrome, Recycling	17	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄ ³⁻	Se	Sn
		TDS	Zn				
Non Ferrous Metals							
1. Nonferrous metal works & basic industry	4	Cd	Cr	Cu	Hg	Pb	Zn
Non Metallic Mineral Products							
1. Cement, concrete, asbestos, plaster	4	COD	Cr	TDS			
2. Porcelain, stoneware, ceramics	2	BOD	COD	NH ₄	NO ₂	NO ₃	Nut
		pH	PO ₄ ³⁻	SS	TDS	TO	
3. Recycling	1	COD	NH ₄	NO ₂	NO ₃	Nut	pH
		PO ₄ ³⁻	SS	TDS	TO		
Paper, Printing & Publishing							
1. Paper Products, Printing, Publishing	9	COD	Na	PO ₄ ³⁻	TDS		
2. Pulp & Paper mills, Paperboards	4	Al	B	BOD	Ca	Cl	Co
		COD	Colour	Cr	Cu	Hg	K

		Mg	Mn	Na	NH ₄	Ni	NO ₃
		Pb	pH	PO ₄ ⁻	SO ₄	SS	TDS
		Temp	TO	Zn			
Petroleum & coal							
1. Petroleum refining & coal products	6	BOD	Cd	COD	Cr	Cu	Fe
		FOG	Ni	pH	Temp	TO	Zn
Rubber							
1. Rubber & Plastic Products	1	COD	Na	TDS			
Textiles							
1. Carpet & rug, cordage, rope & twine, clothing (not leather), Made-up textile goods, knitting products, Wool, cotton, fibre, fabric yarn	16	BOD	Cd	COD	Colour	Cr	Cu
		Fe	Hg	Pb	pH	SO ₄	SS
		TDIS	TDS	Temp	TO	Zn	

Mining	Number	Potential Contaminants					
1. Coal	1	Ca	Cl	FeSO ₄	H ₂ SO ₄	Mg	Mg
		Na	pH	SiO ₂	SO ₄	SS	TDS
2. Copper	1	Cu					
3. Gold and Uranium	1	Cd	Co	Cr	Cu	Fe	Mn
		Ni	Pb	pH	SO ₄	Zn	
4. Iron or Non-ferrous metal	1	Cd	Cr	Cu	Hg	Pb	Zn
5. Manganese	1	Mn					
6. Platinum	1	Cd	Co	Cr	Cu	Fe	Mn
		Ni	Pb	pH	SO ₄	Zn	

Agriculture	Number	Potential Contaminants					
Animal Farming							
1. Other animal farming	1	BOD	COD	NO ₂	NO ₃	PO ⁴⁻	
Animal related services							
1. Kennels, hatcheries etc.	1	BOD	COD	NO ₂	NO ₃	PO ⁴⁻	
Growing Crops, Vegetables & Fruit							
1. Mushrooms, Nurseries, Flowers, shrubs & trees	2	Na	NH ₄	NO ₂	NO ₃	PO ⁴⁻	SO ₄
Other services							
1. Fertilizers and herbicides	2	As	Cd	Cr	Cu	Fe	Hg
		Mn	NH ₄	Ni	NO ₂	NO ₃	Nut
		Pb	pH	PO ₄ ⁻³	TDS	To	Zn

Construction	Number	Potential Contaminants					
1. Construction of Buildings and Other Construction	7	COD	Cr	TDS			

Lower Klip sub-catchment

Table 52: Potential industrial pollution types in the Lower Klip sub-catchment (Witwatersrand Industry Database, 2001).

Manufacturing	Number	Potential contaminants					
Chemicals							
1. Alkalies, chlorine, inorganic chemicals, paints	4	BOD	Cd	COD	Cr	Fe	Hg
		Na	NH ₄	NO ₂	NO ₃	NUT	Pb
		pH	PO ₄	PO ₄ ³⁻	Sn	SS	TDS
		TO	Zn				
Coating and Plating							
1. Plating, dipping and painting - i.e. metal finishing	1	Ag	Al ³⁺	Au	Cd	CN ⁻	COD
		Cr	Cu	Hg	Na	Ni	Pb
		PO ₄	PO ₄ ³⁻	Se	Sn	SO ₄ ²⁻	SS
		TDS	TO	Zn			
Food							
1. Dairy	1	BOD	Ca	COD	Colour	EC	FOG
		Na	NH ₄	NO ₂	NO ₃	NUT	OA
		pH	PO ₄	PO ₄ ³⁻	SOG	SS	TDS
		TKN	TOC				
Food processing							
1. Animal food	1	Ag	BOD	COD	Colour	pH	Se
		SS	Zn				
2. Baking	1	Ag	BOD	COD	Colour	Na	pH
		PO ₄	Se	SS	TDS	Zn	
3. Confectionery and Food (miscellaneous)	1	Ag	BOD	COD	Colour	Na	pH
		PO ₄	Salts	Se	SS	TDS	Zn
4. Sugar	1	Ag	BOD	COD	Colour	NH ₄	NO ₂
		NO ₃	NUT	pH	PO ₄	PO ₄ ³⁻	Se
		SS	Temp	Zn			
Glass							
1. Glass and glass products	2	COD	Cr	Na	TDS		
Iron and steel							
1. Iron and Steel (steel works)	3	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Machinery							
1. Machinery (electrical and not electrical), Motor vehicles, parts etc., Transport equipment, specialist -, parts etc.	10	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				

Medical							
1. Medical appliances	1	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Metal fabrication							
1. Fabricated Metal Products, general equipment, recycling	6	Cd	COD	Cr	Cu	Fe	Hg
		Na	Ni	Pb	PO ₄	Se	Sn
		TDS	Zn				
Non Ferrous Metals							
1. Nonferrous metal works and basic industry	2	Cd	Cr	Cu	Hg	Pb	Zn
Non Metallic Mineral Products							
1. Cement, Concrete, asbestos cement and Plaster products	2	COD	Cr	TDS			
Non Metallic Mineral Products							
1. Porcelain, stoneware, ceramics	2	BOD	COD	NH ₄	NO ₂	NO ₃	NUT
		pH	PO ₄ ³⁻	SS	TDS	TO	
Paper, Printing and Publishing							
1. Paper Products; Printing and Publishing	3	COD	Na	PO ₄	TDS		
2. Pulp and Paper mills, Paperboards	1	Al	B	BOD	Ca	Cl	Co
		COD	Colour	Cr	Cu	Hg	K
		Mg	Mn	Na	NH ₄	Ni	NO ₃
		Pb	pH	PO ₄	SO ₄	SS	TDS
		Temp	TO	Zn			
Petroleum and coal							
1. Petroleum refining and coal products	2	BOD	Cd	COD	Cr	Cu	Fe
		FOG	Ni	pH	Temp	TO	Zn
Textiles							
1. Carpet and rug, cordage, rope and twine, Wool, cotton, fibre, fabric yarn	3	BOD	Cd	COD	Colour	Cr	Cu
		Fe	Hg	Pb	pH	SO ₄	SS
		TDIS	TDS	Temp	TO	Zn	
Agriculture	Number	Potential contaminants					
Animal Farming	2	BOD	COD	NO ₂	NO ₃	PO ₄	
Animal related services							
1. Kennels, hatcheries etc.	2	BOD	COD	NO ₂	NO ₃	PO ₄	
Growing Crops, Vegetables and Fruit							

I. Mushrooms, Nurseries, Flowers, shrubs and trees	2	Na	NH ₄	NO ₂	NO ₃	PO ₄	SO ₄
Other services							
I. Fertilizers and herbicides	2	As	Cd	Cr	Cu	Fe	Hg
		Mn	NH ₄	Ni	NO ₂	NO ₃	NUT
		Pb	pH	PO ₄ ³⁻	TDS	TO	Zn
Construction	Number	Potential contaminants					
Construction of Buildings	4	COD	Cr	TDS			

Appendix 4

Table 53 indicates the ranges of water quality objectives/guidelines as set out by the Klip River Forum. Values for each variable are placed in one of four ranges. These ranges are listed below and are broadly categorised as Ideal, Acceptable, Tolerable and Unacceptable. Tables 54 - 56 in Appendix 5 show the actual data for October 1998 – September 1999 classified according to the ranges in Table 53. Figures 76 – 128 in Appendix 6 are time and cumulative frequency graphs for the variables for the Klip River catchment listed in Tables 54 – 56. These graphs show the trends of the various constituents in the samples over the time period 1 October 1998 to 30 September 1999.

Table 53: Key to Water Quality Objectives/Guidelines for the Klip River Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
COD	mg/l	< 20	20 – 35	35 – 55	> 55
Conductivity	mS/m	< 45	45 – 70	70 – 100	> 100
Faecal coliforms	/100 ml	< 10	10 – 100	100 – 1000	> 1000
Fe	mg/l	< 0.1	0.1 – 0.5	0.5 – 1.0	> 1.0
Mn	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.5	> 0.5
Na	mg/l	< 50	50 – 70	70 – 100	> 100
NH ₄	mg/l N	< 0.25	0.25 – 5.0	5.0 – 10	> 10
NO ₃	mg/l	< 1.0	1.0 – 3.0	3.0 – 6.0	> 6.0
pH		6.5 – 8.5			< 6.5 > 8.5
PO ₄	mg/l	< 0.2	0.2 – 0.4	0.4 – 0.6	> 0.6
SO ₄	mg/l	< 80	80 – 200	200 – 500	> 500

Appendix 5

Table 54: Summary water quality data for Rand Water's Upper Klip sub-catchment sample points for October 1998 to September 1999.

