Makana Municipality
Local Environmental Action Plan
Comprehensive Audit Report
Part I: Water Resources and Wetlands

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1. WATER RESOURCE STATUS AUDIT

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2.1 EXECUTIVE SUMMARY

The ‘water resource’ is defined by the National Water Act (Act 36 of 1998) to include all water in the hydrological cycle. At the national level this includes rainfall and runoff; and water in ecosystems including rivers, lakes or dams, wetlands, estuaries and groundwater. At the Makana level, this includes rivers, dams and groundwater, with small pockets of wetlands.

Three main aspects to the water resource include water quantity (flow and storage); water quality (chemistry and biotic indicators); and habitat structure. Water quality related decisions invariably involve water quantity effects and vice versa. These in turn relate to water use decisions such as discharge of effluent and development of surface water resources. Conversely, changes in flow patterns, re-routing of water resources and changes to water allocation profiles may all affect water quality.

The National Water Act legislates the resource management. There are two approaches:

- *Resource Directed Measures (RDM)*, which provide descriptive and quantitative goals for the state of the resource; and
- *Source Directed Controls (SDC)*, which specify the criteria for controlling impacts such as waste discharge licences and abstraction licences.

Both of these require knowledge of the present state so that ecological objectives can be set; and use can be controlled. An audit is therefore necessary to determine what is termed the *‘Present Ecological State’*.

1.1.1 Water Quantity

Over-abstraction of surface and groundwater is a key concern in Makana. The Department of Water Affairs and Forestry (DWAF) are responsible for the monitoring of surface and groundwater quantity. However the data from these monitoring points are insufficient for water resource planning and complete assessment. Environmental flows and water allocations for domestic, agricultural and industrial use have therefore still to be determined. There is also:

- no assessment of existing lawful use of water including that used for agricultural use;
- no collated data on the present water reserves, and demands, within Makana that has been made accessible to the LEAP team, or is available in an accessible form to stakeholders; and
- no model for projected estimates of domestic, educational (in particular Rhodes University’s projected numbers of entrees), industrial and agricultural growth and therefore water demands.

Auditing of water quantity within Makana is of concern in the Monitoring and Implementation Plans presented. A hydrological model and a water use model are therefore to be suggested for the Implementation Plan.

1.1.2 Water Quality

Traditionally, the term ‘water quality’ has meant water physico-chemistry. However, water quality is more than this, and the term ‘environmental water quality’ (EWQ) is now used. The

EWQ approach involves understanding how the chemical, microbiological, radiological and physical characteristics of water (water quality) link to the responses of living organisms and ecosystem processes (environment). The primary abiotic factors that shape aquatic ecosystems (water quality, flow, and physical or habitat structure) provide the conditions for the biotic processes. These combined biophysical processes link to social and economic processes through the human use of water resources.

To obtain an integrated EWQ picture there are three main kinds of information required: information about the *physico-chemistry* of the water; the presence, absence and abundance of biota in the ecosystem (*biomonitoring*); and the responses of specific biota to specific concentrations of chemicals or mixtures (*ecotoxicology*). The physico-chemistry and biomonitoring together indicate whether there is a need for ecotoxicological assessments, which was the case with the Grahamstown Sewage Treatment Works. Analysis and interpretation of all water quality data followed the ecological Reserve assessment method (Palmer *et al*., 2004b).

1.1.3 Results of the water quality audit

- The Bloukrans River downstream of Grahamstown residential and industrial areas and the sewage treatment works is in a *Poor ecological state* according to the physico-chemical, biomonitoring and ecotoxicological data. The state of the River was also a primary stakeholder concern.
- There was *no nutrient enrichment* (total inorganic nitrogen and soluble ortho-phosphates) at any of the DWAF water quality monitoring sites. *However,* there were no DWAF water quality monitoring data available for the Bloukrans River to date [input still ongoing by DWAF] but the algal growth within the river is indicative of enrichment.
- There was *measurable ecotoxicity* of the influent and effluents around the Grahamstown Sewage Treatment Works (STW). This preliminary study indicates the outlet pipe into the STW dam was *less* toxic than the outlet pipe into the *River*. An ecotoxicity risk assessment is an urgent priority. The need for physico-chemical data collection and collation around the Grahamstown Sewage Treatment Works is therefore also a priority.
- At various sites on the Bushmans and Kariega Rivers, the water is too *salty* to irrigate or for use in domestic or livestock consumption.
- There is significant evidence of *toxic salt levels* at many of the DWAF water quality sites within Makana, dominated by magnesium sulphate and sodium chloride. However, there is a need to determine whether these values are just indicative of low flows combined with abstraction and evaporation; and/or the natural state, reflecting the ancient marine shales underlying parts of Makana. The introduction of reference sites above possible point sources of pollution would be of value.
- The Alicedale tannery effluents, and other potential effluents with recent developments, are also of concern. More data points are needed upstream and downstream of Alicedale on the Bushmans River for both water quality monitoring (DWAF), in conjunction with biomonitoring sites that will potentially facilitate any red flag scenarios of concern.

1.1.4 Habitat Structure within the Rivers

This was assessed within the Bloukrans River and the confluence of the Berg and Palmiet Rivers, as part of the biomonitoring assessments completed. Alien vegetation encroachment, a stakeholder concern, is included in the Biodiversity section of the LEAP Comprehensive Report.

1.1.5 Implementation Plan

The Implementation Plan will therefore include three main suggestions:

1) An ecotoxicological risk assessment, based around Grahamstown and its Sewage Treatment Works;
2) The development of hydrological and water use models for Makana;
3) An assessment of the natural salinity levels within the water resources.

Highlighted from this Audit has been the particular necessity, in addition, for:

4) Water quality and quantity data management by [DWAF and therefore] Makana Municipality;
5) An understanding by both Makana Municipality and stakeholders of water resources and water resource management; and therefore the implementation of the Resource Directed Measures and Source Directed Controls.

This comprehensive audit has been more extensive than budgeting allowed for, and we must thank Unilever Foundation for partial sponsorship of human resources.

2.2 INTRODUCTION

The microbial, physical, chemical and radiological properties of water affect both ecosystem health and the fitness for use of water. Managing water quality requires attention both to ecosystem health and the requirements of water users. Aquatic ecosystems are not always more sensitive to changes in water quality than domestic, agricultural and industrial users. For example faecal pathogens in water may have little effect on the aquatic ecosystem health, yet have a major effect on the human use of water for drinking. It is important however, that aquatic ecosystems are preserved because by doing so there will be sustainable water for domestic, agricultural and industrial users (Palmer *et al.*, 2004a; copies of which are available from the Institute for Water Research, Rhodes University).

The core indicators for freshwater resources reporting include, amongst others:

- Total surface water demand - relates directly to the monitoring required with *Resource Directed Measures (RDM)* which provide descriptive and quantitative goals for the state of the water resource; and
- Effectiveness of water resource management - relates directly to the auditing required with Source Directed Controls (SDC) which specify the criteria for controlling impacts such as waste discharge licences and abstraction licences.

Both of these require knowledge of the present state so that ecological objectives can be set; and use can be controlled. An audit is therefore necessary to determine what is termed the ‘Present Ecological State’. The mandate of this audit is to focus on the Resource Directed Measures.

Traditionally, the term 'water quality' has meant water physico-chemistry. However, water quality is more than this, and the term 'environmental water quality' (EWQ) is now used (Palmer *et al.*, 2004a). The EWQ approach involves understanding how the chemical, microbiological, radiological and physical characteristics of water (water quality) link to the responses of living organisms and ecosystem processes (environment). The primary abiotic factors that shape aquatic ecosystems (water quality, flow, and physical structure) provide the conditions for the biotic processes. These combined biophysical processes link to social and economic processes through the human use of water resources.

To obtain an integrated EWQ audit of Makana Municipality water resources, there are three main kinds of information required: information about the *physico-chemistry* of the water; the presence, absence and abundance of biota in the ecosystem (*biomonitoring*); and the responses of specific biota to specific concentrations of chemicals or mixtures (*ecotoxicology*). The physico-chemistry and biomonitoring together indicate whether there is a need for ecotoxicological assessments. This is discussed in more detail below.

1.2.1 Classification of ecological health

South African water law and policy has undergone extensive review over the past decade, and one of the new fundamental principles is that of sustainability (National Water Act No. 36 of 1998 [NWA]). The concept of sustainability implies long-term maintenance of ecosystem biodiversity, structure and function, and delivery of ecosystem goods and services (Palmer *et al*., 2004).

The NWA legislates the protection of aquatic ecosystems so that they can go on offering their goods and services to future generations. Sustainable use (which includes alteration of water quality) is key. The NWA refers to the ecological Reserve which comprises descriptions and quantitative definitions of the structure, water quality, and water quantity required by aquatic ecosystems to maintain a defined level of ecosystem health. Implementation of the ecological Reserve requires numerical and descriptive cues, or trigger values, that indicate a change of ecological condition that may in turn be indicating a change in sustainability of the water resource.

Different levels of water resource health are described by the following classification system:
Excellent or Natural: unimpacted
Good: slightly to moderately impacted
Fair: heavily impacted
Poor: unacceptably heavily impacted.

This classification is a key step in protecting aquatic ecosystems. Most of the trigger values that mark the boundaries between these different classes have been determined in terms of chemical concentrations.

In South Africa the trigger values for a suite of toxic variables are listed in the DWAF Guidelines for the Protection of Aquatic Ecosystems Volume 7 (1996), and were used for the Preliminary Audit (Appendix 1). Since then, method development has proceeded and Makana inorganic salts data have been further assessed in terms of ecological health (Jooste and Rossouw, 2002; Palmer *et al.,* 2004b) (Section 3.1).

1.2.2 Physico-chemistry

Physico-chemical data provide some information on seasonal variability and trends, and the analyses of these data are an important step in determining the quality of water resources. Physico-chemical variables potentially affecting aquatic ecosystems have been grouped as:

- *system variables*; which are characteristics of particular sites or regions *e.g.* temperature, pH, total dissolved solids, dissolved oxygen concentration, total suspended solids and total dissolved solids which includes inorganic salts and ions;
- *nutrients*; which are food for plants and microbes *e.g.* phosphates, nitrates and nitrites; and
- *toxic substances e.g.* metal ions, ammonia, pesticides and herbicides.

Each variable has an effect either beneficial or detrimental, on aquatic organisms. The effect of each variable on individual organisms is also influenced by the tolerance limits of the organism. In addition to individual variables, aquatic ecosystems are the ultimate receivers of whole effluents, which consist of combinations of water quality variables. The description and value of each variable is considered below.

Surface water nutrients measure the ratio of total inorganic nitrogen to soluble orthophosphate (TIN: PO4) together with the absolute orthophosphate concentration in a body of water. Median values give a useful indication of the degree of change in the system. A decrease in the ratio between total inorganic nitrogen and soluble orthophosphate (TIN: PO4) implies a deterioration of the resource, while an increase in the ratio indicates an improvement in the system. Higher PO_4 concentrations, however, indicate impacted conditions.

High levels of nitrates in water can cause health effects in humans when ingested and can also result in algal blooms, eutrophication and a decline in water quality. When measured over time, this indicator provides a measure of the decline or improvement of water.

The *measurement* of surface water nutrients does not allow evaluation of the potential harm contaminated water may have on both people and ecosystems. Instead, this indicator highlights the *potential impact* of impaired water quality on people and ecosystems. The indicator measures the percentage exceedance of South African Water Quality Guideline values in surface waters (DWAF, 1996) to give an indication of the potential toxicity of those waters.

Not all DWAF monitoring stations measure actual in-stream toxicity. In the Eastern Cape Province, levels of aluminium, copper, iron, manganese, nickel, lead and zinc are not measured or monitored in any of the water courses because there is very little activity that may cause elevated levels of these metals (such as mining). However, with the development of tanneries in Grahamstown, DWAF are now monitoring chrome from river sites above and below the Sewage Treatment Works (STW) on a monthly basis.

1.2.2.1 pH

The pH of natural water is determined by geological and atmospheric influences. Most fresh waters are relatively well buffered and more or less neutral, with pH ranging from 6 to 8. Human-induced acidification of rivers is normally the result of industrial effluents. Alkaline pollution is less common but may result from certain industrial effluents and anthropogenic eutrophication.

1.2.2.2 Electrical conductivity

Material dissolved in water is commonly measured as total dissolved solids (TDS), electrical conductivity (EC) or salinity (where individual salts are considered). Conductivity is a measure of the ability of a sample of water to conduct an electrical current. TDS and EC usually correlate closely for a particular type of water. Very little information is available on the tolerances of freshwater organisms to increased EC. Generally it is the rate of change rather than the absolute change that is important.

1.2.2.3 TIN (total inorganic nitrogen)

Nitrogen occurs abundantly in nature and is an essential constituent of many biochemical processes. Nitrogen is one of the nutrients that are required by plants for growth and reproduction. However, it is also implicated in excessive plant growth resulting from nutrient enrichment (eutrophication) of aquatic systems. In both natural and polluted waters, nitrogen may be present in many forms but the forms that are measured by the common water quality test include ammonia (NH_3^+), ammonium (NH_4^+), nitrites (NO_2^-) and nitrates (NO_3^-).

Ammonia and ammonium are reduced forms of inorganic nitrogen and their relative proportions are controlled by water temperature and pH. Nitrite is the inorganic intermediate, and nitrate is the end product of the oxidation of organic nitrogen and ammonia. Because of their co-occurrence and rapid inter-conversion, nitrite and nitrate are often measured and considered together. The term total inorganic nitrogen includes both the dissolved forms of inorganic nitrogen and those adsorbed onto suspended inorganic and organic material, since they are all available for uptake by algae and higher plants. Inorganic nitrogen concentrations below 0.5 mg/l are considered to be sufficiently low that they can limit eutrophication and reduce the likelihood of growths of blue-green algae and other plants.

1.2.2.4 Soluble reactive phosphorus

Phosphorus can occur in numerous organic and inorganic forms, and may be present in waters as dissolved or as particulate forms. Phosphorus is an essential macronutrient, and is accumulated by a variety of living organisms. Soluble orthophosphate is the only form that can be used by aquatic organisms. In un-impacted river systems, phosphorus is readily taken out of solution and used by plants. Phosphorus is considered to be the principal nutrient controlling the degree of eutrophication in aquatic ecosystems. High concentrations of phosphorus are likely to occur in waters that receive sewage and leaching or runoff from cultivated land.

1.2.2.5 Fluoride

Fluoride is highly reactive and will attack most material including glass. It readily forms complexes with many metals. However, most fluorides are insoluble in water. Typically the concentration of fluoride in unpolluted surface water is approximately 0.1mg/l. Drinking water is estimated to contribute between 50% and 75% of the total dietary fluoride intake in adult human beings. In domestic water supplies and industrial supplies used in the food and beverage industries, the fluoride concentration in the water should not exceed 0.7mg/l. Excessive amounts of fluoride result in tooth damage in young animals and bone lesions that cause crippling in older animals. If fluoride is ingested it is completely absorbed, and distributed throughout the body. Most of the fluoride is retained in the skeleton and a small proportion in the teeth in vertebrates and high doses of fluoride interfere with carbohydrate, lipid, protein, vitamin, enzyme and mineral metabolism.