	K14	K11	K9	K6	K5	K4	K3	K1	K21	K10
COD (mg/l)	19.32	19.84	20.05	20.32	20.74	22.53	25.84	29.26	28.33	28.39
Conductivity (mS/m)	29.86	30.86	197.10	81.59	81.18	67.64	62.50	65.41	64.64	67.00
Feacal Coliforms (counts/100ml)						14451.00			7238.59	
Fe (mg/l)	0.26	0.06	16.57	0.11	0.11	0.05	0.05	0.19	0.06	0.09
Mn (mg/l)	0.42	0.33	12.07	1.50	3.21	0.78	0.43	0.41	0.30	0.30
Na (mg/l)	14.21	28.68	82.50	44.95	44.91	47.64	49.09	52.05	53.77	53.89
NH ₄ (mg/l N)	0.74	0.08	8.32	1.18	3.30	0.34	0.66	0.70	0.14	0.20
NO ₃ (mg/l)	0.44	0.14	0.45	1.70	4.08	3.88	4.38	4.65	3.99	3.95
pH	6.60	7.36	3.65	7.95	7.57	7.64	7.85	7.66	8.02	8.04
PO ₄ (mg/l)	0.10	0.08	0.05	0.41	0.16	0.41	0.56	0.66	0.69	0.69
SO ₄ (mg/l)	26.77	65.18	902.14	202.27	215.05	139.00	116.64	104.59	117.49	123.51

Table 55: Summary water quality data for Rand Water's Rietspruit sub-catchment sample points for October 1998 to September 1999.

	E7	E8	E17	N4	N7	N8	R1	R2	R3	R4	R5	R6
COD (mg/l)	24.00	25.00	37.14	23.00	25.11	31.48	31.00	27.00	37.00	24.00	25.03	30.80
Conductivity (mS/m)	245.00	165.00	184.91	165.00	97.85	105.03	275.00	70.00	115.00	200.00	175.89	111.82
Feacal Coliforms (counts/100ml)			5039.50		340810.12	16982.84					16594.56	8523.70
Fe (mg/l)	0.15	7.60	0.12	7.70	2.89	0.05	4.70	0.11	0.51	0.05	0.07	0.06
Mn (mg/l)	3.10	8.70	4.06	30.00	5.80	0.39	25.00	2.20	6.40	0.41	0.30	0.38
Na (mg/l)	125.00	100.00	105.35	43.00	32.72	72.64	210.00	36.00	47.00	110.00	84.84	73.51
NH ₄ (mg/l N)	0.67	3.90	0.62	3.60	3.50	1.68	33.00	1.60	6.10	0.11	0.42	0.64
NO ₃ (mg/l)	3.20	0.72	1.63	1.40	2.60	2.91	2.60	0.81	0.89	2.70	1.95	3.66
pH	7.10	6.60	7.46	3.50	4.94	7.90	5.60	8.00	6.90	7.90	8.15	7.94
PO ₄ (mg/l)	0.17	0.17	0.21	0.13	0.26	0.64	0.10	0.10	0.09	0.09	0.22	0.57
SO ₄ (mg/l)	790.00	660.00	729.56	500.00	397.16	285.38	950.00	160.00	220.00	570.00	620.79	321.25

Table 56: Summary water quality data for Rand Water's Lower Klip sub-catchment sample points for October 1998 to September 1999.

	K25	K18	K19
COD (mg/l)	27.34	27.75	27.59
Conductivity (mS/m)	82.93	78.73	83.52
Feacal Coliforms (counts/100ml)	37264.79	12967.67	13409.44
Fe (mg/l)	0.05	0.06	0.05
Mn (mg/l)	0.30	0.32	0.77
Na (mg/l)	64.02	60.45	71.00
NH ₄ (mg/l N)	0.33	2.83	0.20
NO ₃ (mg/l)	4.07	4.15	4.53
pH	8.00	7.98	8.00
PO ₄ (mg/l)	0.71	1.09	0.73
SO ₄ (mg/l)	161.18	157.38	159.79

Appendix 6

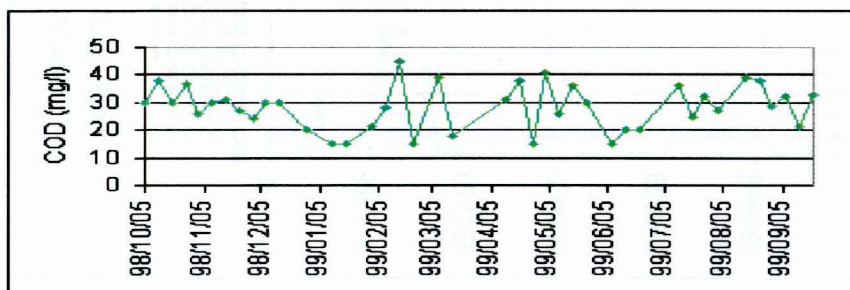


Figure 75: COD at C-K21 from 1 October 1998 to 30 September 1999.

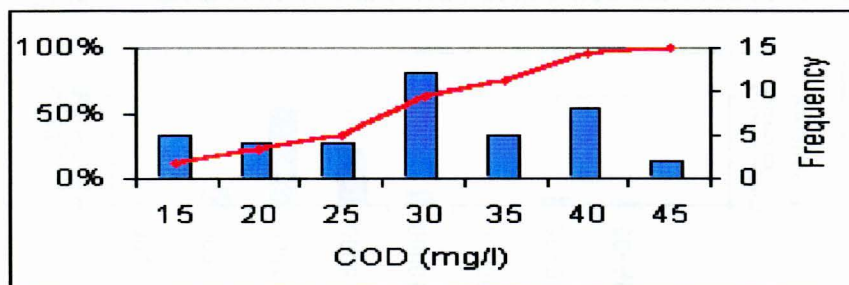


Figure 76: Frequency and cumulative percentage COD at C-K21 from 1 October 1998 to 30 September 1999.

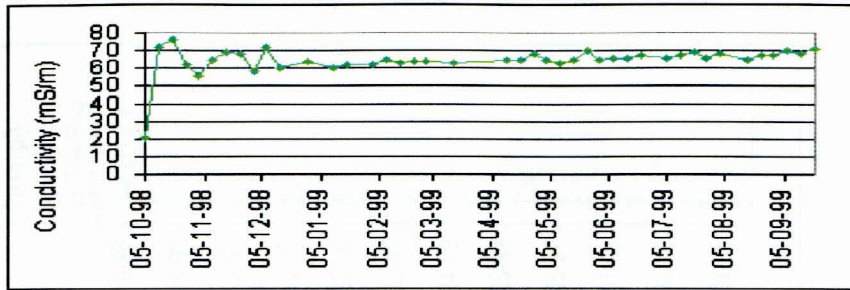


Figure 77: Conductivity at C-K21 from 1 October 1998 to 30 September 1999.

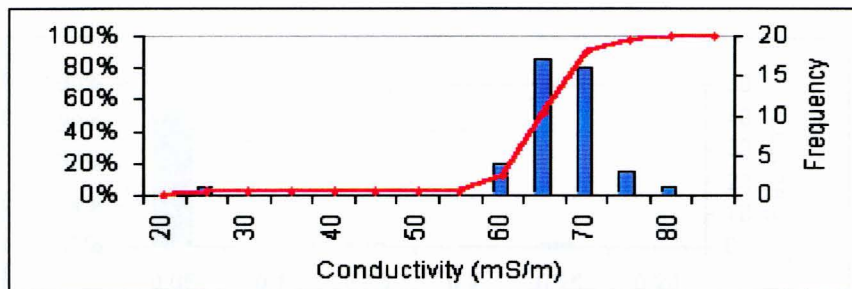


Figure 78: Frequency and cumulative percentage Conductivity C-K21 from 1 October 1998 to 30 September 1999.

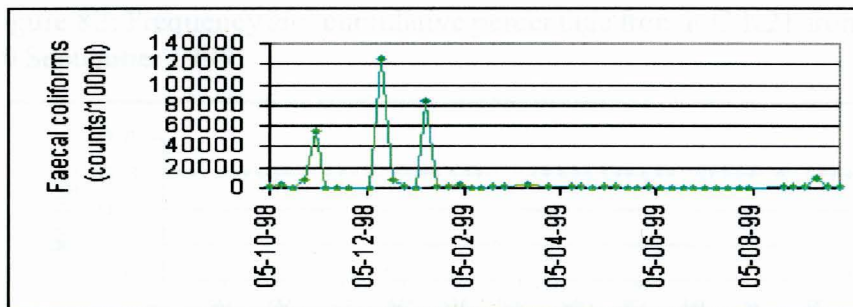


Figure 79: Faecal coliforms at C-K21 from 1 October 1998 to 30 September 1999.

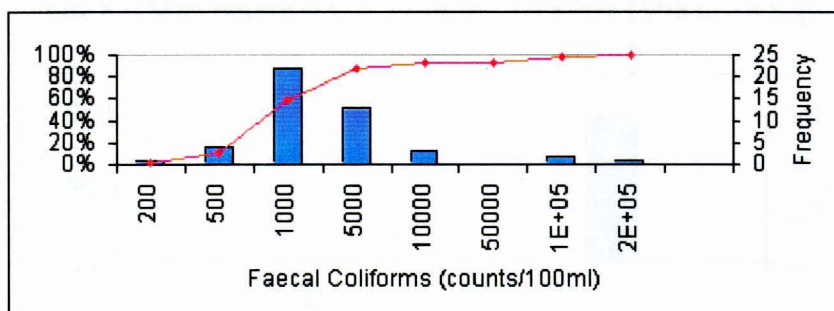


Figure 80: Frequency and cumulative percentage Faecal coliforms at C-K21 from 1 October 1998 to 30 September 1999.

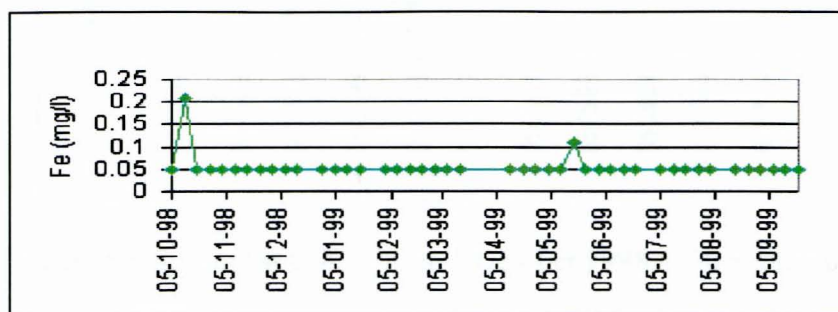


Figure 81: Iron at C-K21 from 1 October 1998 to 30 September 1999.

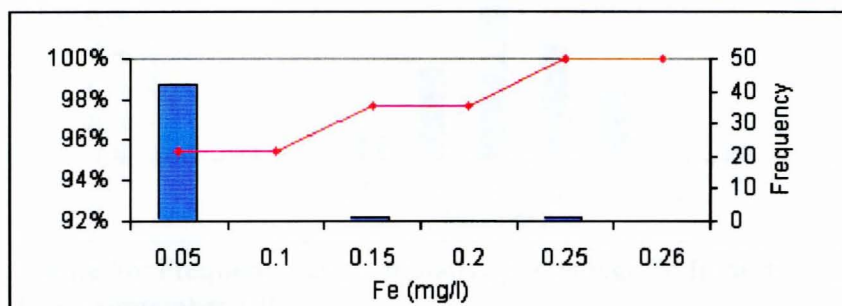


Figure 82: Frequency and cumulative percentage Iron at C-K21 from 1 October 1998 to 30 September 1999.

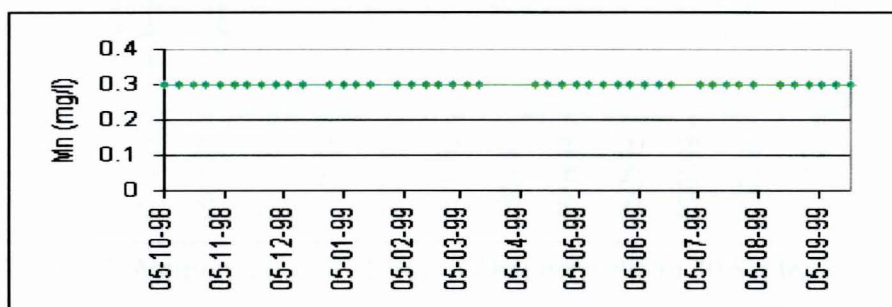


Figure 83: Manganese at C-K21 from 1 October 1998 to 30 September 1999.

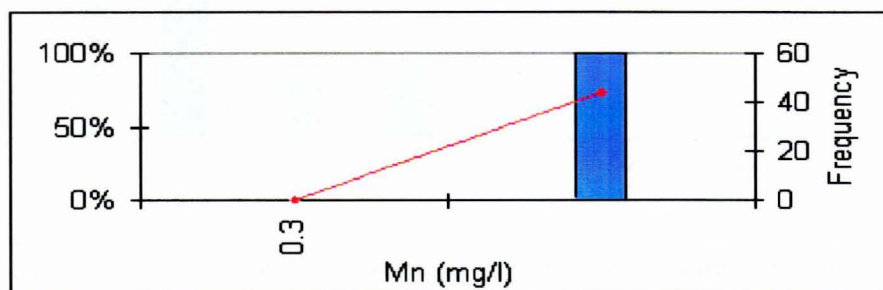


Figure 84: Frequency and cumulative percentage Manganese at C-K21 from 1 October 1998 to 30 September 1999.

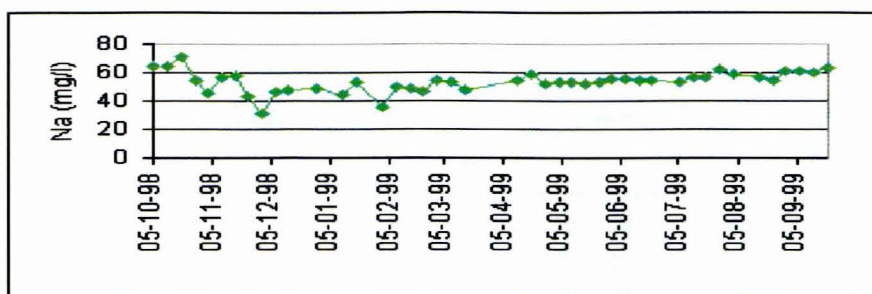


Figure 85: Sodium at C-K21 from 1 October 1998 to 30 September 1999.

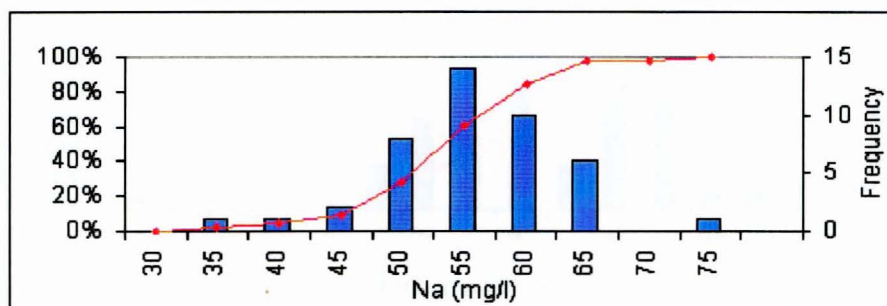


Figure 86: Frequency and cumulative percentage Sodium at C-K21 from 1 October 1998 to 30 September 1999.

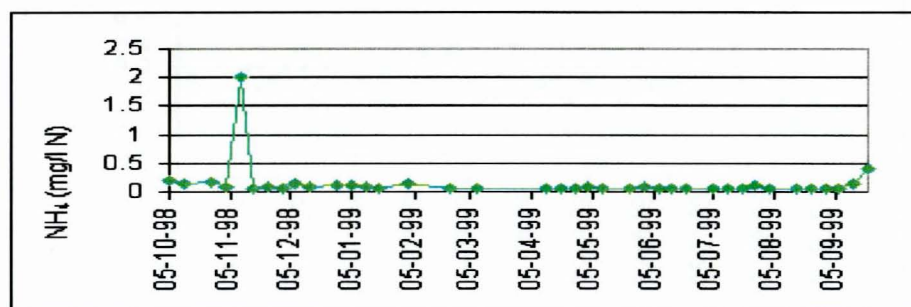


Figure 87: Ammonia at C-K21 from 1 October 1998 to 30 September 1999.

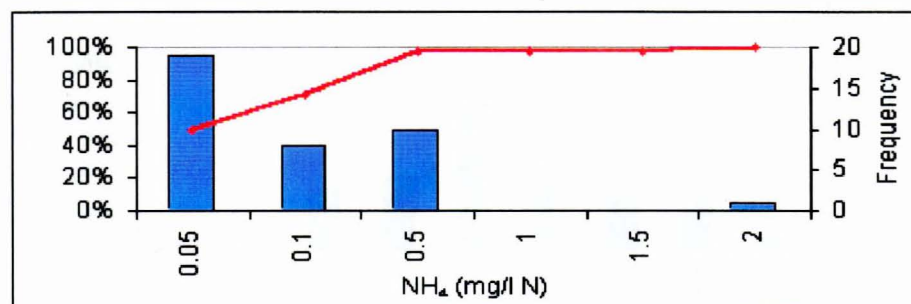


Figure 88: Frequency and cumulative percentage Ammonia at C-K21 from 1 October 1998 to 30 September 1999.

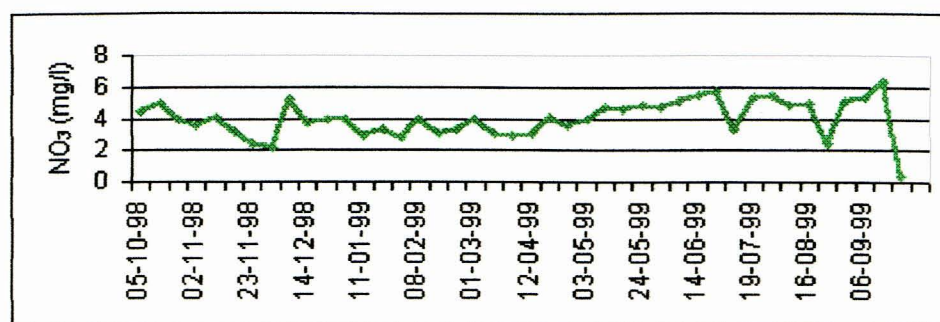


Figure 89: Nitrate at C-K21 from 1 October 1998 to 30 September 1999.