Temperature is usually considered in water quality assessments. However, there are presently no sources of water discharges in Makana that will potentially cause sudden temperature changes of ecological significance, except for dam discharges. It is considered by the authors that DWAF or Makana Municipality do not presently have the manpower to monitor ecological effects relative to other more pressing issues and therefore temperature has not been included in this audit.

Physico-chemical data on their own have limitations, however, in interpreting potentially detrimental effects to the environment. They are usually based on monthly samples collected at sampling points that have more to do with sampling convenience than ecological understanding. Because of the low frequency and range of variables analysed, these data may indicate that conditions are more ecologically favourable than is the reality. Biomonitoring is therefore a useful tool.

1.2.3 Biomonitoring

Biomonitoring is based on organisms always being present in the water, experiencing the full frequency and duration of extreme chemical concentrations. The presence or absence of sensitive organisms, or a change in community structure, can indicate the effects of change in water chemistry, which may not be detected by the chemical data record. Organisms also respond to different physicochemical concentrations, and have different tolerance limits and preferences. The presence, absence or abundance and tolerances of organisms provide the links between water physico-chemistry and biotic responses.

Biomonitoring indices used to assess changes in water quality include the Fish Assemblage Integrity Index (FAII), the Riparian Vegetation Index (RVI) and the Index of Habitat Integrity (IHI). The FAII categorizes fish communities according to an intolerance rating which takes into account trophic preference and specialization, requirement for flowing water during different life-stages, and association with habitats with unmodified water quality. The RVI determines the status of riparian vegetation within river segments based on the qualitative assessment of a number of criteria – vegetation removal, cultivation, construction, inundation, erosion/ sedimentation and alien species of vegetation. The IHI has been developed to assess the impact of major disturbances on river reaches. These disturbances include water abstraction, flow regulation, and bed and channel modification.

Invertebrates are the most useful to monitor because there are so many of them and they have a diverse range of tolerances. For the purposes of this limited, initial investigation, only the invertebrates have been monitored. Invertebrates have the advantage, as biomonitoring indicators, of being sedentary and remaining in one area.

Biomonitoring can be used for different purposes, including

- surveillance of the general ecological state of an aquatic ecosystem;
- assessment of an impact (both before and after the impact, or upstream and downstream of the impact) – both diffuse and point-source impacts;
- audit of compliance with ecological objectives or regulatory standards; and
- detection of long-term trends in the environment as a result of any number of perturbations.

The SASS (South African Scoring System, Version 4, Chutter 1998; and Version 5, Dickens & Graham 2002) is one of the techniques that is a well recognised measure of water quality in South Africa. It is based on the presence of families of aquatic invertebrates and their sensitivity to water quality changes. The SASS method produces three different and complimentary scores, SASS Score, Number of Taxa and ASPT (Average Score per Taxon). The ASPT is the least variable of the scores (Dallas, 2000; Dickens & Graham, 2002) and also provides the most reliable measure of an Excellent/Natural Class; with the other two scores aiding interpretation. However, ASPT gives more reliable results in "clean" rivers, while in "polluted" rivers, SASS Score may be more reliable (Chutter, 1998). There are also exceptional cases where, in polluted rivers, the ASPT score can be unreasonably high. In these cases the SASS Score will indicate the presence of pollution.

People with fairly basic training can undertake the SASS method. SASS assessments are usually completed in conjunction with the Integrated Habitat Assessment System (IHAS) which gives an indication of the number of habitats available to invertebrates.

The advantage of biomonitoring indices is that they provide an integrated indication of how biota are responding to the presence of chemical variables that are not monitored by chemical analysis. Although these variables may not be identifiable, this does prompt management and decision makers to identify and manage these variables. However, while biological assessments are useful indicators, they are merely red flags indicating a change in conditions. Unless ecotoxicological tests are undertaken (see below), it is not possible to predict to which environmental stressors the organisms are responding.

1.2.4 Ecotoxicology

Generally, *toxicology* refers to laboratory-based toxicity tests, while *ecotoxicology* refers to a greater degree of environmental realism where testing is linked to ecosystem structure and function. Ecotoxicology is the study of the effects of chemical solutions and mixtures such as industrial effluents on living organisms. The information provided by toxicity tests is a useful link between physico-chemical data and biomonitoring data as it provides information on the concentrations of chemicals at which the organisms are affected. Physico-chemical and biomonitoring data together may indicate a need for an ecotoxicological assessment, as was the case with the Grahamstown Sewage Treatment Works.

DWAF are working towards a change in policy regarding the management of complex industrial wastewater. Presently, water pollution is only controlled by managing levels of single substances in wastewater. However, a source directed control will be introduced by legislation, possibly in 2005, in the form of compulsory toxicity testing of complex industrial wastewater (Direct Estimation of Ecological Effect Potential = DEEEP; DWAF 2003). A complex wastewater discharge is defined as an industrial waste discharge with the discharge containing more than 10% complex industrial wastewater, by volume. This DEEEP policy involves looking directly at the effect(s) a mixture of substances may have on the environment, principally through the process of toxicity testing of the complex discharges. It is therefore appropriate that toxicology is introduced here as one of the steps in an integrated environmental water quality management programme for Makana.

Although there are numerous methods to use in toxicity testing, the 48-hour toxicity test, where mortality is recorded using the standard laboratory test organism *Daphnia pulex*, is the simplest and most appropriate for this initial audit. Cultures of these small crustaceans are maintained at the UCEWQ-IWR laboratories.

1.2.5 Stakeholder issues

A meeting was held with Stakeholders in March 2004 and the following categories of issues were raised:

1) *Human Health*
   - Cholera risk: concern was expressed about the safety of river water. This was in respect to the direct drinking of river water as well as indirect contact.
   - Municipal water purification standards: concern was voiced that the purification standards of the municipal water may be inadequate.

2) *Water Services*
   - Improved access to safe drinking water: a call was made for the provision of taps to new areas.
   - Lack of sanitation infrastructure in townships: the effect of poor structure on human and ecosystem health was highlighted.
   - Poor water drainage system in townships: concern regarding its effect on erosion of the landscape and resultant sedimentation in rivers was recorded.
   - The need for increased education regarding water conservation was also recorded.

3) *Ecosystem Health*
   - Pollution of the Bloukrans River: concern was voiced over the impact of the sewage treatment works, and the dumping of rubbish in or near the river.
   - Indigenous vegetation removal: concern over the impact of this on the riverine ecosystem.
   - Alien vegetation: the increase in alien vegetation in the riparian zone was seen as a threat to the ecosystem.

Stakeholder issues categorized under Human Health are *not* addressed in this audit except in the context of water quality data from the water resources. Similarly, issues categorized under Water Services are addressed in the Sustainable Development Framework. Indigenous and alien vegetation issues are addressed in the Biodiversity section of the LEAP Comprehensive and Monitoring Reports.

2.3 METHODS

1.2.6 Water quantity / hydrological assessment

Ground and surface water quantities are monitored by DWAF, with data captured at either the Cradock or Port Elizabeth offices. However staff shortages in both offices means up-to-date data are not available to members of the public. Budget limitations did not allow analysis of available data from the 12 DWAF monitoring weirs in Makana.

1.2.7 Physico-chemistry assessment

Water quality data were obtained from the DWAF database (Pretoria). A list of the DWAF water quality monitoring points used are detailed in Table 1 and also appear in Figure 1. Five water quality variables were selected for the purpose of this report as they provide information on different aspects of water quality: salinity (electrical conductivity [EC]), pH, nutrient status (phosphates and total inorganic nitrogen (TIN), and toxicity (fluorides). Water quality of the water resource is reported in terms of three water user groups - domestic, agriculture and livestock (Appendix 1), and in terms of the river ecosystem health classes (Table 2). Scatter plots with trend lines, and box-and-whisker plots of monthly medians and data within the 25% to 75% distribution of selected water quality variables, were drawn using Statistica to show historical and seasonal changes.

To define the *Present Ecological State* (PES), the DWAF guidelines used for the Preliminary Water Resource Audit (Appendix 1), which are based principally on international data, have been recently refined in terms of EC and individual inorganic salts, nutrients and the ecological health classes (Jooste and Rossouw, 2002; Palmer *et al.*, 2004b). Both the EC and Nutrient values are used to define the health classes.

- EC values >85mS/m are indicative of a potential salt impact, and identification of the particular salt or salts involved is essential (Palmer *et al.*, 2004b,c). EC data (95th percentile) and six individual inorganic salts were assessed using DWAF water quality data from the past five years, where sample sizes equalled or were greater than 60. Individual salt analysis was based on the Jooste and Rossouw model (2002), where the ionic data for the salt ions Ca, Mg, K, Na, Cl and SO_4^{2-} were reconstituted to obtain inorganic salt concentrations in mmols/l. These concentrations were then converted to mg/l by multiplying each by the respective salt's formula mass. These values were then used to classify each site by comparing the reconstituted salt concentrations to the most recent benchmark category boundary values (Palmer *et* al., 2004b).
- For Nutrients, the median (50th percentile) SRP and TIN values were calculated for each site using DWAF water quality data, and compared to the default benchmark category boundary concentrations (Table 2).

The overall water quality Ecological Health Class at each Makana site was therefore classified as follows (Palmer *et al.*, 2004c):

1) Where EC < or = 85mS/m:

If EC < or = 30 mS/m	Natural
If EC is 31 - 55 mS/m	Good
If EC is 56 – 85 mS/m	Fair

2) Where EC > 85mS/m, Classes were defined in terms of:
   Nutrients (lowest class between the TIN and SRP), AND
   Inorganic salts (lowest class between all salts, with magnesium sulphate the most ecologically toxic).

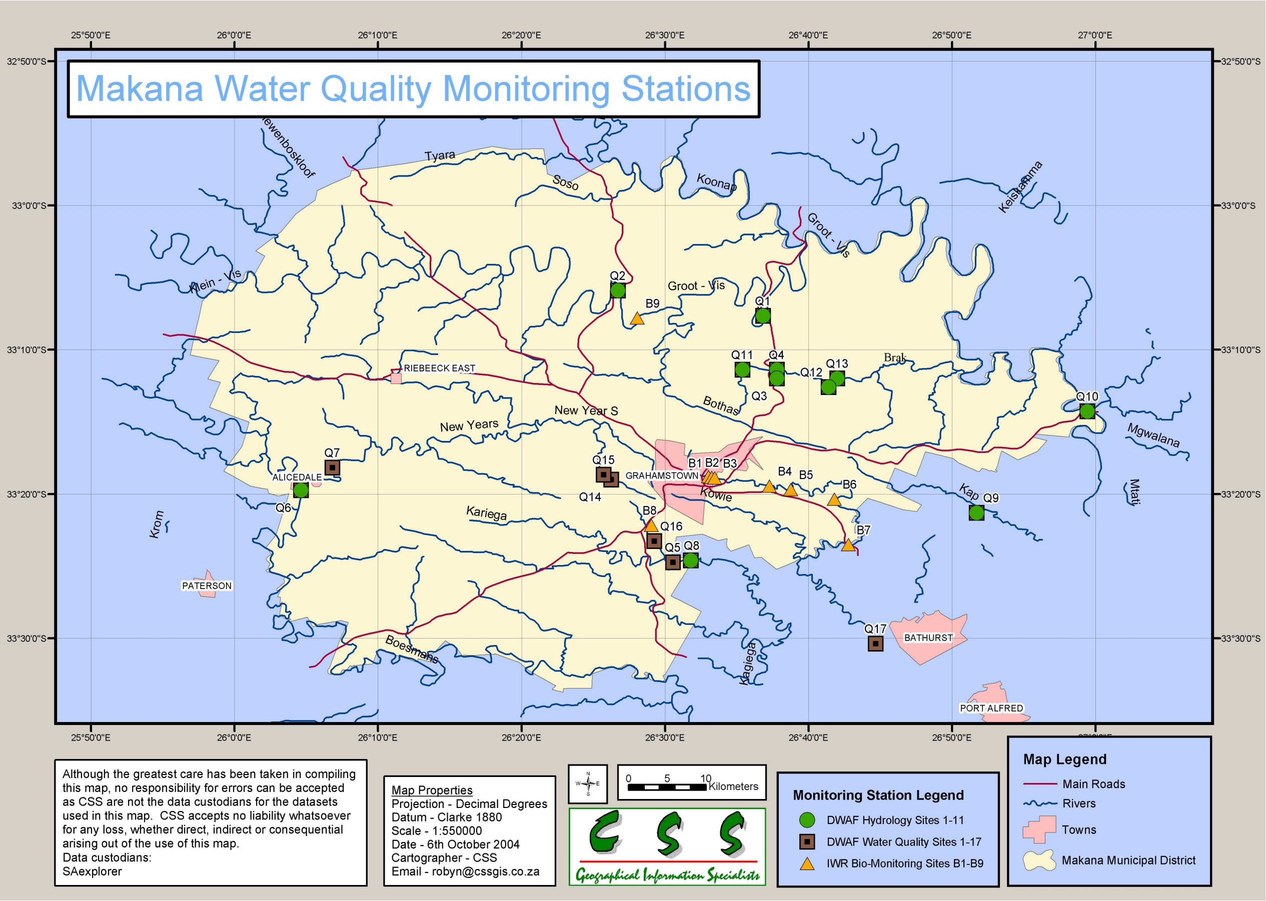

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Figure 1. Map of the water quality monitoring stations within the Makana Municipality

Table 1. Department of Water Affairs and Forestry water quality monitoring sites. Those listed without a DWAF number site are the sites introduced by Mr Pieter Retief (DWAF Port Elizabeth) as extra monitoring sites sampled monthly, for which no data are available at time of audit. GHT=Grahamstown; STW=Sewage Treatment Works.

Site code	**DWAF site number**	**Location**	**Common name**	**Latitude**	**Longitude**	**Data record**
Q1	Q9H001	Great Fish River	Fort Brown Peninsula	33.127778	26.613889	1987-2003
Q2	Q9H012	Great Fish River	Brand Legte Piggot's Bridge	33.098333	26.445556	1972-2003
Q10	Q9H018	Great Fish River	Matomela's location	33.237778	26.990278	1971-2004
Q6	P1H003	Boesmans River	Donkerhoek Alicedale	33.329167	26.0775	1974-2003
Q16	P3R001	Howisonpoort Dam	Thomas Baines	33.387778	26.4875	1972-1999
Q14	P1R001	Jameson Dam	Jameson	33.316667	26.4375	1978-1998
Q9	Q9H013	Kap River	Kap River Mt. Forest View	33.355278	26.861944	1979-1991
Q8	P3H001	Kariega River	Smithfield	33.554444	26.603611	1971-2003
Q15	P1R002	Milner Dam	Jameson	33.311111	26.428889	1978-1985
Q7	P1R003	New Years Dam	New Years Drift West	33.303056	26.113889	1978-2004
Q5	P3R002	Settlers Dam	Newingreen	33.412222	26.509167	1978-1999
Q17	P4H001	Kowie River	Bathurst Wolfscrag	33.506	26.745	1971-2003
		Market St East GHT	Bloukrans River			*
		Market St West GHT	Bloukrans River			*
		Upstream GHT STW	Bloukrans River			*
		GHT STW	Tributary of Bloukrans River			*
		Down-stream GHT STW	Bloukrans River	33.1926	26.3559	*

Table 2. Trigger values for different water quality variables used in this report, for determination of ecological health classes, based on present guideline data (DWAF 1996; Palmer et al. 2004b).