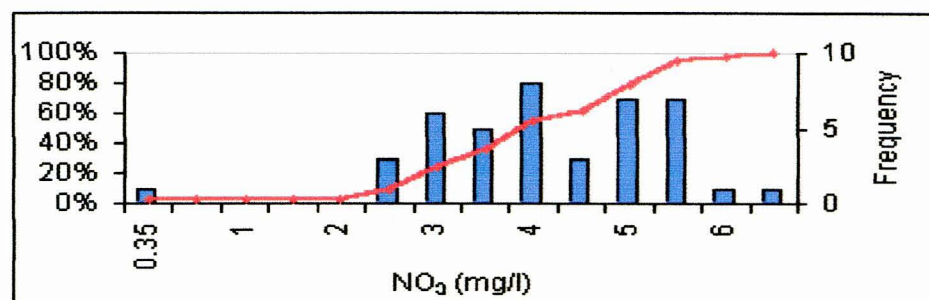


Figure 90: Frequency and cumulative percentage Nitrate at C-K21 from 1 October 1998 to 30 September 1999.

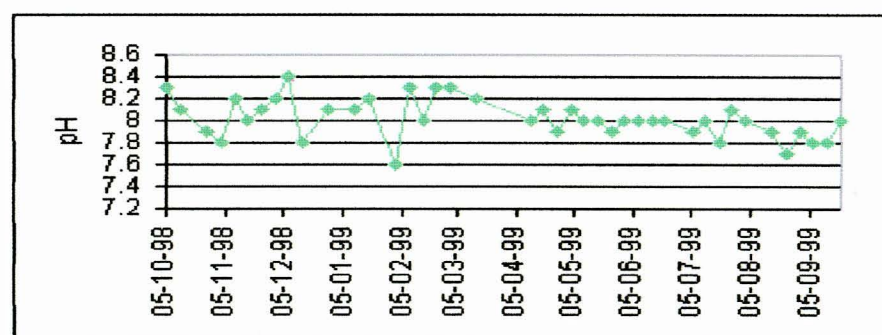


Figure 91: pH at C-K21 from 1 October 1998 to 30 September 1999.

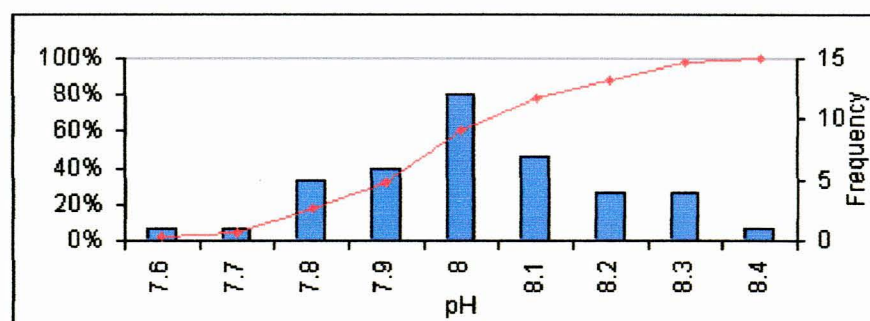


Figure 92: Frequency and cumulative percentage pH at C-K21 from 1 October 1998 to 30 September 1999.

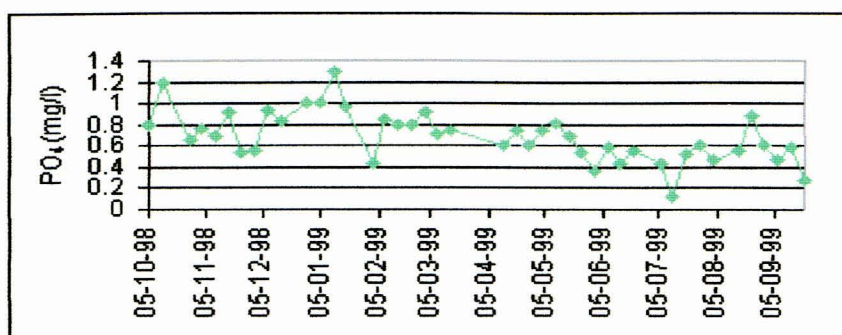


Figure 93: ortho-Phosphate at C-K21 from 1 October 1998 to 30 September 1999.

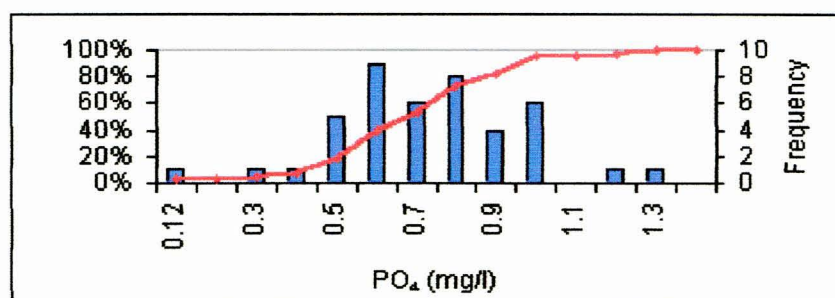


Figure 94: Frequency and cumulative percentage ortho-Phosphate at C-K21 from 1 October 1998 to 30 September 1999.

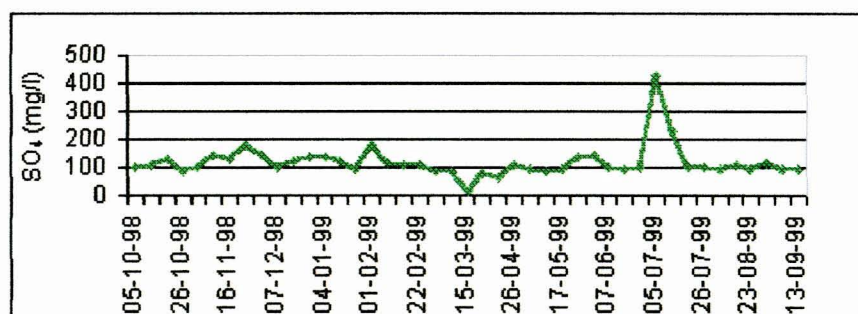


Figure 95: Sulphate at C-K21 from 1 October 1998 to 30 September 1999.

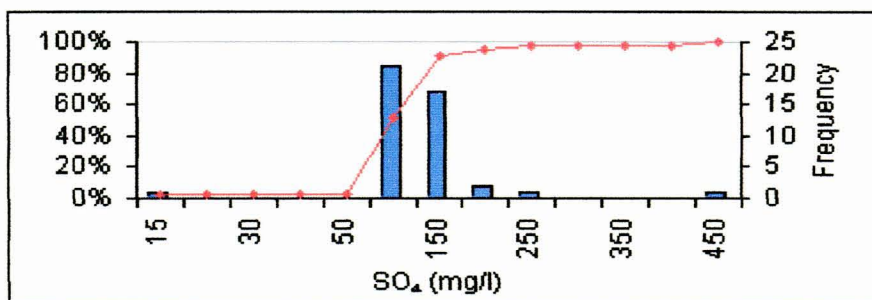


Figure 96: Frequency and cumulative percentage Sulphate C-K21 from 1 October 1998 to 30 September 1999.

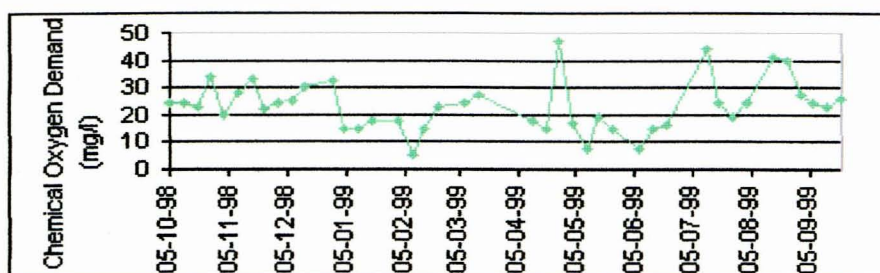


Figure 97: COD at C-R-6 from 1 October 1998 to 30 September 1999.

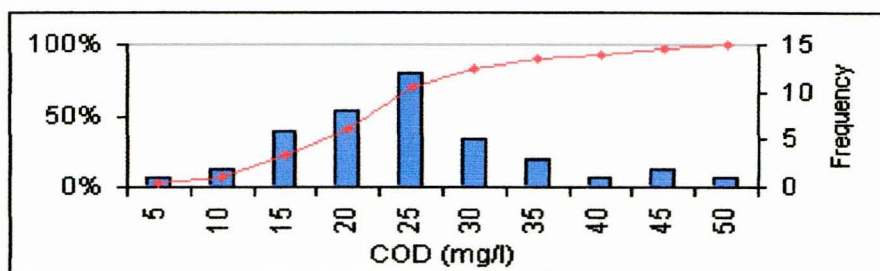


Figure 98: Frequency and cumulative percentage COD at C-R6 from 1 October 1998 to 30 September 1999.