Variables	**Domestic**	**Irrigation**	**Livestock**	**Aquatic Ecosystems**			
				Excellent/ Natural	**Good**	**Fair**	**Poor**
pH	6.0-9.0	6.5-8.4	NR	6.5-8.0	5.75-6.46 & 8.05-9.0	5.0-5.7 & 9.05-10.0	<5.0 or >10.0
F mg/l	0 - 1.0	<2.0	0 - 2.0	1.5	2.02	2.54	>2.54
NO_2 & NO_3 mg/l	0 - 6.0						
NO_3 mg/l			0 - 100				
EC mS/m	0-70	<40	0-153.85				
Individual salts (95th %)							
$MgSO_4$ mg/l				16	27	37	>37
Na_2SO_4 mg/l				20	36	51	>51
$MgCl_2$ mg/l				15	33	51	>51
$CaCl_2$ mg/l				21	63	105	>105
NaCl mg/l l				45	217	389	>389
$CaSO_4$ mg/l				351	773	1195	>1195
Nutrients (median)							
SRP mg/l				<0.0051	0.0051 - 0.025	0.0251 - 0.125	>0.125
TIN mg/l		<5		<0.251	0.251 – 1.0	1.01 – 4.0	>4

1.2.8 Biomonitoring assessment

1.2.8.1 Sampling sites

In November 2002 and September 2003, the Kowie Catchment Campaign, represented by Dr Ferdi de Moor and Ms Helen Barber-James (Departments of Freshwater Invertebrates) and Dr Jim Cambray (Department of Ichthyology), all of the Makana Biodiversity Centre, Albany Museum Grahamstown, undertook biomonitoring on the Bloukrans River. Seven sites were chosen for invertebrate and fish biomonitoring. Two reports were submitted to Makana Municipality (de Moor *et al.* 2002; Barber-James *et al*. 2003).

Biomonitoring of invertebrates was repeated in 2004 by the LEAP water quality team at sites 1, 3, 4 and 5 in March; and sites 1-5 in September 2004 (Table 3; Figure 1). Sites 6 and 7 were dry and neither annual nor seasonal variability of invertebrates were recorded. Two further sites were added for LEAP: at the confluence of the Palmiet and Berg Rivers in Thomas Baines Nature Reserve (B8) (sampled March and September 2004); and at the Double Drift Game Reserve causeway on the Great Fish River (B9) (sampled March 2004). No suitable biomonitoring sites were found within the vicinity of Alicedale on the Bushmans River.

Appendix 2 records pictorial details of the sites on the Bloukrans and Palmiet/Berg Rivers.

1.2.8.2 Method

The SASS5 methods are clearly recorded in de Moor *et al.* (2002). Briefly, sampling of different habitats allows groups of macro-invertebrates to be identified to family level; and different scores are assigned to each group according to their tolerance and sensitivity to water quality conditions. The total SASS Scores and Average Score Per Taxon (ASPT) were used as the measures of ecosystem health.

At each site the Integrated Habitat Assessment System was used to record habitat availability.

Chutter's guidelines for interpreting SASS scores in non-acidic waters (ph>6) (Table 4) give combinations of Total SASS scores and ASPT which provide an indication of Present Ecological State in terms of water quality. With the further analyses of individual salts, these guidelines have been refined in terms of ecological health classes (Table 5; Palmer *et al.*, 2004b,c).

Table 3. Description of biomonitoring site locations.

Sampling site code	**Site location**
Bloukrans River: Has its headwaters near Grahamstown, after which the river flows in a south-easterly direction and later joins the Kowie River.	
B1	Section of non-canalized river below small road-bridge near Matthew Street and Fort England Hospital. 33°18'46"S 26°32'29" E.
B2	Stream flowing out of the sewage farm (treated sewage effluent) into the Bloukrans River (Fig. 3). 33°18'56"S 26°33'36" E.
B3	Section of river below farm-road bridge close to N2 highway bridge. 33°19'04"S 26°34'05" E.
B4	Section of river below Railroad bridge and immediately below road bridge. 33°19'26"S 26°36'00" E.
B5	Section of river below road on Mr. Duncan's farm. 33°19'40"S 26°38'35" E.
Confluence of Palmiet and Berg Rivers: In Thomas Baines Nature Reserve	
B8	At confluence of the two rivers, 33°22'18"S 26°28'35" E
Great Fish River: Forms part of the north-eastern boundary of the Makana Municipality. It is one of the larger rivers in the region. One site was chosen for sampling	
B9	The Double Drift causeway, 33°05'18"S 26°46'51" E.

Table 4. Guidelines for interpreting SASS4 scores in non-acidic waters (pH>6) (Chutter, 1998).

Total score	ASPT	Water quality
>100	>6	water quality natural, biotope diversity high
<100	>6	water quality natural, biotope diversity reduced
>100	<6	borderline case between water quality natural and some deterioration in water quality, interpretation should be based on the extent by which Total Score exceeds 100 and ASPT < 6
50-100	<6	some deterioration in water quality
<50	Variable	major deterioration in water quality

Table 5. The default benchmark category boundaries for the biotic index SASS (Palmer *et al.*, 2004b).

Class boundary	Range of ASPT Scores
Excellent/Natural	7
Good	6
Fair	5
Poor	<5

1.2.9 Ecotoxicological assessments

The 48-hour acute toxicity test using *Daphnia pulex* was based on the standard toxicity test (Slabbert *et al.*, 1998).

1.2.9.1 Sample collection

During 2004, several samples of sewage influent and effluent were collected in 2-litre bottles at the inlet point, the outlet pipe into the dam, and the outlet point into the river, from the Grahamstown Sewage Treatment Works (Table 15). The samples were brought to the UCEWQ-IWR laboratory, filtered and stored at 4°C overnight before being tested.

1.2.9.2 Exposure concentrations

100%, 50%, 25%, 12.5%, 6.25% whole effluent and a control (0% effluent) were used for the inlet point, with *D. pulex* culture medium as the diluent. 100%, 75%, 50%, 25%, 12.5% and 0% effluent were used for the outlet pipe and the outlet point into the Bloukrans River tributary.

1.2.9.3 Test organisms

The UCEWQ laboratory at the IWR, Rhodes University maintains a *D. pulex* culture, which is regularly used in inter-laboratory proficiency testing. Neonates (less than 24 hours old) from this culture were used in this study.

1.2.9.4 Test procedure

The standard protocol was followed (Slabbert *et al.*, 1998), with 20 neonates per effluent dilution. Mortalities were recorded at 1hr, 2hrs, 4hrs, 8hrs, 24hrs and 48hrs. LC_{50} values were calculated using the Probit or Trimmed Spearman-Karber models (if the calculated chi-square for heterogeneity was greater than the tabular value at the p=0.05 probability for the Probit).

1.3 RESULTS

1.3.1 Water quantity / hydrological results

DWAF monitoring weir data are insufficient for water resource planning and complete assessment. Environmental flows and water allocations for domestic, agricultural and industrial use have therefore still to be determined.

Makana does not have:

- an assessment of existing lawful use of water including that used for agricultural use;
- collated data on the present water reserves, and demands, within Makana that has been made accessible to the LEAP team, or is available in an accessible form to stakeholders; and
- a model for projected estimates of domestic, educational (in particular Rhodes University's projected numbers of entrees), industrial and agricultural growth and therefore water demands.

The DWAF offices (Port Elizabeth) are presently establishing a system of data capture called Water Management Systems. This is not in use yet but should in future provide a complete dataset of hydrological (and water quality) data for Makana.

1.3.2 Physico-chemical results

Appendix 1 gives descriptions of water quality of the selected sites in terms of three water user groups; domestic, irrigation and livestock, and if appropriate, ecosystem health. Data accumulated over the complete period of collection of data at each site by DWAF are presented as box-and-whisker plots of monthly medians, and data within the 25% to 75% range around the median. Interpretations of values, included in the Appendix, are based on the DWAF aquatic ecosystem water quality guidelines (1996).

Ecosystem health data and classification of DWAF water quality monitoring sites are given below. Table 6 shows the assigned ecosystem health classes of the selected water quality variables (according to the trigger values described in Table 2) for the selected DWAF sites, based on the Jooste and Rossouw (2002) and Palmer *et al.* (2004b) methods. Due to incomplete data sets or a lack of adequate sample sizes for data from the last five years, only 7 of the 12 DWAF water quality monitoring sites selected for this study yielded data suitable for Present Ecological State (PES) assessments.

The analyses for each site are presented below in the form of summary tables with brief descriptions of the findings. Median values are presented for Total Inorganic Nitrogen (TIN) and Soluble Reactive Phosphorus (SRP); the 95th percentile for Electrical Conductivity (EC); and the reconstituted values for six inorganic salts, listed in descending order of toxicity.

Analysis of water samples

Water samples were taken from each site and sent for full inorganic and metal analyses to DWAF had not yet had complete analyses at the time of submitting the audit.

Table 6. Summary of ecosystem health classification of the DWAF sites utilized in this study. Fluoride = F; Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC. * See individual salts classifications in following tables for each site.

Site code	**Location**	**Variable category**		**Nutrients**		**Overall Nutrient class**	**Overall Salt class***	**Inorganic salts of concern**
		pH	**F**	**TIN**	**SRP**			
Q1	Great Fish River	Good	Natural	Good	Fair	Fair	Poor	$MgSO_4$, Na_2SO_4, NaCl
Q2	Great Fish River	Good	Natural	Good	Fair	Fair	Poor	$MgSO_4$, Na_2SO_4, NaCl
Q10	Great Fish River	Good	Natural	Good	Fair	Fair	Poor	$MgSO_4$, Na_2SO_4, NaCl
Q8	Kariega River	Good	Natural	Natural	Good	Good	Poor	$MgSO_4$, $MgCl_2$, $CaCl_2$, NaCl
Q17	Kowie River	Good	Natural	Good	Good	Good	Poor	$MgSO_4$, $MgCl_2$, $CaCl_2$, NaCl
Q6	Bushmans River	Good	Natural	Natural	Good	Good	Poor	$MgSO_4$, $CaCl_2$, NaCl
Q7	New Years Dam	Good	Natural	Natural	Fair	Fair	Poor	$MgSO_4$, NaCl
Q16	Howisonpoort Dam	Poor	Natural	Natural	Good	Good		
Q14	Jameson Dam	Fair	Natural	Natural	Fair	Fair		
Q9	Kap River	Good	Natural	Natural	Good	Good		
Q15	Milner Dam	Poor	Natural	Natural	Good	Good		
Q5	Settlers Dam	Good	Fair	Natural	Good	Good		

Table 7. Summary results for Site Q1 on the Great Fish River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q1		**Data Source**: DWAF weir Q9H001	**Site Descriptor**: Great Fish River, NNE of Grahamstown
Variables		**Value**	**Category**
Nutrients 50% (mg/l)	TIN	0.62	Good
	SRP	0.12	Fair
Electrical Conductivity (mS/m)		199	>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	222.6	Poor
	Na_2SO_4	298.2	Poor
	$MgCl_2$	Undetectable	
	$CaCl_2$	Undetectable	
	NaCl	483.21	Poor
	$CaSO_4$	Undetectable	

TIN, $MgCl_2$, $CaCl_2$ and $CaSO_4$ suggest that this site on the Great Fish River may be considered to be in a Good state. However the second nutrient variable SRP, with a value of 0.12mg/l, places this is a Fair Class. The inorganic salts $MgSO_4$ (222.6mg/l), Na_2SO_4 (298.2mg/l) and most notably NaCl (483.21mg/l with a value of more than double that of the default benchmark boundary for a fair classification) are of concern and place this in a Poor Class for inorganic salts.

Table 8. Summary results for site Q2 on the Great Fish River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q2		**Data Source**: DWAF weir Q9H012	**Site Descriptor**: Great Fish River, NNW of Grahamstown
Variables		**Value**	**Category**
Nutrients 50% (mg/l)	TIN	0.48	Good
	SRP	0.098	Fair
Electrical Conductivity (mS/m)			>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	249.02	Poor
	Na_2SO_4	323.76	Poor
	$MgCl_2$	Undetectable	
	$CaCl_2$	Undetectable	
	NaCl	555.75	Poor
	$CaSO_4$	Undetectable	

There were insufficient data for any kind of present ecological state assessment based on EC or individual inorganic salts. The TIN value of 0.48mg/l puts the site well within the bounds of the Good category, but SRP, having a value of 0.098mg/l, means the site is classified as Fair. For inorganic salts, the $MgSO_4$, Na_2SO_4 and NaCl are of concern and place this in a Poor Class for inorganic salts.

Table 9. Summary results for site Q10 on the Great Fish River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code:Q10		**Data Source:** DWAF weir Q9H018	**Site Descriptor:** Great Fish River, eastern boundary of the municipality
Variables		Value	Category
Nutrients 50% (mg/l)	TIN	0.29	Good
	SRP	0.09	Fair
Electrical Conductivity (mS/m)		211	>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	245.4	Poor
	Na_2SO_4	262.7	Poor
	$MgCl_2$	Undetectable	
	$CaCl_2$	Undetectable	
	NaCl	582.1	Poor
	$CaSO_4$	Undetectable	

In terms of SRP, the site may only be categorised as Fair. Magnesium and sodium sulphate salt concentrations are far in excess of the Fair category benchmark value. Although the salts $MgCl_2$, $CaCl_2$ and $CaSO_4$ all put the site in the Excellent/Natural category, it is the two most toxic salts which have values exceeding the benchmark value for the worst class (magnesium and sodium sulphates). The site is therefore in a Poor state.

Table 10. Summary results for site Q8 on the Kariega River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q8		**Data Source:** DWAF weir P3H001	**Site Descriptor:** Kariega River, South of Grahamstown
Variables		**Value**	**Category**
Nutrients 50% (mg/l)	TIN	0.155	Excellent or Natural
	SRP	0.024	Good
Electrical Conductivity (mS/m)		717	>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	252	Poor
	Na_2SO_4	Undetectable	
	$MgCl_2$	365	Poor
	$CaCl_2$	575	Poor
	NaCl	2517.3	Poor
	$CaSO_4$	Undetectable	

The TIN data classify the site as Excellent/Natural. However for nutrients, the SRP value places the site condition in the Good category. Both the $MgSO_4$ (the most toxic) and $MgCl_2$ values are well in excess of the default benchmark value for the Fair category. The median NaCl concentration at this site was the highest of all the sites analysed, being 2517.3mg/l, compared to the Fair default benchmark category boundary of 1195mg/l. Overall the site was classified in terms of inorganic salts as Poor.