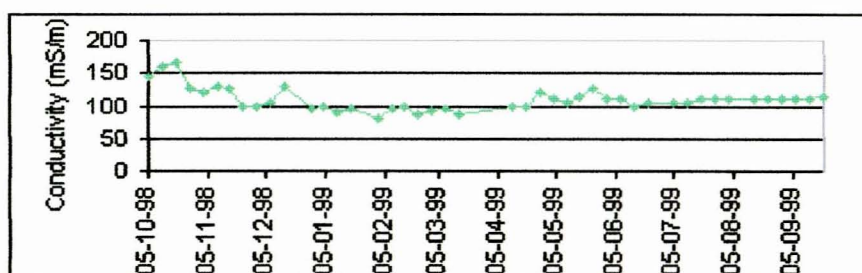


Figure 99: Conductivity at C-R6 from 1 October 1998 to 30 September 1999.

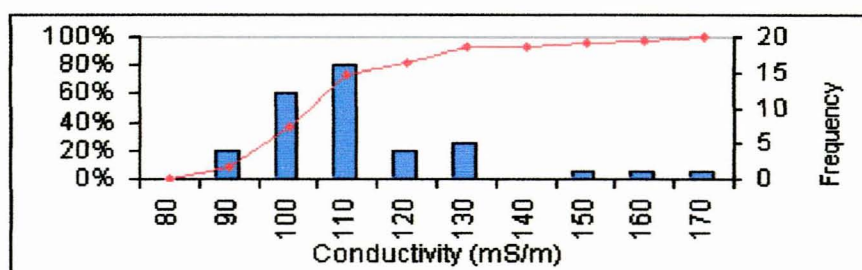


Figure 100: Frequency and cumulative percentage Conductivity C-R6 from 1 October 1998 to 30 September 1999.

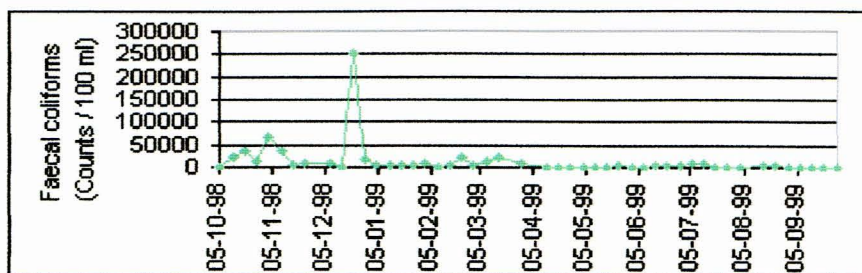


Figure 101: Faecal coliforms at C-R6 from 1 October 1998 to 30 September 1999.

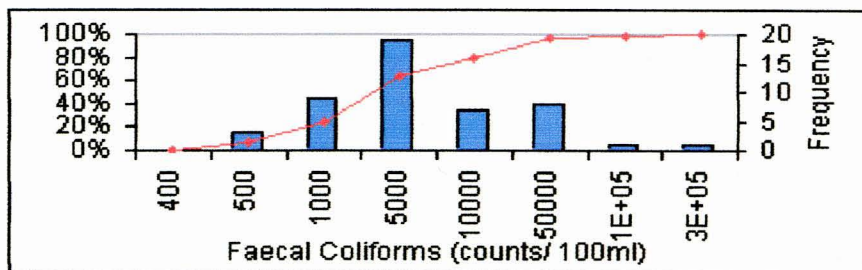


Figure 102: Frequency and cumulative percentage Faecal coliforms at C-R6 from 1 October 1998 to 30 September 1999.

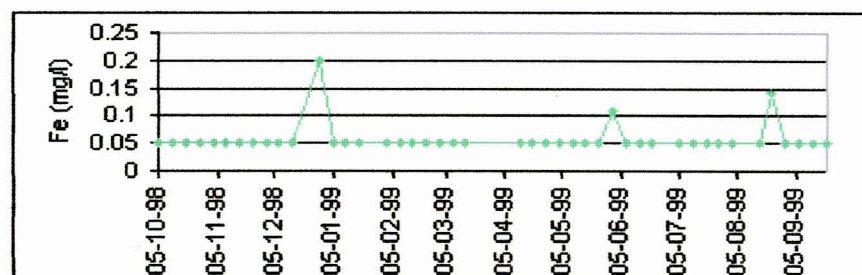


Figure 103: Iron at C-R6 from 1 October 1998 to 30 September 1999.

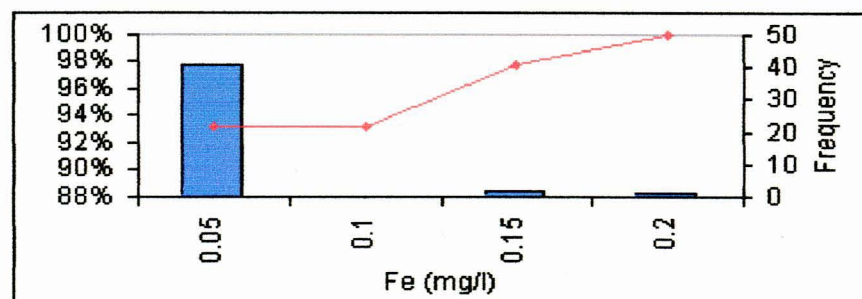


Figure 104: Frequency and cumulative percentage Iron at C-R6 from 1 October 1998 to 30 September 1999.

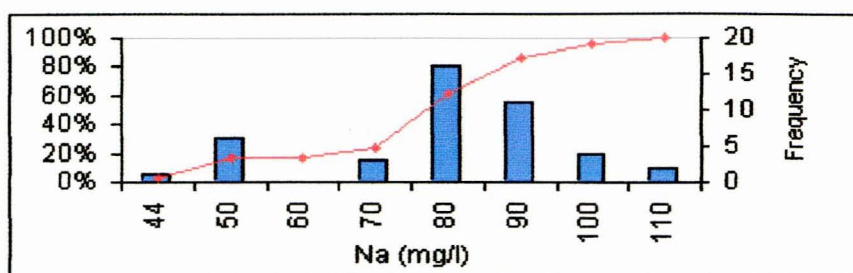


Figure 105: Frequency and cumulative percentage Sodium at C-R6 from 1 October 1998 to 30 September 1999.

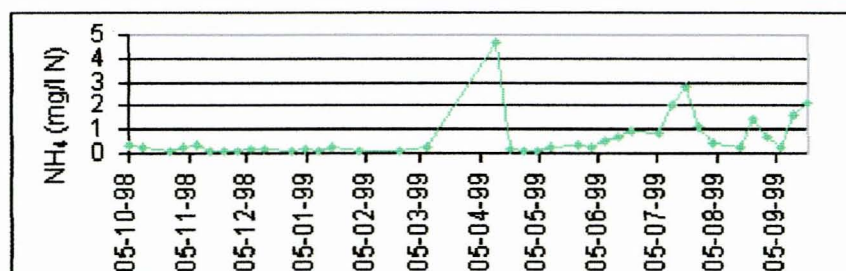


Figure 106: Ammonia at C-R6 from 1 October 1998 to 30 September 1999.

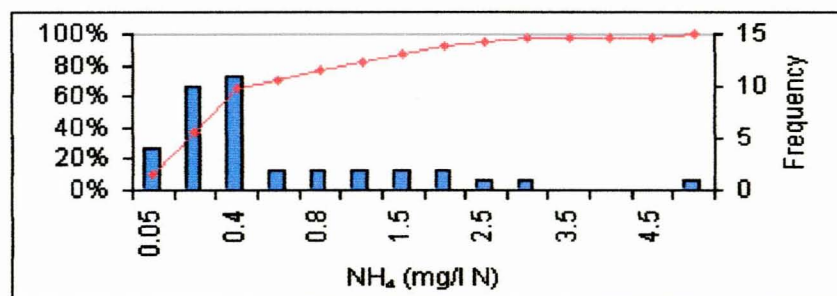


Figure 107: Frequency and cumulative percentage Ammonia at C-R6 from 1 October 1998 to 30 September 1999.

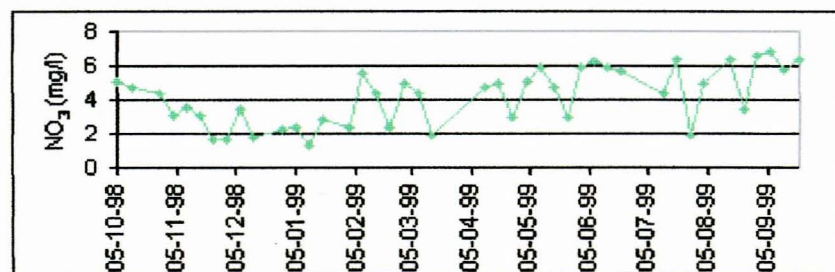


Figure 108: Nitrate at C-R6 from 1 October 1998 to 30 September 1999.

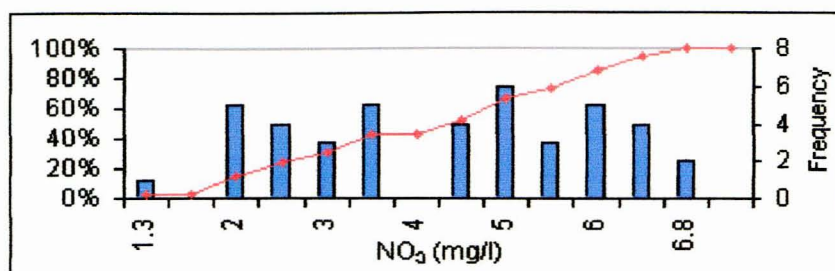


Figure 109: Frequency and cumulative percentage Nitrate at C-R6 from 1 October 1998 to 30 September 1999.

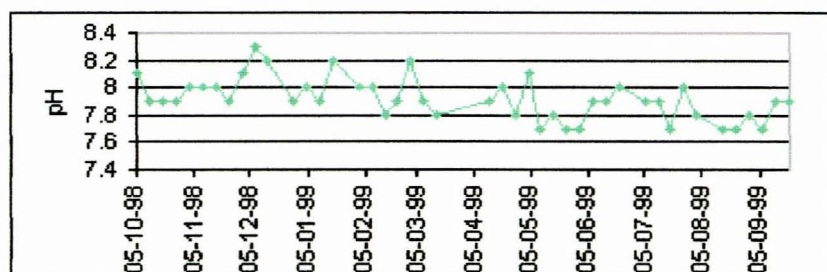


Figure 110: pH at C-R6 from 1 October 1998 to 30 September 1999.

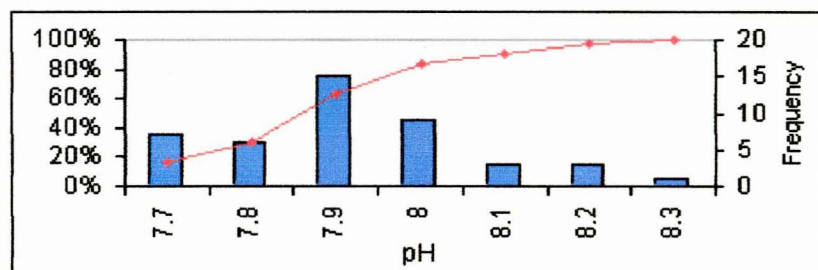


Figure 111: Frequency and cumulative percentage pH at C-R6 from 1 October 1998 to 30 September 1999.

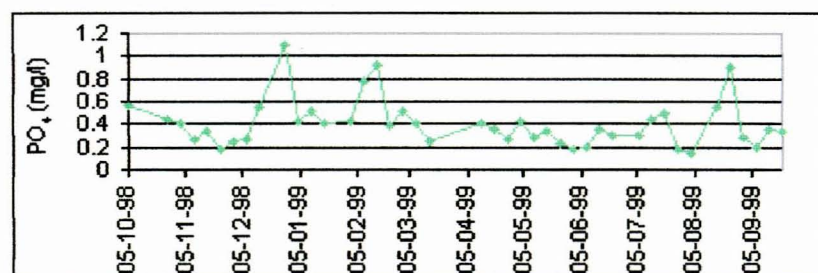


Figure 112: ortho-Phosphate at C-R6 from 1 October 1998 to 30 September 1999.

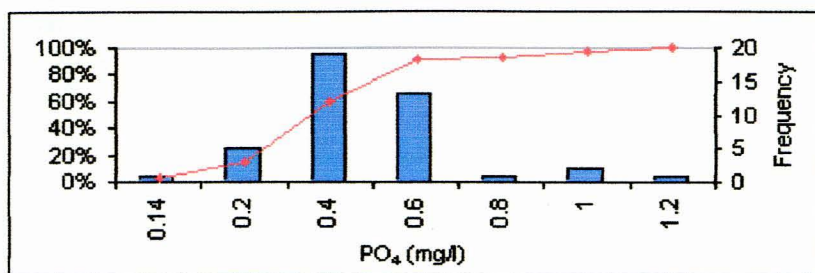


Figure 113: Frequency and cumulative percentage ortho-Phosphate at C-R6 from 1 October 1998 to 30 September 1999.

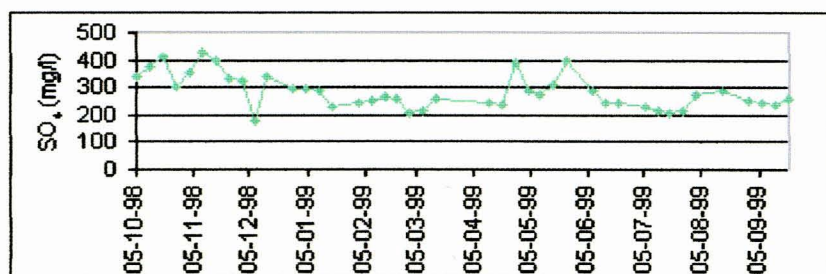


Figure 114: Sulphate at C-R6 from 1 October 1998 to 30 September 1999.

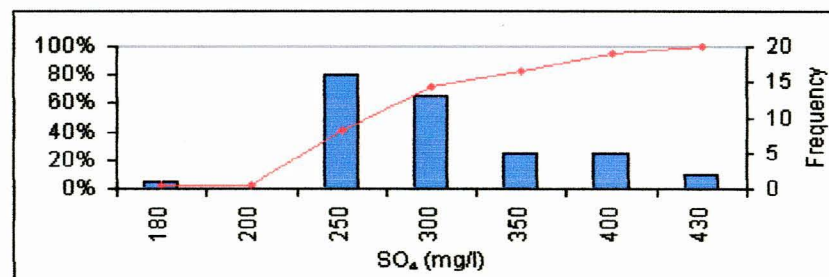


Figure 115: Frequency and cumulative percentage Sulphate at C-R6 from 1 October 1998 to 30 September 1999.

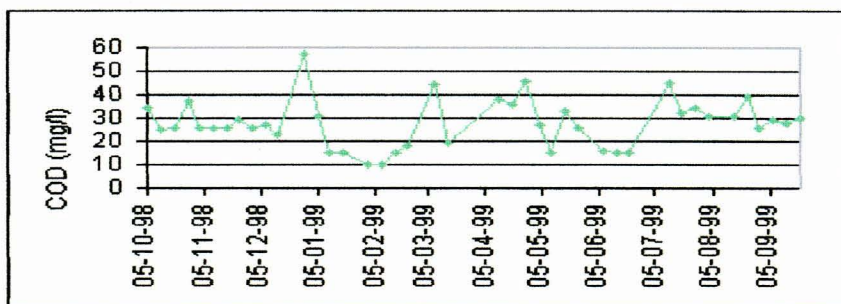


Figure 116: COD at C-K19 from 1 October 1998 to 30 September 1999.

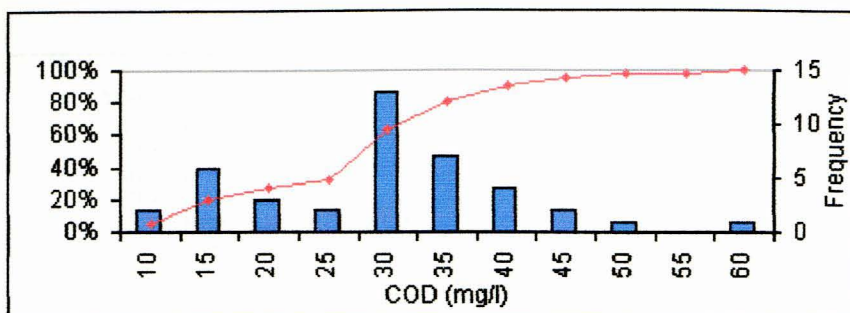


Figure 117: Frequency and cumulative percentage COD at C-K19 from 1 October 1998 to 30 September 1999.

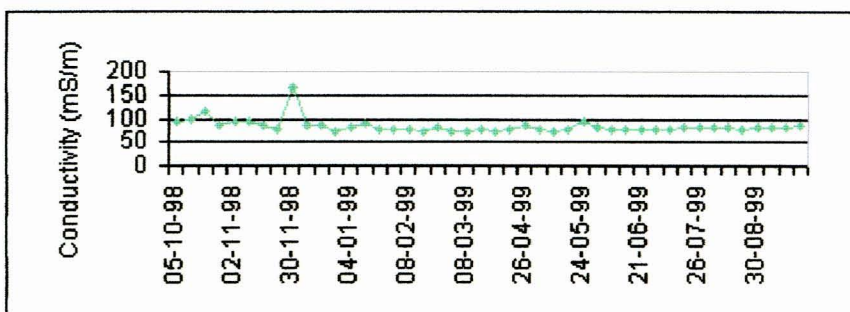


Figure 118: Conductivity at C-K19 from 1 October 1998 to 30 September 1999.

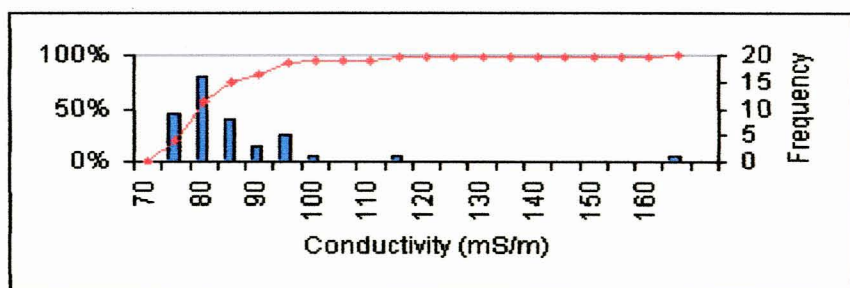


Figure 119: Frequency and cumulative percentage Conductivity at C-K19 from 1 October 1998 to 30 September 1999.