Table 11. Summary results for site Q17 on the Kowie River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q17		**Data Source:** DWAF weir P4H001	**Site Descriptor:** Kowie River, SE of Grahamstown
Variables		**Value**	**Category**
Nutrients 50% (mg/l)	TIN	0.07	Excellent or Natural
	SRP	0.025	Good
Electrical Conductivity (mS/m)		500	>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	222.6	Poor
	Na_2SO_4	Undetectable	
	$MgCl_2$	221.1	Poor
	$CaCl_2$	315.2	Poor
	NaCl	1944	Poor
	$CaSO_4$	Undetectable	

The median TIN value (0.07mg/l) classes the site in the Excellent/Natural category. The SRP median value (0.025mg/l) for the site is exactly the default benchmark value between the Good and the Fair categories. Median values for magnesium sulphate (222.6mg/l), magnesium chloride (221.1mg/l) and once again most notably, sodium chloride (1944mg/l), were found to be unusually high, thus classifying water quality as Poor in terms of inorganic salts.

Table 12. Summary results for site Q6 on the Bushmans River. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q6		**Data Source**: DWAF weir P1H003	**Site Descriptor**: Bushmans River, South of Alicedale
Variables		Value	Category
Nutrients 50% (mg/l)	TIN	0.081	Excellent/Natural
	SRP	0.025	Good
Electrical Conductivity (mS/m)		491	>85
Inorganic Salts 95% (mg/l)	$MgSO_4$	391	Poor
	Na_2SO_4	Undetectable	
	$MgCl_2$	1.21	Excellent/Natural
	$CaCl_2$	183.2	Poor
	NaCl	2042.82	Poor
	$CaSO_4$	Undetectable	

The nutrient data median values (TIN and SRP) place the site overall in terms of Nutrients in the Good Class. However, the magnesium sulphate (391mg/l) and the extremely high NaCl (2042.82mg/l) median values place the site in the Poor category.

Table 13. Summary results for site Q7 at the New Years Dam. Total Inorganic Nitrogen = TIN; Soluble Reactive Phosphorus = SRP; Electrical Conductivity = EC.

Site Code: Q7		**Data Source**: DWAF weir P1R003	**Site Descriptor**: New Years Dam, NE of Alicedale
Variables		Value	Category
Nutrients 50% (mg/l)	TIN	0.097	Excellent/Natural
	SRP	0.028	Fair
Electrical Conductivity (mS/m)		99.1	>85
Inorganic 95% (mg/l)	$MgSO_4$	50.64	Poor
	Na_2SO_4	-	Undetectable
	$MgCl_2$	-	Undetectable
	$CaCl_2$	40.3	Good
	NaCl	313.6	Poor
	$CaSO_4$	-	Undetectable

In terms of TIN data, water quality at the dam can be classified as Excellent/Natural. The SRP median value places the site in the Fair category with a value of 0.028mg/l, only slightly over the benchmark for the Good category. In terms of nutrients, the site is therefore Fair. Unlike most of the other sites, but possibly due to it being a dam site, only classifications based on the magnesium sulphate and sodium chloride median values categorised the site as Poor, while the remaining inorganic salts classified the site as either Excellent/Natural or Good. In relation to all other sites in the region, the median values for magnesium sulphate and sodium chloride at this site were the lowest. In terms of inorganic salts, the site was classified as ecologically Poor.

1.3.3 Biomonitoring results

The interpretation of SASS, ASPT and IHAS scores is preferably based on comparisons of site data with reference sites (unpolluted) upstream of potential pollution sources. Regrettably within the Makana area, this is not possible in the case of Bloukrans River with Grahamstown containing the headwaters and also the source of pollution. Similarly, along the Bushmans River in the vicinity of Alicedale, no suitable biomonitoring sites were found.

Table 14 summarises all biomonitoring data collected for the nine sites, on the Bloukrans River, Great Fish River, and Palmiet/Berg River confluence. Scores for each habitat at each site are included in Appendix 2. The average score per taxon (ASPT) values are compared to the default benchmark values given in Table 5 in order to classify each site.

Table 14 ASPT, total SASS score and IHAS for each of the nine Bloukrans, Palmiet/Berg and Great Fish River sites sampled by the Kowie Catchment Campaign (2002 and 2003) and the UCEWQ-IWR (2004). B1-B9 refer to the numbers allocated to each biomonitoring site (Table 3; Figure 1).

Total Scores	B1	B2	B3	B4	B5	B6	B7	B8	B9
ASPT NOV 02	2.6		3.6	4.2	5.0	6.1			
ASPT SEP 03	3.6	3.5	3.8	5.6	4.7	5.7	5.0		
ASPT MAR 04	4.5		5.0	4.5	4.5			4.9	4.5
ASPT SEP 04	2.5	3.1	5.3	4.3	4.4			4.2	
SASS NOV 02	13		32	42	60	97			
SASS SEP 03	25	14	23	51	42	120	50		
SASS MAR 04	50		60	77	81			89	27
SASS SEP 04	23	40	79	77	131			75	
IHAS (%) MAR 04	50		51	52	53			65	24
IHAS (%) SEP 04	29	37	43	43	48			50	

1.3.3.1 ASPT scores

Site B1, situated on the Bloukrans River closest to Grahamstown, had no ASPT values exceeding 5. This classifies the site as being in a Poor ecological condition.

Data for site B2 obtained in September 2003 and 2004 were both well below the Fair default benchmark value, thus classifying the site as Poor.

Site B3 shows an increase in ASPT over the time between the first sampling in 2002 and the most recent in 2004. ASPT values for November 2002 and September 2003 were 3.6 and 3.8, putting the site in the Poor category; however for March 2004 and September 2004 ASPT increased to 5 and 5.3 respectively, allowing the site to be classified as Fair.

Except for September 2003, ASPT values for site B4 were found to be below 5 and put the site in the Poor category. The score recorded in September 2003 of 5.6 is close to the benchmark value for the Good category and reveals the potential for variability in river water quality, possibly due to seasonality.

At site B5 a steady decline in ASPT value can be seen over time. The ASPT recorded in November 2002 of 5.0 classifies the site as Fair. However the values for September 2003, March 04 and September 04 place the site in the Poor category.

Due to the absence of flowing water at site B6 during sampling in 2004, biomonitoring data for these times are unavailable. However for November 2002 and September 2003, ASPT values were 6.1 and 5.7 respectively. These scores suggest that the site is in a Good or Fair condition.

The only data available for site B7 is from September 2003, at which time ASPT was found to be 5.0, thus classifying the site as Fair.

For site B8, biomonitoring was not undertaken during 2002 or 2003. However ASPT values recorded in March and September 2004 decrease from 4.9 to 4.2 placing the site in the Poor category, suggesting either decreasing water quality state over the year or seasonal variation.

Due to high flows, the habitats of Stones and Gravel, and Sand and Mud were unsuitable for biomonitoring at site B9 (Great Fish; March 2004). Biomonitoring was therefore limited to vegetation habitat only, thus with low confidence in interpretation. The vegetation does however provide some idea of the ecological state of the river and suggests the site shows some deterioration in water quality.

1.3.3.2 Total SASS and IHAS scores

ASPT values were used (above) to classify water quality at each of the biomonitoring sites. However, IHAS percentage values and total SASS score are a useful aid to interpretation of biomonitoring data and hence, Present Ecological State assessment.

IHAS or availability of habitats may be related to a degree to seasonal flow variations. Sites B1-B8 have low IHAS scores reflecting degraded conditions over time, with few habitats and therefore few niches for invertebrate habitation.

For “polluted” rivers, SASS scores may be more reliable than ASPT (Chutter, 1998) and therefore both have been considered in the interpretation of this data. Referring to Table 14 and using Chutter’s Guidelines for interpreting SASS 4 Scores in non-acidic waters (Table 4), Site B1 showed poor total SASS scores (50 or lower), and ASPT values were relatively variable. Water quality at the site therefore appears to have undergone, and remains in, a state of major deterioration.

A similar case exists with site B2, although there are fewer data. For site B3, 2002 and 2003 revealed a similar interpretation as for sites B1 and B2, with total SASS scores below 50. However, the 2004 data suggest an improvement in water quality from “major” to “some deterioration”.

This trend of slight improvement in water quality downstream from Grahamstown seems to continue at site B4 and B5, with total SASS scores exceeding 50 for the September 2003 and both 2004 samples, although all ASPT values for the site were less than 6. Interpretation based on Chutter’s guidelines (Table 4) indicates water quality at site B6 is likely to be in a borderline condition between “natural” and “some deterioration”.

At sites B7 and B8, Chutter's guidelines classify water quality at the sites as having "some deterioration". Total SASS and ASPT scores suggest there is some deterioration in water quality (using SASS and Chutter's guidelines, 1998) and the site can be placed in the Poor ecosystem health class (Palmer et al. 2004 using only ASPT scores). In considering IHAS in conjunction with the total SASS scores, Site B8 on the Palmiet/Breg River is the only site that has relatively high IHAS scores. Therefore the poor condition is more likely to be linked to water quality rather than poor habitat conditions.

Only one sample was undertaken for site B9 (Great Fish River, based on a vegetation habitat sample). A total SASS score of 27 and an ASPT of 4.5 suggest there is major deterioration of water quality at the site.

1.3.4 Ecotoxicology results

Probit and Trimmed Spearman-Kärber (TSK) models used for the analysis produced the LC_{50} values shown in Table 15. The lower these values, the more toxic the effluent.

Table 15. LC_{50} (%) values from 48-hour acute *Daphnia pulex* toxicity tests of sewage influent and effluent, calculated using Probit or Trimmed Spearman-Kärber (TSK) analyses. The respective, higher Chi square or percentage trim values indicate lower confidence in the LC_{50} values.

Date	Sewage source	Method of analysis	48-hr LC_{50} (%)	48 hr Confidence limits		Chi square	% Trim
				Lower	Upper		
26/04/2004	Inlet	Probit	23.86	19.99	28.48	0.8	
16/05/2004	Inlet	TSK	14.03	9.93	19.83		43.75
09/06/2004	Inlet	TSK	58.8	48.81	70.84		36.67
21/07/2004	Inlet	Probit	4.97	1.41	6.87	0.27	
01/09/2004	Inlet	Probit	30.02	23.87	37.91	6.68	
17/06/2004	Outlet pipe into dam	TSK	55.33	43.79	69.93		42.5
31/08/2004	Outlet into the river	TSK	43.1	31.09	59.74		15
06/09/2004	Outlet into the river	TSK	39.43	27.87	55.79		20

The LC_{50} values give an indication of the level of dilution required for the effluent to be unlikely to have ecologically toxic effects on the freshwater invertebrates found in the water resources. The lower the LC_{50}, the greater the need for dilution of the tested source.

The LC_{50} values for the inlet point ranged from 4.97% to 58.8%, with a mean value of 26.34%, indicating a high degree of likelihood of ecological invertebrate toxicity. For the outlet pipe into the Sewage Treatment Works Dam, the LC_{50} value remained lower than expected, at 55.33% with upper and lower confidence limits of 43.79% and 69.93%. Of great concern are the LC_{50} values for the outlet point into the Bloukrans River tributary which were found to be lower than the values for the outlet into the dam.

2.4 CONCLUSIONS

Availability of water resources, both ground and surface, is a key concern in Makana. The data collated from the monthly Department of Water Affairs and Forestry (DWAF) monitoring of surface and groundwater quantity are insufficient for water resource planning and complete assessment. There is also:

- no assessment of existing lawful use of water including that used for agricultural use;
- no collated data on the present water demands, within Makana that is available in an accessible form to stakeholders; and
- no model for projected estimates of domestic, educational (in particular Rhodes University's projected numbers of entrees), industrial and agricultural growth and therefore water demands.

The water quality audit gave the following concerns:

- The Bloukrans River downstream of Grahamstown residential and industrial areas and the sewage treatment works is in a Poor ecological state. The state of the River was also a primary stakeholder concern.
- There was no nutrient enrichment (total inorganic nitrogen and soluble ortho-phosphates) at any of the DWAF water quality monitoring sites. However, there were no DWAF water quality monitoring data available for the Bloukrans River to date [input still ongoing by DWAF] but the algal growth within the river is indicative of enrichment.
- There was measurable ecotoxicity of the influent and effluents around the Grahamstown Sewage Treatment Works (STW). This preliminary study indicates the outlet pipe into the STW dam was less toxic than the outlet pipe into the River. An ecotoxicity risk assessment is an urgent priority. The need for physico-chemical data collection and collation around the Grahamstown Sewage Treatment Works is therefore also a priority.
- At various sites on the Bushmans and Kariega Rivers, the water is too salty to irrigate or for use in domestic or livestock consumption.
- There is significant evidence of toxic salt levels at many of the DWAF water quality sites within Makana, dominated by magnesium sulphate and sodium chloride. However, there is a need to determine whether these values are just indicative of low flows combined with abstraction and evaporation; and/or the natural state, reflecting the ancient marine shales underlying parts of Makana. The introduction of water quality reference sites above possible point sources of pollution is necessary.
- The Alicedale tannery effluents, and other potential effluents with recent developments, are also of concern. More data points are needed upstream and downstream of Alicedale on the Bushmans River for both water quality monitoring (DWAF), in conjunction with biomonitoring sites that will potentially facilitate the indication of red flag scenarios of concern.

The Implementation Plan will therefore include three principle suggestions:

1) An ecotoxicological risk assessment, based around Grahamstown and its Sewage Treatment Works;
2) The development of hydrological and water use models for Makana;
3) An assessment of the natural salinity levels within the water resources.

Highlighted from this Audit has been the particular necessity, in addition, for:

4) Water quality and quantity data management by [DWAF and therefore] Makana Municipality;
5) An understanding by both Makana Municipality and stakeholders of water resources and water resource management; and therefore the implementation of the Resource Directed Measures and Source Directed Controls. Environmental Water Quality (consisting of physico-chemistry, biomonitoring and ecotoxicology) is soon to be

incorporated more fully into water quality management within Catchment Management Agencies. UCEWQ-IWR therefore proposes educational workshops for Makana Municipality are introduced before legislation becomes effective.

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APPENDIX 1: Department of Water Affairs and Forestry (DWAF) data captured at each DWAF water quality site are recorded graphically. Greater detailed analyses of the Present Ecological State of the sites are recorded in Section 4.1.

1. SITE Q1 (GREAT FISH RIVER)

ELECTRICAL CONDUCTIVITY

Domestic use

EC values at this site on the Great Fish River are mostly between 100 and 250mS/m (Figure 2a). The water is thus likely to have a marked salty taste and would probably not be used due to its appearance. It is not likely to produce any adverse health effects in the short term.

Irrigation

Moderately salt sensitive crops could be maintained using this water for irrigation.

Livestock

With EC values such as those recorded for this site, no significant adverse effects on livestock are foreseen, although there could be an initial reluctance to drink.

Ecological status

The Electrical Conductivity EC values are too high to use EC as an assessment criterion and individual salts were assessed.

PHOSPHORUS

Ecological status

The site is located in the middle reaches of the Great Fish River. Phosphate levels are generally high in this part of the river, probably due to the phosphate-rich sedimentary rocks of the catchment, although land-use that may have negative impacts on the environment. Phosphate concentrations are generally higher during summer months, but drop from July to September. This can be attributed to increased runoff during summer months.

pH

Domestic use

The pH values on this site of the Great Fish River are within the range of 6.0 – 9.0 throughout the year no adverse effects on health are expected. There might be very slight effects on taste noticeable on occasion.

Irrigation

Throughout the year on this site the higher limit of the pH range is higher than 8.4. Irrigation with such water may cause foliar damage, potentially affecting crop yield or quality of marketable products. There may be problems with encrustation of irrigation pipes and clogging of drip irrigation systems.

Ecological status

Because pH values are mostly between 8.0 and 9.0 (Figure 2c), this site is within the good boundary.

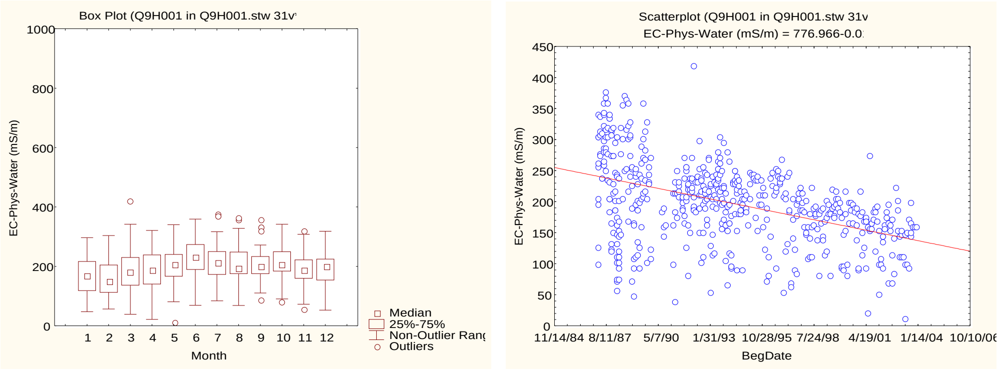

Figure 2a EC values for Site Q1 on the Great Fish River

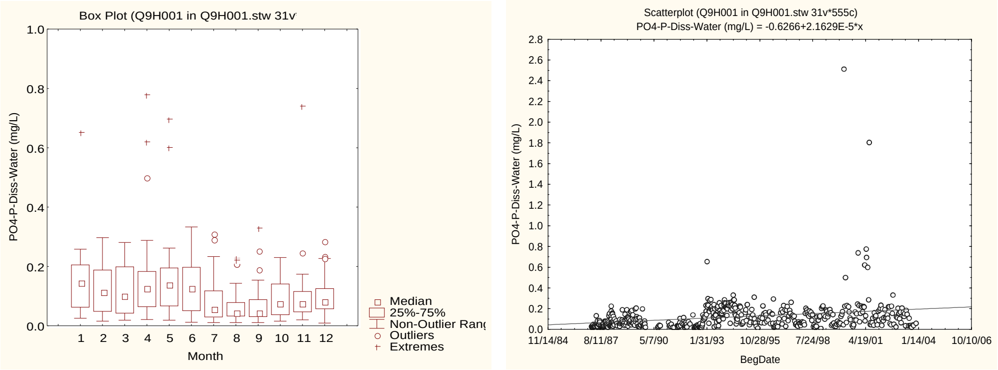

Figure 2b Phosphate values for Site Q1 on the Great Fish River.

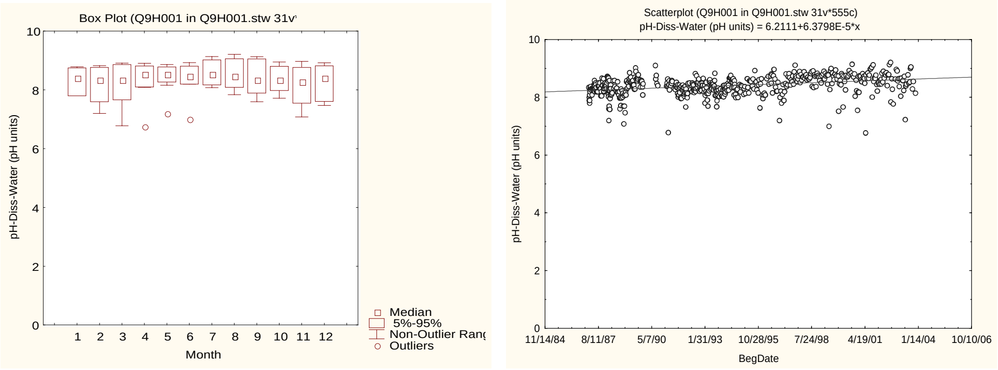

Figure 2c pH values for Site Q1 on the Great Fish River

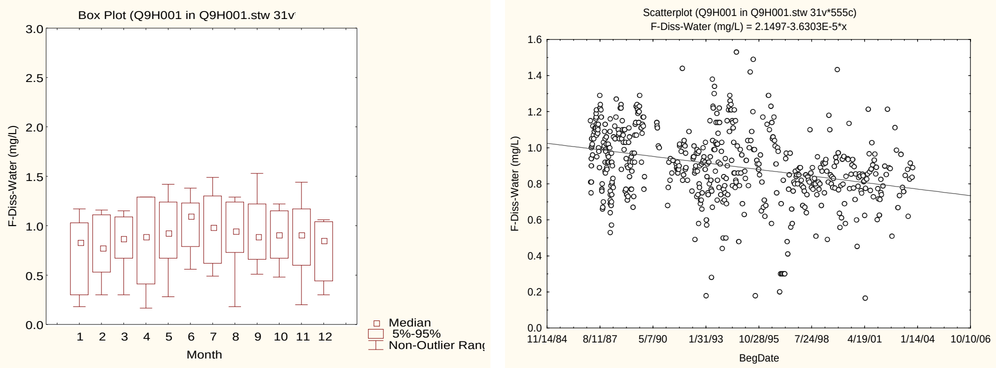

Figure 2d Fluoride concentrations (mg/l) for Site Q1 on the Great Fish River

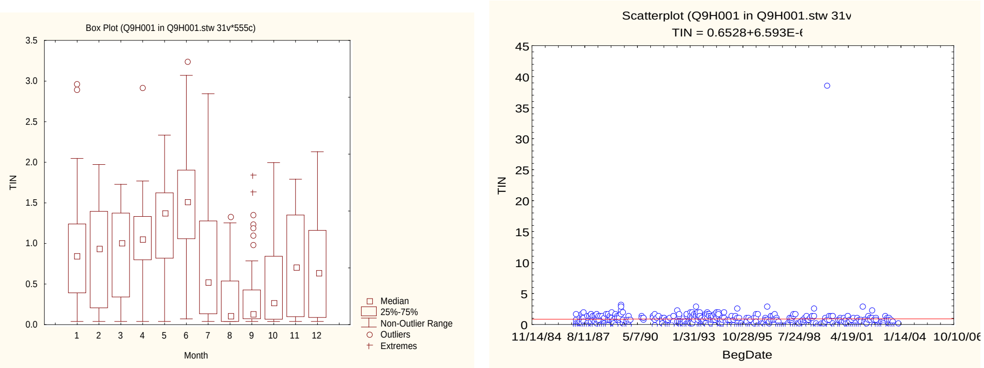

Figure 2e TIN (mg/l) for Site Q1 on the Great Fish River

FLUORIDE

Domestic use

The fluoride concentrations on this site (Figure 2d) are between 0 and 1.5mg/l throughout the year with not much variation, and at the range from 1.0 to 1.5mg/l a slight mottling of dental enamel may occur in sensitive individuals, otherwise there are no other adverse health effects expected.

Irrigation

The fluoride concentrations on this site (Figure 2d) are less than 2.0 mg/l throughout the year, and therefore there should be no adverse effects on crops.

Livestock

The fluoride concentrations on this site (Figure 2d) will have no adverse effects on livestock health.

Ecological status

This site is still in its natural ecological status (Figure 2d).

TIN (Total Inorganic Nitrogen)

Ecological status

On site Q1, TIN values seem to increase from summer to winter (January to June) and there is a marked decrease from winter to spring (June to September), with an increase again towards summer (Figure 2e).

2. SITE Q2 (GREAT FISH RIVER)

No electrical conductivity data

PHOSPHORUS

Ecological status

The site is also located in the middle reaches of the Great Fish River. Phosphate levels are generally high in this part of the river, probably due to the phosphate-rich sedimentary rocks of the catchment, although land-use that may have negative impacts on the environment (Figure 3a).

pH

Domestic use

The pH on this site (Figure 3b) ranges from 7.0 to 9.0 throughout the year and this pH range has no significant toxic effects on health. There may be slight effects on the taste of water.

Irrigation

Use of this water for irrigation may increase problems with foliar damage that may affect crop yield and the quality of marketable products. There may be problems with encrustation of irrigation pipes and clogging of drip irrigation systems.

Ecological status

This site is in a good ecological status with a pH range between 7.0 and 9.0 throughout the year without much variation.

FLUORIDE

Domestic use

Drinking water from this site (Figure 3c), with fluoride concentrations between 0.5 and 1.5 mg/l may cause mottling of dental enamel in sensitive individuals, otherwise no other health effects should occur.

Irrigation

Water from this site has low fluoride concentrations throughout the year, which will have no adverse effects on crops.

Livestock

The fluoride concentrations less than 2mg/l found in the water from this site (Figure 3c) will not have adverse effects on livestock health.

Ecological status

This site is within the natural boundary with fluoride concentrations less than 1.5mg/l (Figure 3c).

TIN (Total Inorganic Nitrogen)

Ecological status

There is no seasonal variation in TIN levels throughout the year.

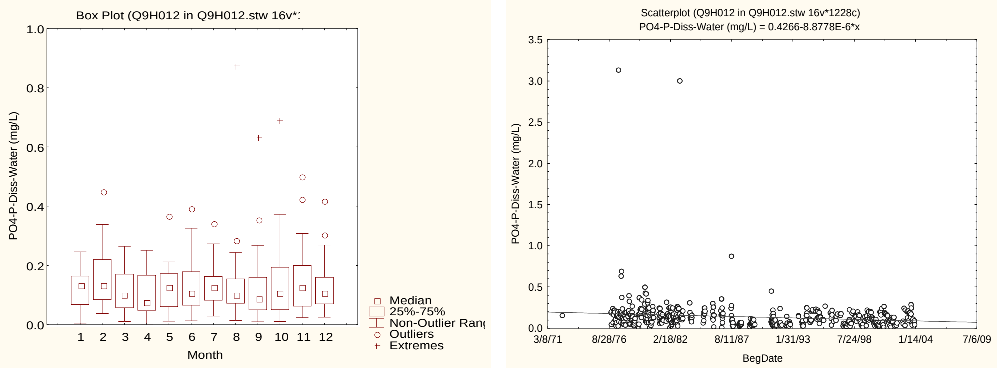

Figure 3a Phosphate values for Site Q2 on the Great Fish River.

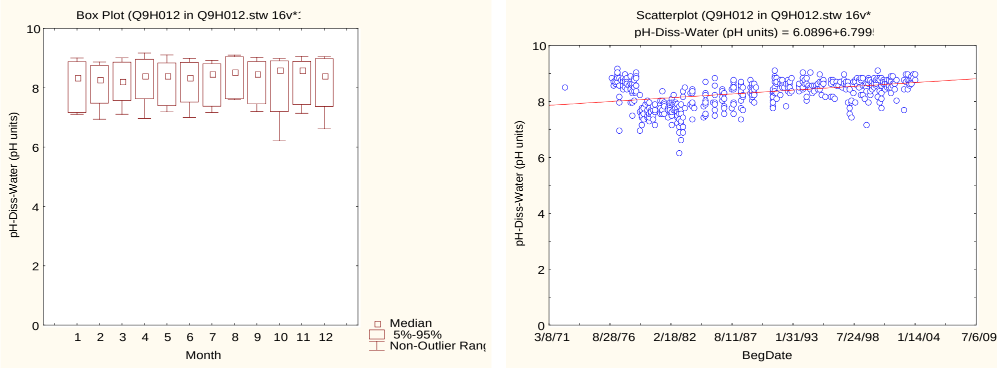

Figure 3b pH values for Site Q2 (Great Fish River)

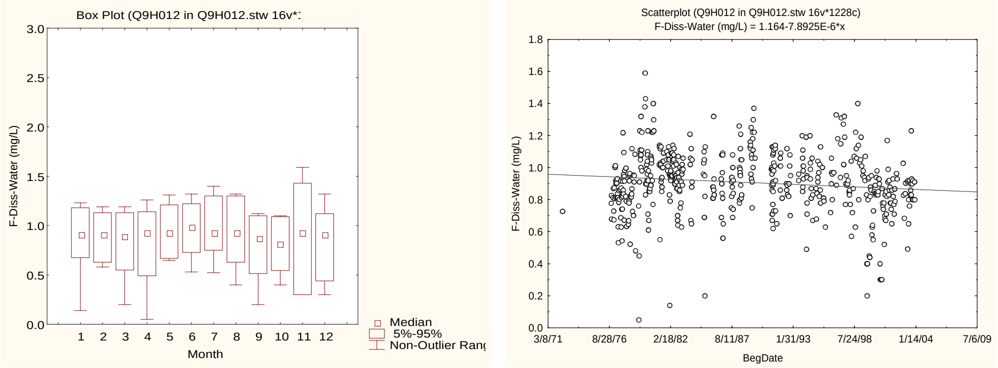

Figure 3c Fluoride concentrations (mg/l) of Site Q2 in the Great Fish River

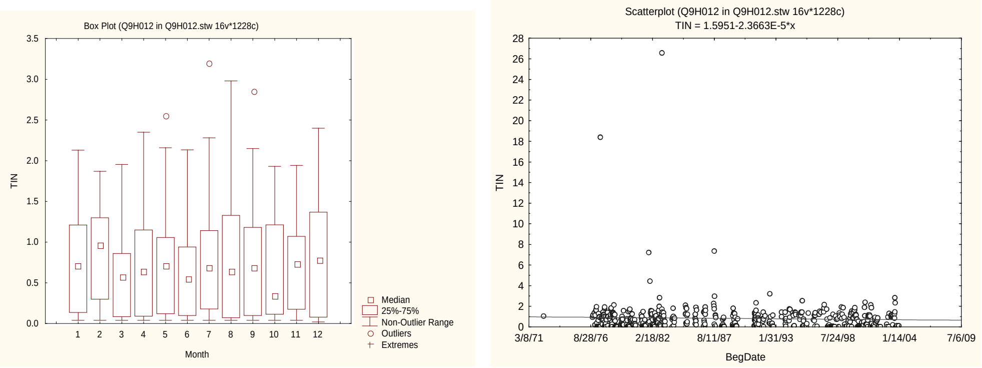

Figure 3d TIN (mg/l) for Site Q2 on the Great Fish River

3. SITE Q10 (GREAT FISH RIVER)

Electrical Conductivity

Domestic

Like Site Q1, also on the Great Fish River, the 25th – 75th percentile EC values range from approximately 90 to 250mS/m (Figure 4a). Thus water quality does not seem to have changed significantly between the two sites. Adverse health effects as a result of consumption of this water are not likely.