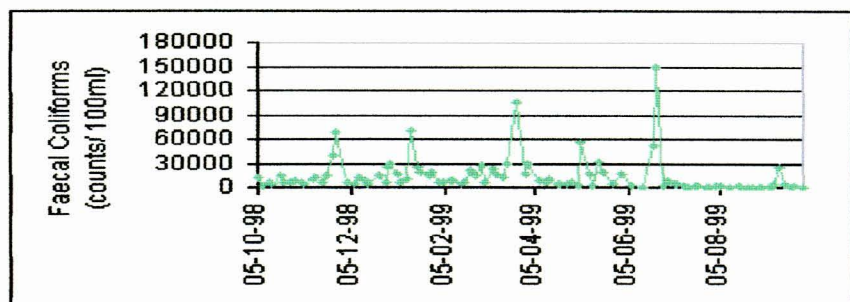


Figure 120: Faecal coliforms at C-K19 from 1 October 1998 to 30 September 1999.

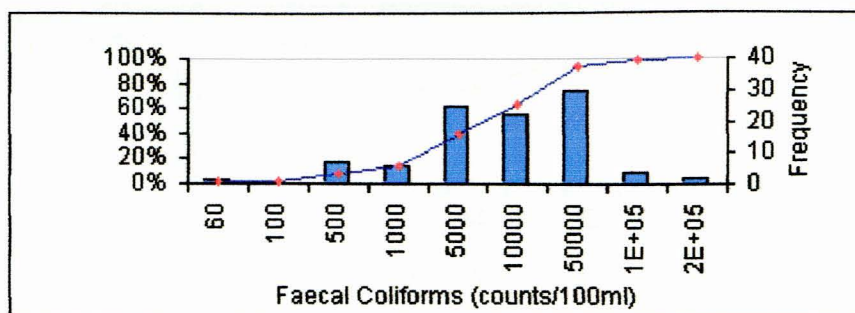


Figure 121: Frequency and cumulative percentage Faecal coliforms at C-K19 from 1 October 1998 to 30 September 1999.

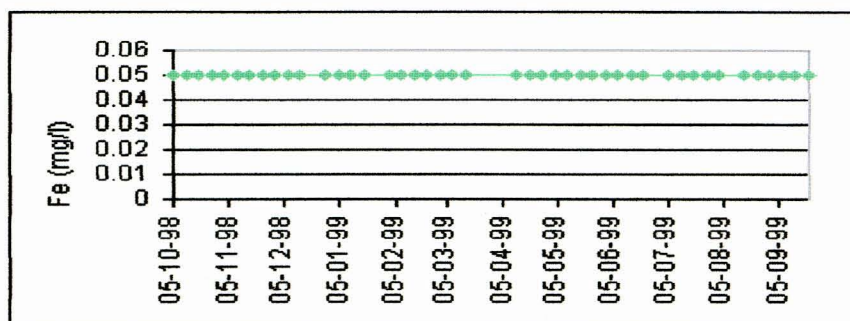


Figure 122: Iron at C-K19 from 1 October 1998 to 30 September 1999.

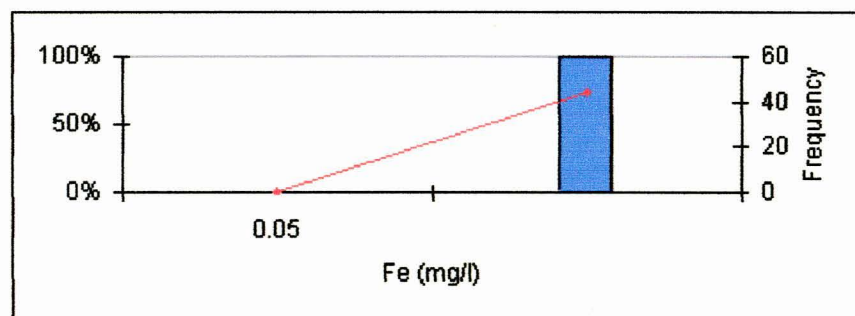


Figure 123: Frequency and cumulative percentage Iron at C-K19 from 1 October 1998 to 30 September 1999.

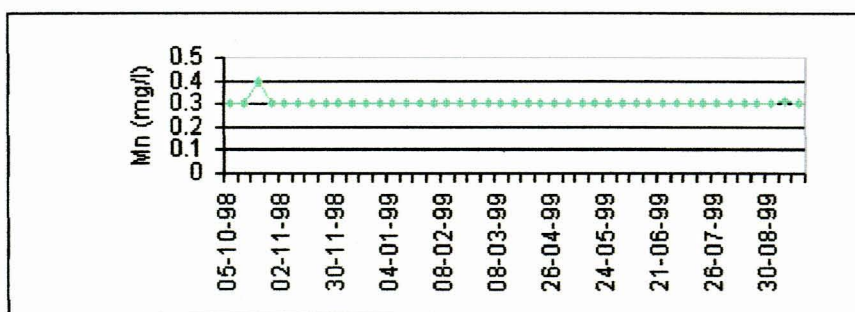


Figure 124: Manganese at C-K19 from 1 October 1998 to 30 September 1999.

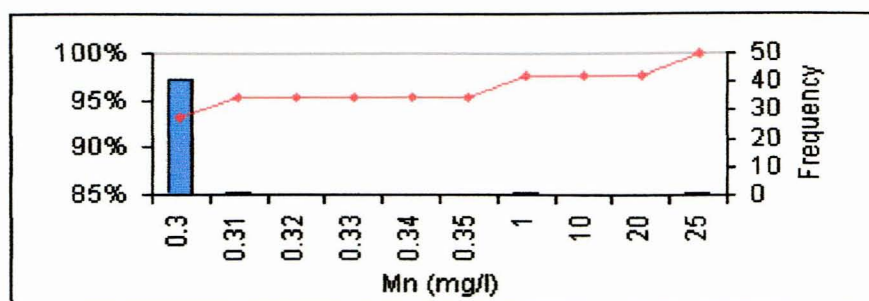


Figure 125: Frequency and cumulative percentage Manganese at C-K19 from 1 October 1998 to 30 September 1999.

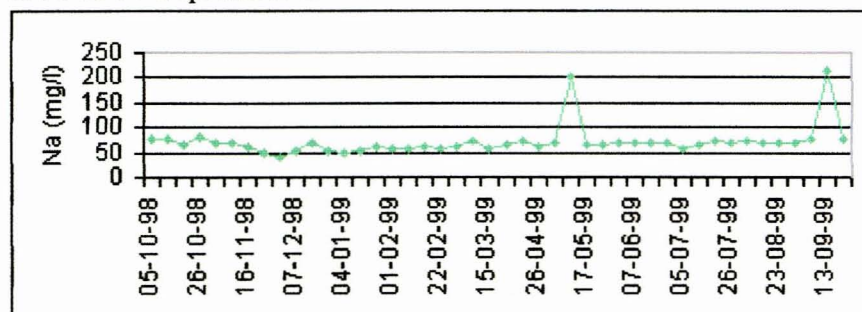


Figure 126: Sodium at C-K19 from 1 October 1998 to 30 September 1999.

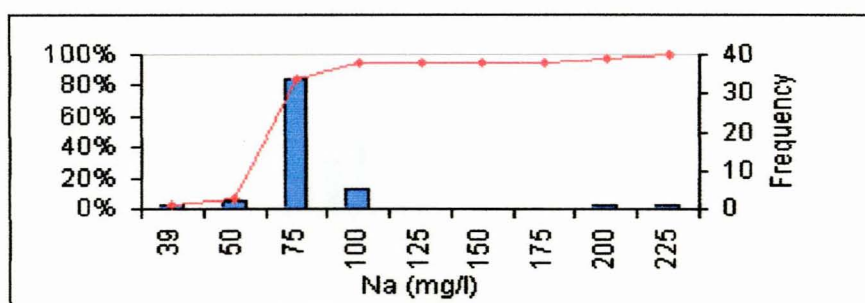


Figure 127: Frequency and cumulative percentage Sodium at C-K19 from 1 October 1998 to 30 September 1999.

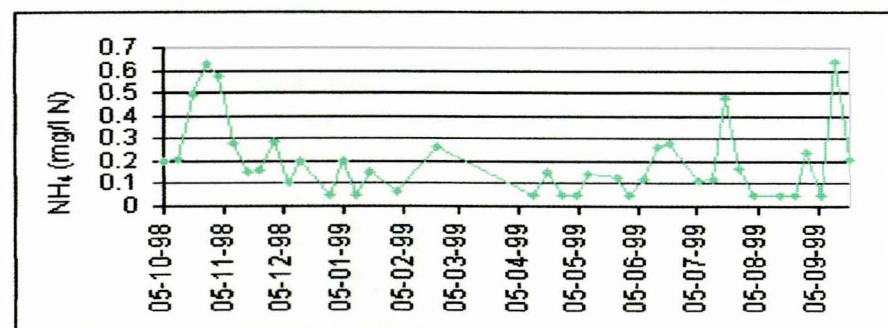


Figure 128: Ammonia at C-K19 from 1 October 1998 to 30 September 1999.