Irrigation

Moderately salt tolerant crops could be maintained under irrigation using this water.

Livestock

No significant adverse effects on livestock are foreseen.

Ecological status

As EC values are higher than 85, in-depth analyses of individual salts was necessary.

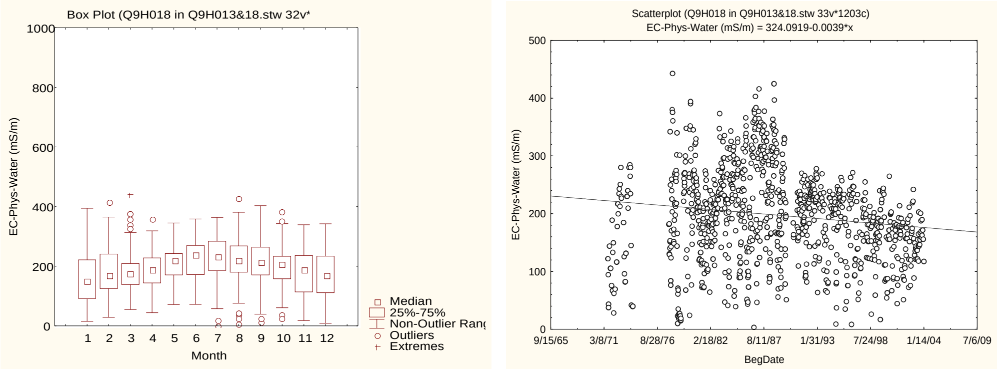

Figure 4a EC values for Site Q10 on the Great Fish River.

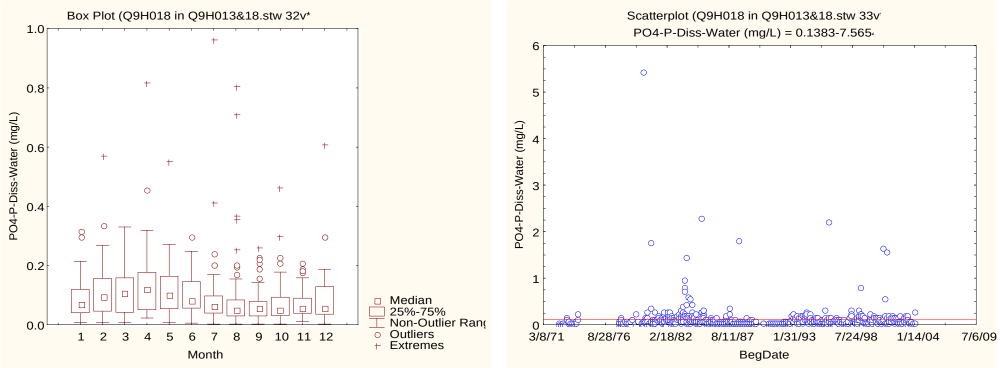

Figure 4b Phosphate values for Site Q10 on the Great Fish River.

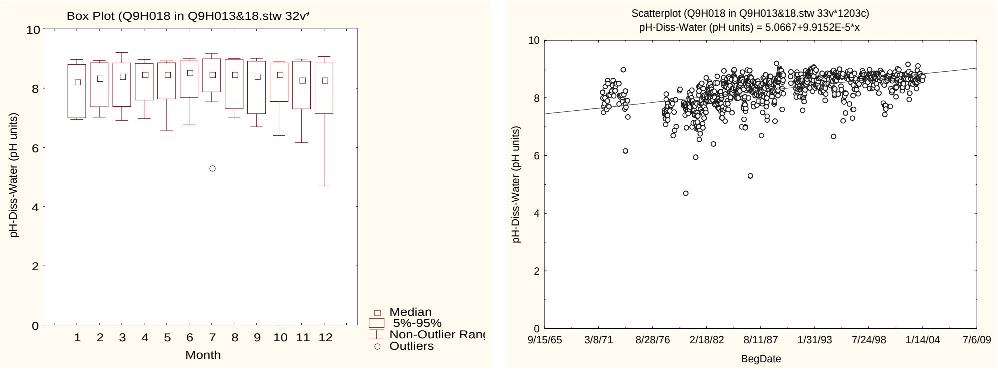

Figure 4c pH values of Site Q3 on the Great Fish River

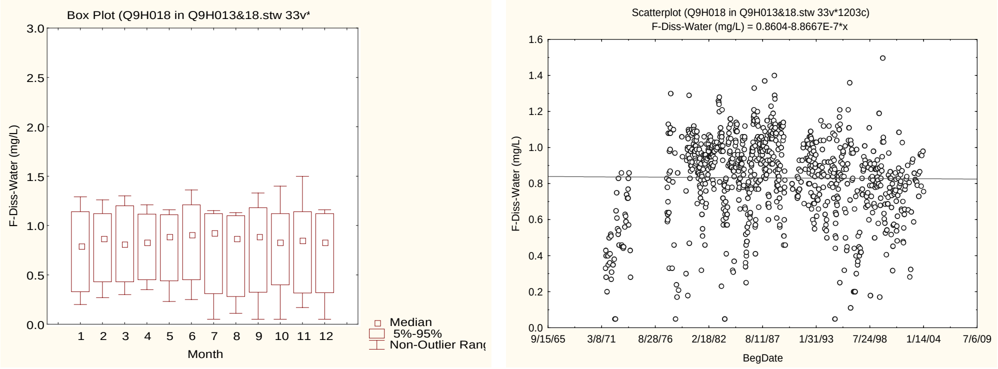

Figure 4d Fluoride concentrations (mg/l) of Site Q3 on the Great Fish River

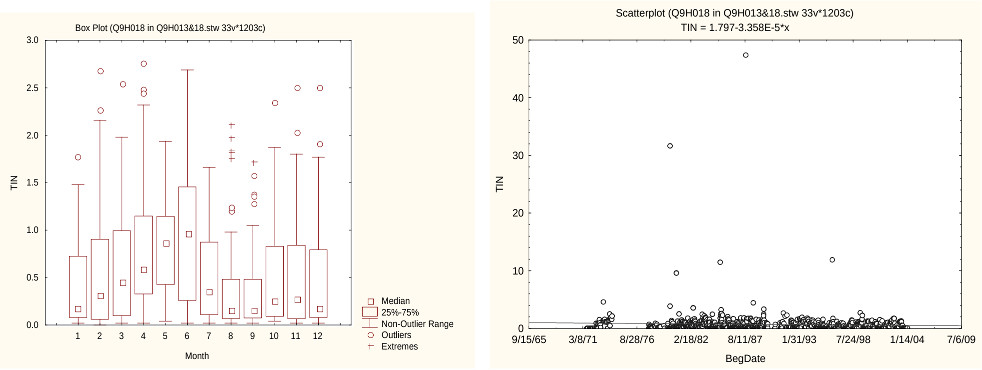

Figure 4e TIN (mg/l) for Site Q10 on the Great Fish River

PHOSPHORUS

Ecological status

Phosphate concentrations are generally higher during summer months, but drop from July to September (Figure 4b). This can be attributed to increased runoff during summer months.

pH

Domestic use

The water from this site (Figure 4c) is within the domestic use water quality target range of 6.0-9.0 where no significant effects on health can be expected, although there might be slight effects on the taste of the water.

Irrigation
The upper limit of the range 8.4 (Figure 4c), may cause problems with foliar damage that may affect crop yield and the quality of marketable products. Irrigation pipes and drip irrigation systems may have problems.

Ecological status
Similar to the sites Q1 and Q2 on the Great Fish River, this site is within the good pH boundary.

FLUORIDE
Domestic use
Fluoride concentrations in this site range from 0 to 1.5 mg/l throughout the year with little variation (Figure 4d). Drinking water from this site may cause slight mottling of dental enamel in sensitive individuals.

Irrigation
Water from this site has low fluoride concentrations throughout the year, which will have no adverse effects on crops.

Livestock
The fluoride concentrations (less than 2mg/l) (Figure 4d) will not have adverse effects on livestock health.

Ecological status
This site is within the natural boundary of fluoride concentration (less than 1.5mg/l) (Figure 4d).

TIN (Total Inorganic Nitrogen)
Ecological status
On site Q10 there is an increase in TIN levels from summer to winter, followed by a decrease in spring (from June to September), and then a slight increase again from spring towards summer (Figure 4e). The months, August, September, December and January are within the Excellent/Natural boundary. The months February to July and October and November are within the Good boundary.

4. SITE Q6 (BUSHMANS RIVER)

ELECTRICAL CONDUCTIVITY
Domestic
The EC values at this site can be seen to be much higher than those recorded for most other sites. At any time of year maximum EC values were never below 400mS/m (Figure 5a). In terms of domestic use, short-term consumption may be tolerated, although disturbance of the body’s salt balance is likely. At concentrations higher that 450mS/m (seen for most months of the year), effects such as corrosion or scaling increase and noticeable short term health effects should be expected.

Irrigation
Use of this water for irrigation of selected crops is still possible, although yield decreases will occur and management and soil requirements are likely to become restrictive.

Livestock
With such high EC values, use of this water for livestock watering (especially of pigs and/or poultry), a significant decline in production is likely. Exposure to such water should be kept to a minimum.

Ecological status
The majority of EC values were well above 85mS/m (Figure 5a). An in-depth study of individual salts was necessary to determine the ecological impact.

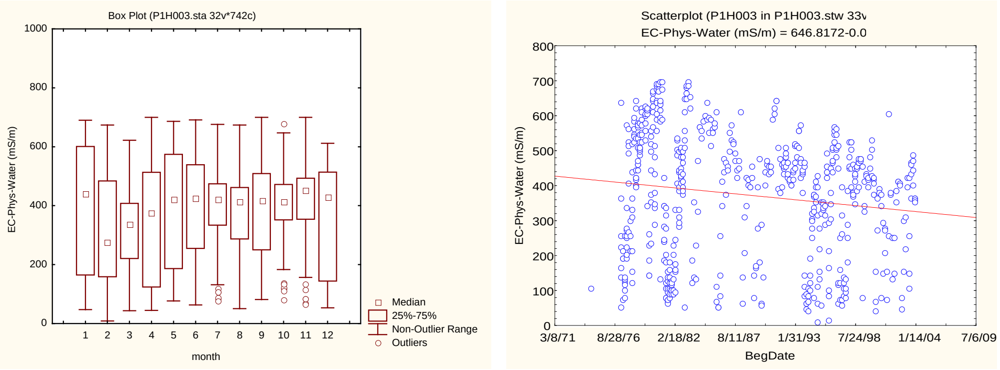

Figure 5a EC values for Site Q6 on the Bushmans River.

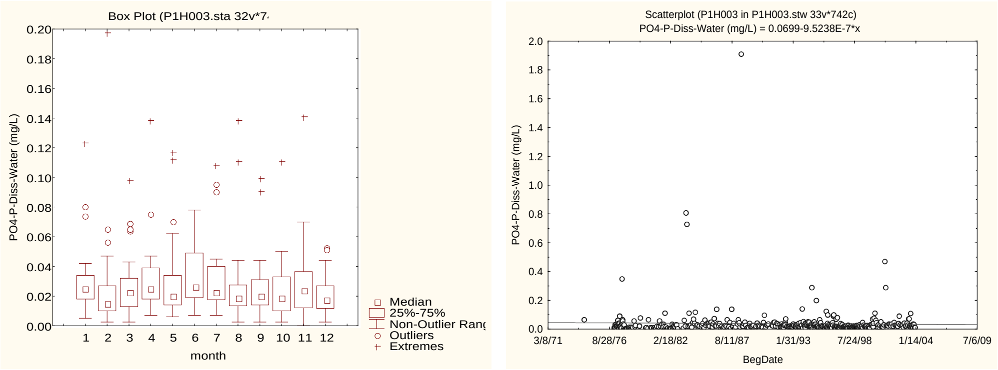

Figure 5b Phosphate values at Site Q6 on the Bushmans River.

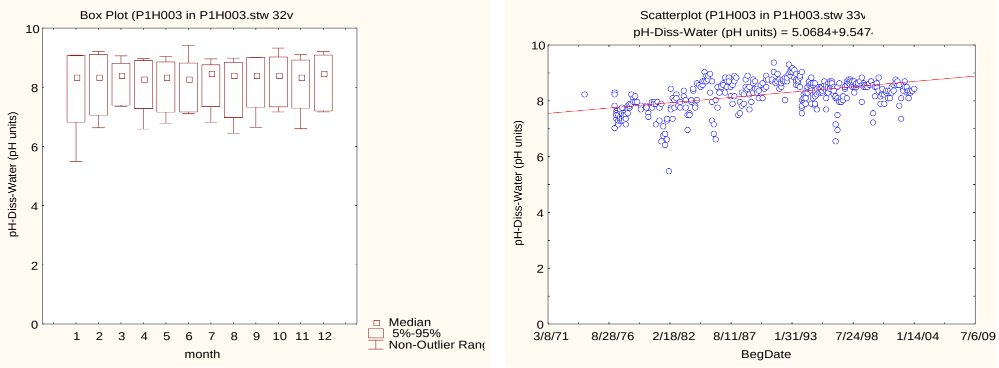

Figure 5c pH values of Site Q6 on the Bushmans River

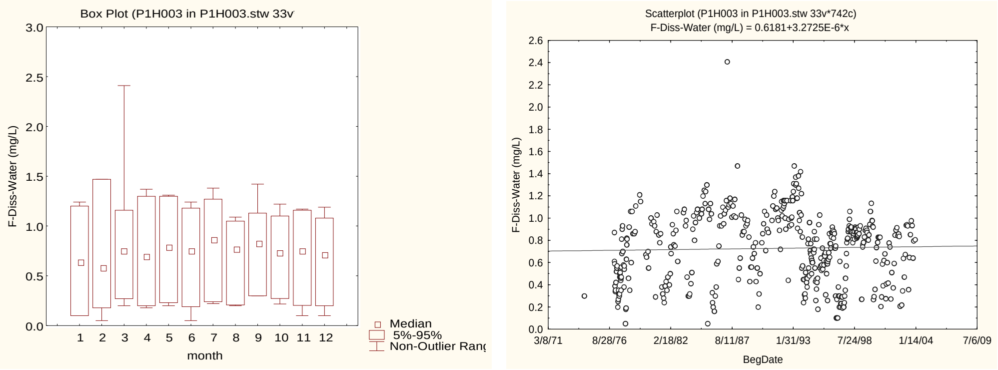

Figure 5d Fluoride concentrations (mg/l) of Site Q6 on the Bushmans River

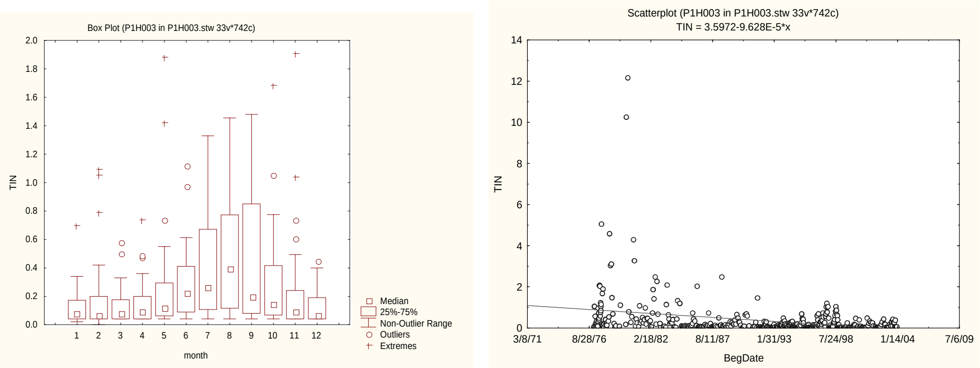

Figure 5e TIN (mg/l) for Site Q6 on the Bushmans River

PHOSPHORUS

Ecological status

The site is located in the middle reaches of the Bushmans River closer to Alicedale. Generally the phosphate levels were low (median fluctuating below 0.04) (Figure 5b).

pH

Domestic use

The pH range of this site (Figure 5c) will not have significant effect on health. Slight effects on taste may occasionally be noticed.