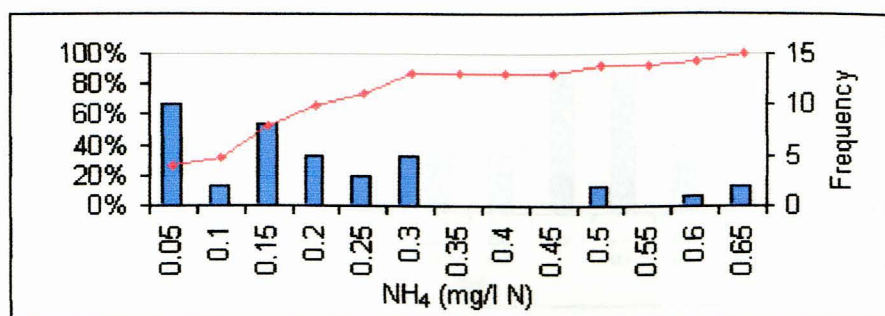


Figure 129: Frequency and cumulative percentage Ammonia at C-K19 from 1 October 1998 to 30 September 1999.

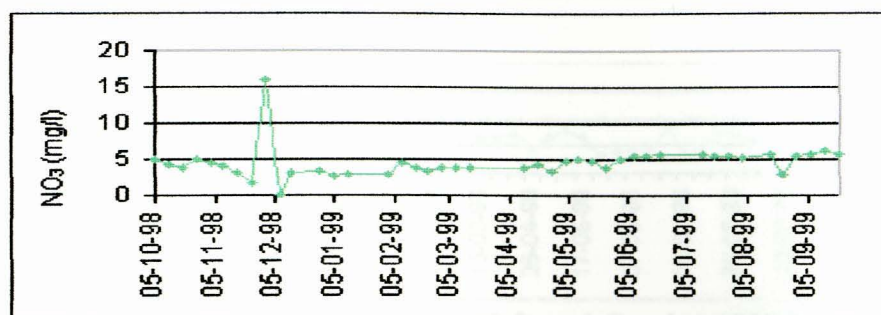


Figure 130: Nitrate at C-K19 from 1 October 1998 to 30 September 1999.

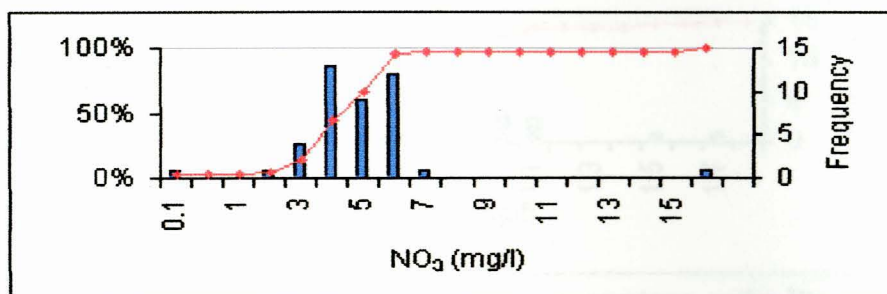


Figure 131: Frequency and cumulative percentage Nitrate at C-K19 from 1 October 1998 to 30 September 1999.

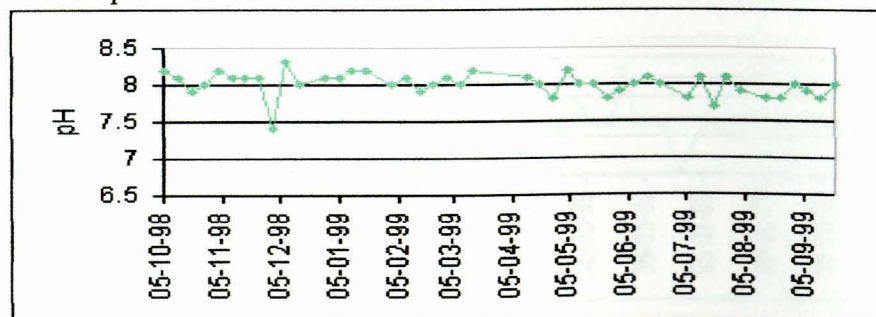


Figure 132: pH at C-K19 from 1 October 1998 to 30 September 1999.

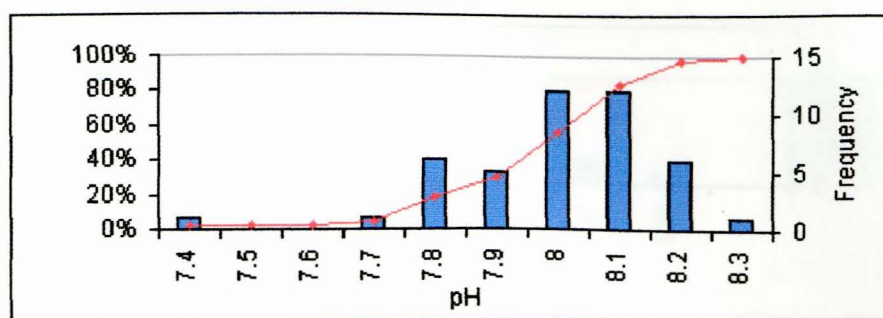


Figure 133: Frequency and cumulative percentage pH at C-K19 from 1 October 1998 to 30 September 1999.

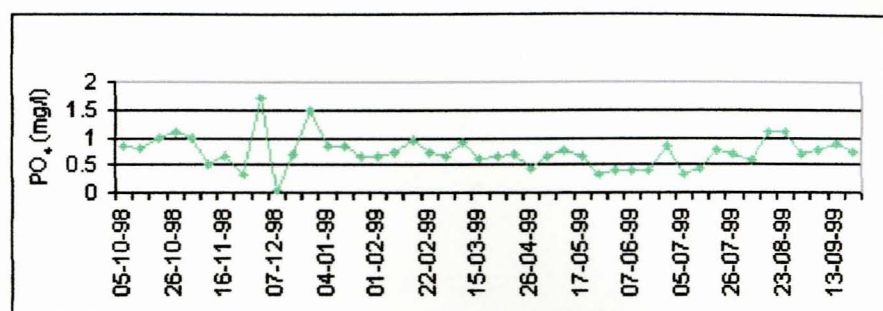


Figure 134: ortho-Phosphate at C-K19 from 1 October 1998 to 30 September 1999.

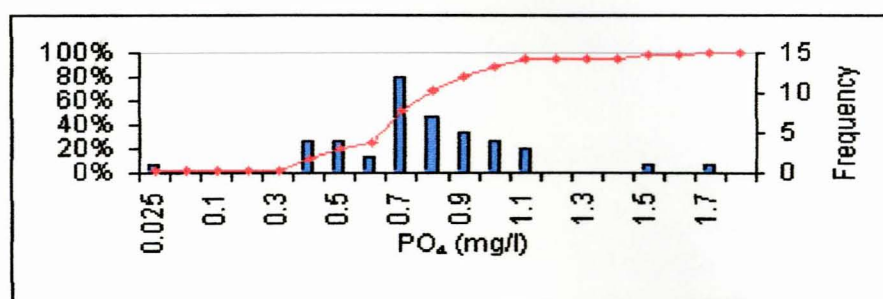


Figure 135: Frequency and cumulative percentage ortho-Phosphate at C-K19 from 1 October 1998 to 30 September 1999.

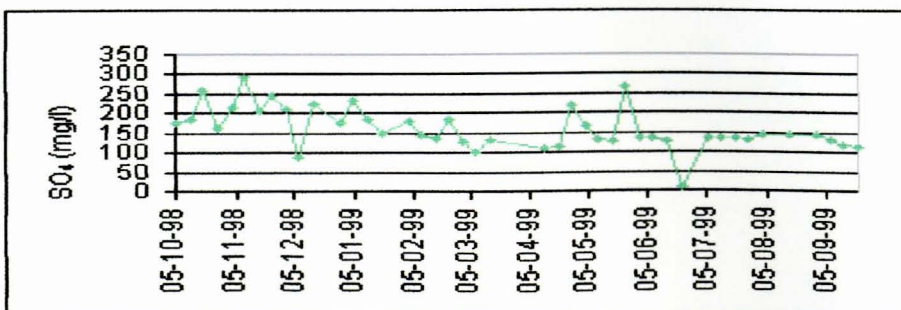


Figure 136: Sulphate at C-K19 from 1 October 1998 to 30 September 1999.

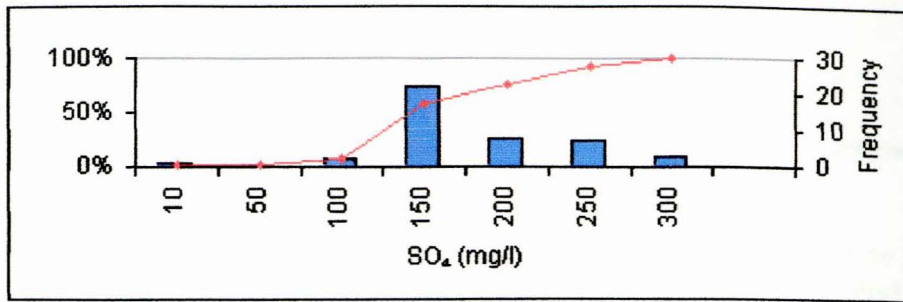


Figure 137: Frequency and cumulative percentage Sulphate at C-K19 from 1 October 1998 to 30 September 1999.

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