Irrigation
The upper limits of the range higher than 8.4 (Figure 5c), may cause problems of foliar damage, affecting crop yield and the quality of marketable products. There may also be problems with encrustation of irrigation pipes and clogging of drip irrigation systems.

Ecological status
This site is within the good pH boundary between 6.5 and 9.0 (Figure 5c).

FLUORIDE

Domestic use
The fluoride concentrations at this site are generally below 1.5 mg/l although many of the non-outlier range almost reaches 2.5 mg/l. Drinking water from this site may lead to slight mottling of dental enamel in sensitive individuals otherwise no other health effects may occur.

Irrigation
Irrigation with water from this site will have not adverse effects on crops.

Livestock
Water from this site will have no adverse effects on livestock health.

Ecological status
This site is within the natural boundary of fluoride concentration (<1.5mg/l) (Figure 5d).

TIN (Total Inorganic Nitrogen)

Ecological status
TIN levels on this site increase during the winter months (May to August), with the highest TIN levels in August. The TIN levels decrease from August to December, and remain at low levels from December to April (Figure 5c). TIN levels are within the natural boundary from September to May, and within the good boundary from June to August.

5. SITE Q16 (HOWISONPOORT DAM)

ELECTRICAL CONDUCTIVITY

Domestic use
The EC values for water at this site lie between 10 and 90mS/m, and for most months values are well below 70mS/m (Figure 6a). This water is therefore within DWAF target range for domestic use.

Livestock
With such values, the use of water from this site will be suitable for livestock watering purposes.

Agriculture
Although wetting of salt sensitive crops with this water should be avoided, moderately salt sensitive crops could be sustained using a low- frequency irrigation system.

Ecological status
In ecological terms concern would be drawn to the month of August EC when values are higher.

PHOSPHORUS

Ecological status

Howisonpoort Dam is on the Kariega River. It is characterised by very low concentration of phosphates and therefore little nutrient enrichment (Figure 6b). The site is in a ‘good’ condition.

pH

Domestic use

In January the pH range on this site is between 4 and 7.5. In February and March the lowest limit of the pH range is below 6, toxic effects associated with dissolved metals are likely to occur and the water taste is slightly sour. For the rest of the year, pH levels range between 6.0 and 9.0 with no significant effects on health although slight effects on taste may occasionally be noticeable.

Irrigation

The lower limit of the pH ranges of the water is less than 6.5 for most months of the year (especially low for the first three months of the year). At pH levels below 6.5 there may be problems with foliar damage when the crop foliage is wet, giving rise to yield reduction or decrease in the quality of marketable materials. There could also be increasing problems with corrosion of metal and concrete in irrigation equipment.

Ecological status

The pH range of this site is within the good boundary, except for January where the lower limit of the range is less than 5, which is classified as poor.

FLUORIDE

Domestic use

The fluoride concentrations at this site are below 0.5 mg/l (Figure 6d) throughout the year, and within this range no adverse effects or tooth damage may occur.

Irrigation

The fluoride concentrations at this site will have no adverse effects on crops.

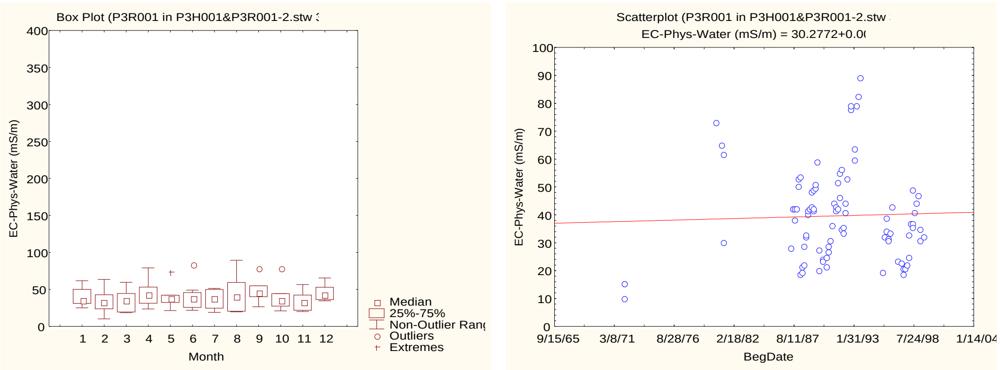

Figure 6a EC values for Site Q16 at the Howisonpoort Dam

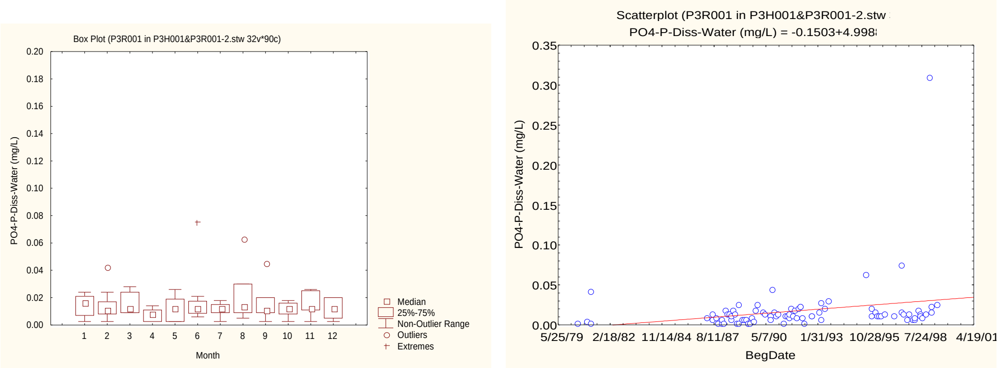

Figure 6b Phosphate values at Site Q16 at Howisonpoort Dam.

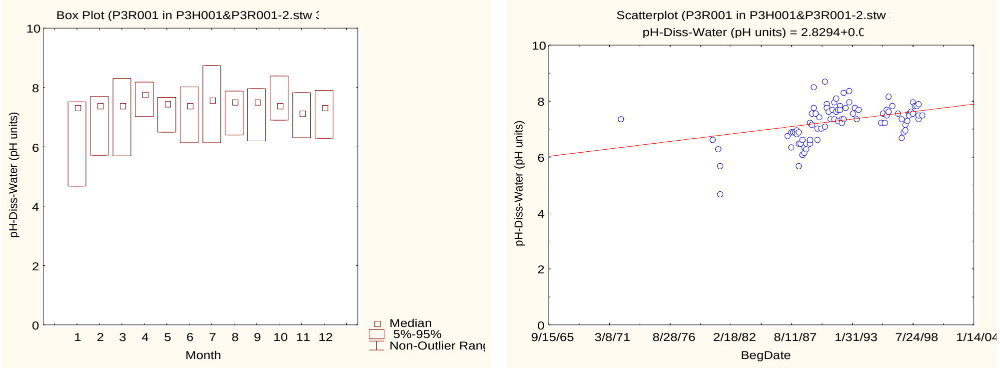

Figure 6c pH values of Site Q16 in Howisonpoort Dam

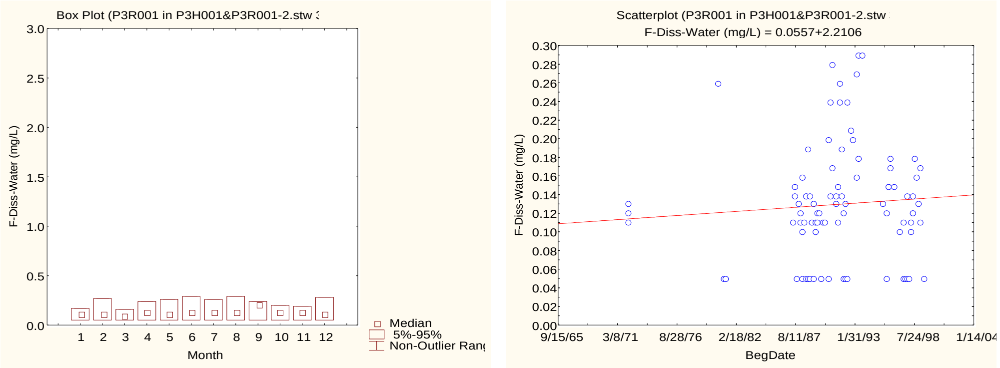

Figure 6d Fluoride concentrations (mg/l) of Site Q16 in Howisonpoort Dam

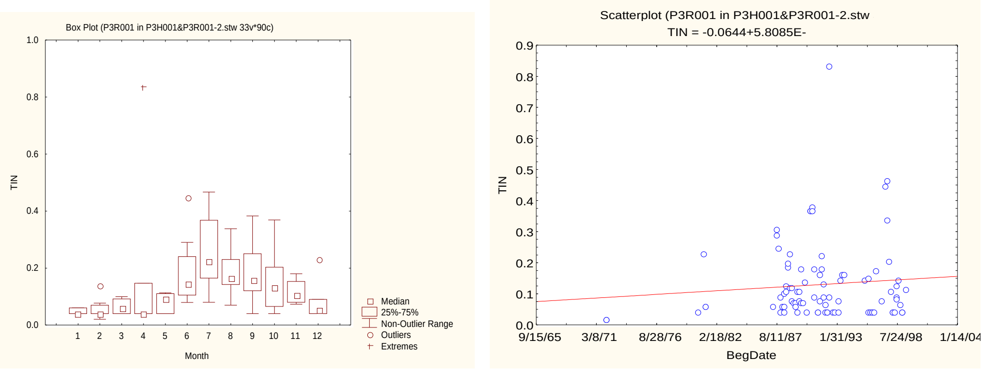

Figure 6e TIN (mg/l) for Site Q16 on Howisonpoort Dam

Livestock
The fluoride concentrations at this site will have no adverse effects on will have no adverse effects on livestock health.

Ecological status
The fluoride concentrations at this site are within the natural boundary

TIN (Total Inorganic Nitrogen)

Ecological status
The TIN levels on this site increase towards winter (May to July), and decrease towards summer (July to December) (Figure 6e).

6. SITE Q14 (JAMESON DAM)

ELECTRICAL CONDUCTIVITY

Domestic
For much of the year, the EC range is well within the DWAF guideline Target Water Quality Range for domestic use of 0 to 40mS/m. For January, November and December however, EC values were much higher. As these values did not exceed 150mS/m no health effects are likely (Figure 7a).

Irrigation
Similarly for agricultural purposes, it is only the EC values above 90mS/m such as seen in November that are of real concern. Irrigation of salt sensitive crops with such water should be avoided.

Livestock
As far as livestock watering is concerned, these EC values are well within acceptable limits.

Ecological status
Since for most of the year, EC values are less than 30mS/m, the water may be considered to be in a natural state.

PHOSPHORUS

Ecological status

The Jameson dam is also located in the New Years River in the upper reaches. Phosphate concentration is small, especially in March, July and October (Figure 7b). The site is in a ‘good’ condition.

pH

Domestic use

During January and February in this site, the lower limit is 6.0 (Figure 7c), there may be toxic effects associated with dissolved metals, and the water may have a slightly sour taste. For all the other months the pH ranges between 6.0 and 8.0, no significant effects on health are expected although there may occasionally be slight effects on the taste of the water.

Irrigation

On this site, most of the time during the year the lower limit of the pH is below 6.5 (Figure 7c), which may cause problems with foliar damage when crop foliage is wet, giving rise to yield reduction or a decrease in the quality of marketable materials. There could also be problems with corrosion of metal and concrete in irrigation equipment at such low pH levels.

Ecological status

At this site pH levels of the water would be classified as being in a good state, except for the first two months of the year where the pH range of the water is in a fair state.

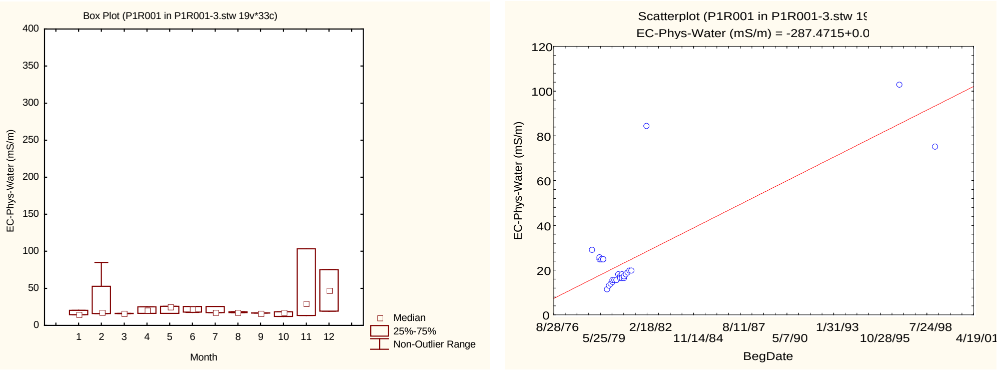

Figure 7a EC values for Site Q14 at Jameson Dam

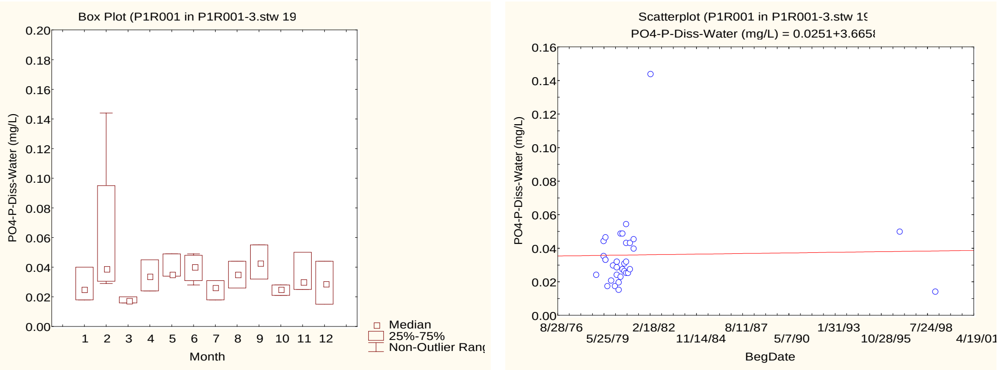

Figure 7b Phosphate values for Q14 at Jameson Dam

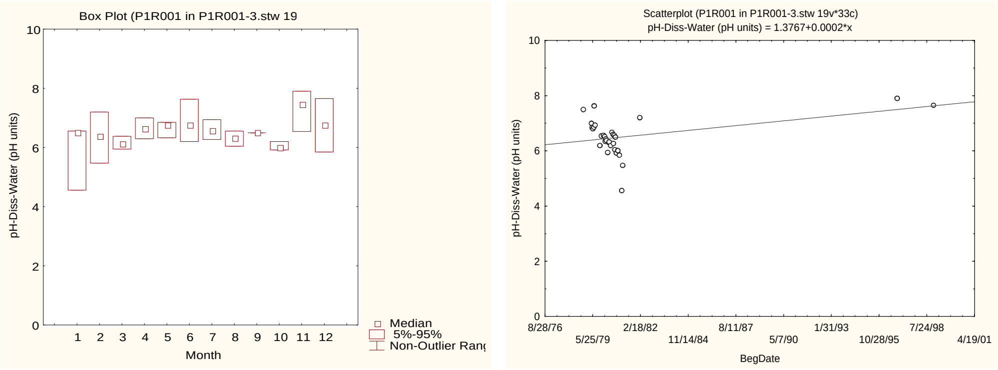

Figure 7c pH values of Site Q14 in Jameson Dam

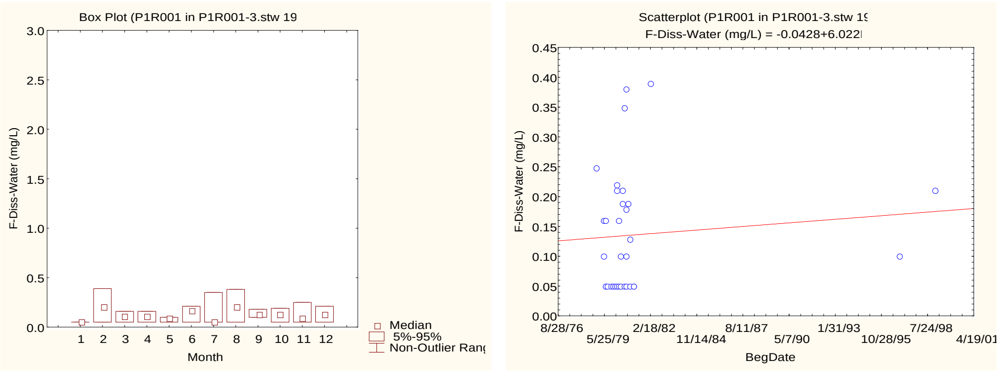

Figure 7d Fluoride concentrations (mg/l) of Site Q14 in Jameson Dam

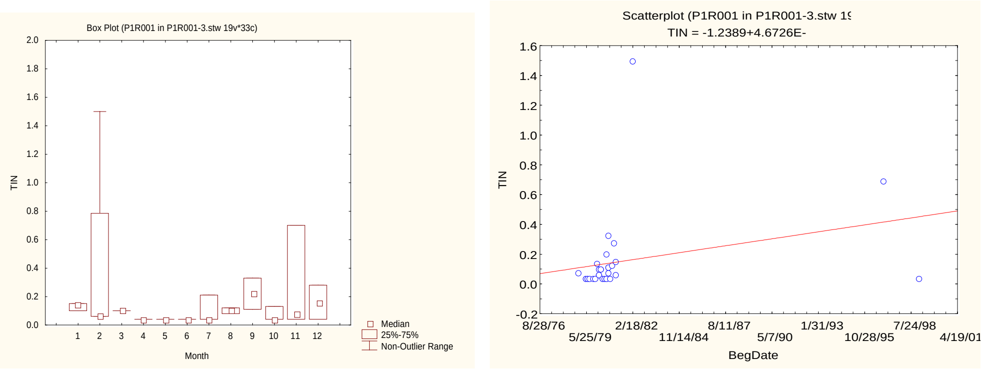

Figure 7e TIN (mg/l) for Site Q14 on Jameson Dam

FLUORIDE

Domestic use

Fluoride concentrations at this site are below 0.5 mg/l (Figure 7d) throughout the year, and within this range no adverse effects or tooth damage may occur.

Irrigation

The fluoride concentrations in the water from this site will have no adverse effects on crops.

Livestock
The fluoride concentrations in the water from this site will have no adverse effects on livestock health.

Ecological status
The fluoride concentrations at this site are below 1.5 mg/l, and therefore within the natural boundary.

TIN (Total Inorganic Nitrogen)

Ecological status
The TIN levels at this site are within the natural boundary throughout the year (Figure 7e).

7. SITE Q9 (KAP RIVER)

ELECTRICAL CONDUCTIVITY

Domestic use
The EC data for this site is relatively variable. For the first three months of the year, EC values can be seen to fluctuate between approximately 50mS/m to close to 200mS/m (Figure 8a). This means that at its worst the water will be likely to have a salty taste and possibly have some effects on plumbing and appliances such as increased corrosion. The water should be safe to drink.

Irrigation
Moderately salt tolerant crops could be maintained using a low-frequency application of this water without significant yield decreases.

Livestock
This water should be completely safe for livestock watering, apart from a possible initial reluctance to drink in the case of poultry and/or pigs.

Ecological status
As the median EC values were mostly between 55 and 85mS/m, for example in the months: April, May, June; the ecological condition of site should be fair. However, the presence of values larger than 85mS/m at other times during the year called for further investigation of individual salts.

PHOSPHORUS

Ecological status
The site is located in one of the tributaries of the Great Fish River. Individual salts were investigated further.

pH

Domestic use
The pH levels on this site are range between 6.0 and 9.0 throughout the year (Figure 8c), no significant effects on health are expected, although there may occasionally be effects on the taste of the water.

Irrigation

For most of the year on this site the lower limits of the pH range are less than 6.5, except for April, June and September, where the lower limits are slightly higher (Figure 8c). At the pH levels less than 6.5, there may be problems with foliar damage when crop foliage is wet resulting in yield reduction or a decrease in the quality of marketable materials. There may also be problems with corrosion of metal and concrete in irrigation equipment.

Ecological status

The pH in this water is in the good ecological boundary.

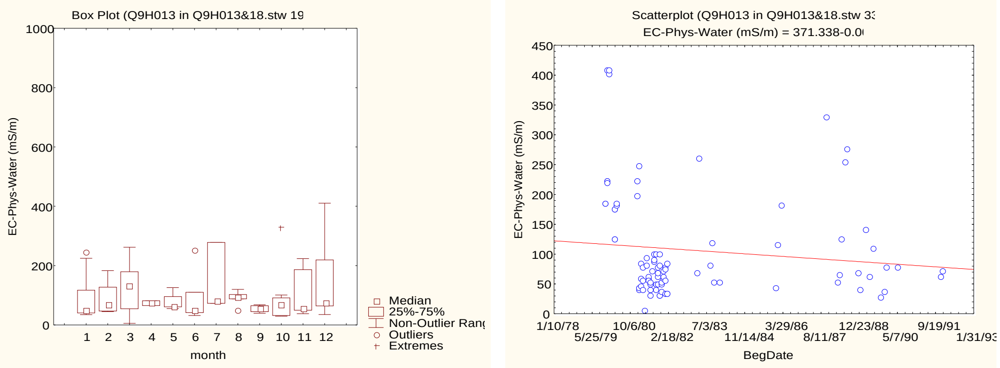

Figure 8a EC values for Site Q9 on the Kap River

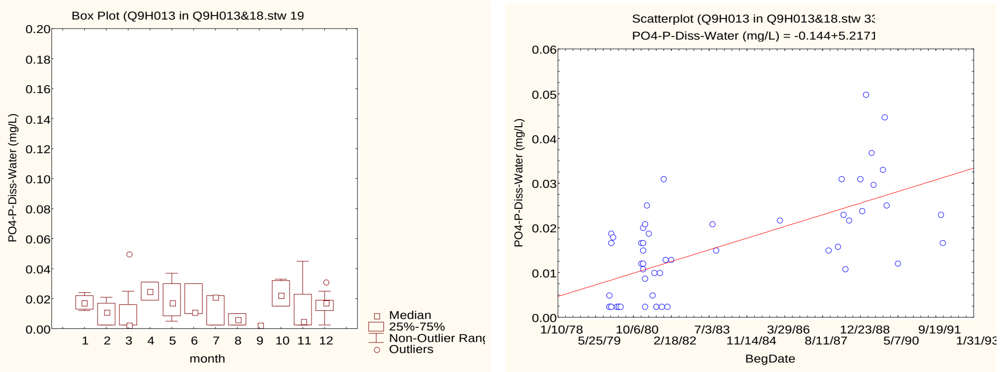

Figure 8b Phosphate values for Site Q9 on the Kap River

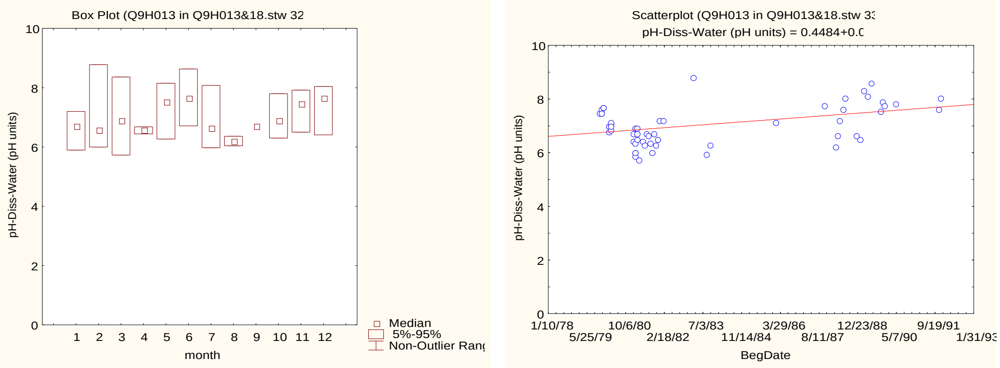

Figure 8c pH values of Site Q9 on the Kap River

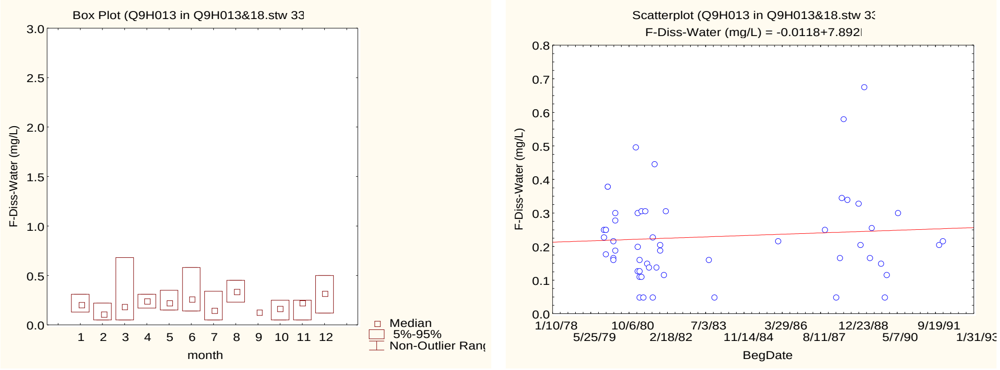

Figure 8d Fluoride concentrations (mg/l) for Site Q9 on the Kap River

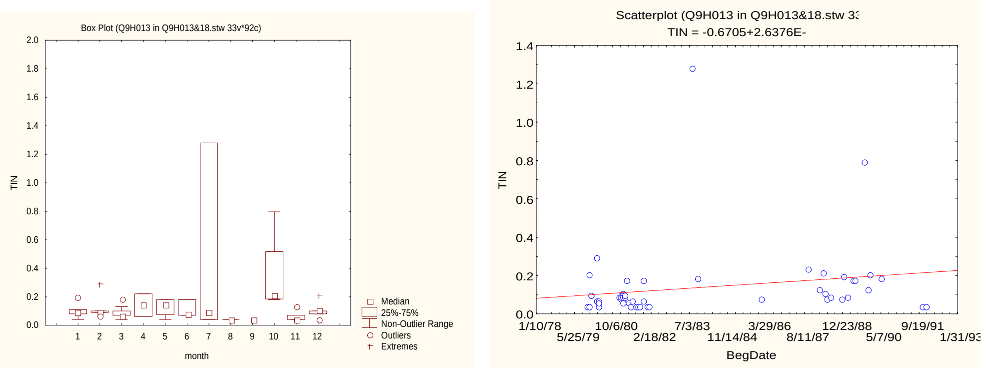

Figure 8e TIN (mg/l) for Site Q9 on the Kap River

FLUORIDE

Domestic use

The fluoride concentration levels at this site are less than 1.0 mg/l throughout the year (Figure 8d), and there are no adverse health effects or tooth damage expected at this range.

Irrigation

The fluoride concentrations in the water from this site will have no adverse effects on crops.

Livestock

The fluoride concentrations in the water from this site will have no adverse effects on livestock health.

Ecological status

Fluoride concentrations at this site are below 1.5 mg/l, and therefore within the natural boundary.

TIN (Total Inorganic Nitrogen)

Ecological status

The TIN levels on this site are within the natural boundary throughout the year.

8. SITE Q8 (KARIEGA RIVER)

ELECTRICAL CONDUCTIVITY

Domestic use

As with the Bushmans River, EC values are elevated relative to DAWF target water quality ranges. This water will have an extremely salty taste and noticeable short-term health effects are likely. Alternative sources of water should be used for drinking.

Irrigation

As the EC values for this site are mostly between 200 and 600mS/m (Figure 9a), the likelihood of sustainable irrigation being possible is not high.

Livestock

Care should be taken when allowing stock to access these waters, particularly in the early part of the year. With EC values of 450mS/m and 600mS/m, poultry, pig production will in all likelihood, decline.

PHOSPHORUS

Ecological status

This site is located in the lower reaches of the Kariega River. The phosphate concentration was very low throughout the year fluctuating around 0.04 mg/l (Figure 9b). The site is in a 'good' ecological state.

pH

Domestic use

The pH levels on this site are on the range between 6.0 and 9.0 throughout the year (Figure 9c), no significant effects on health are expected, although there may be occasional effects on the taste of the water.

Irrigation

Water at this site is in the pH range between 6.5 and 8.4 for most of the year, except for January, June and September where the pH range is slightly higher (Figure 9c). At the pH range between 6.5 and 8.4, there are no adverse effects on crops expected. At pH levels higher than 8.4, there may be problems with foliar damage, affecting crop yield or visual quality of visual marketable products. There may also be problems with encrustation of irrigation pipes and clogging of drip irrigation systems.

Ecological status

The pH of the water in this site is within the good ecological boundary.

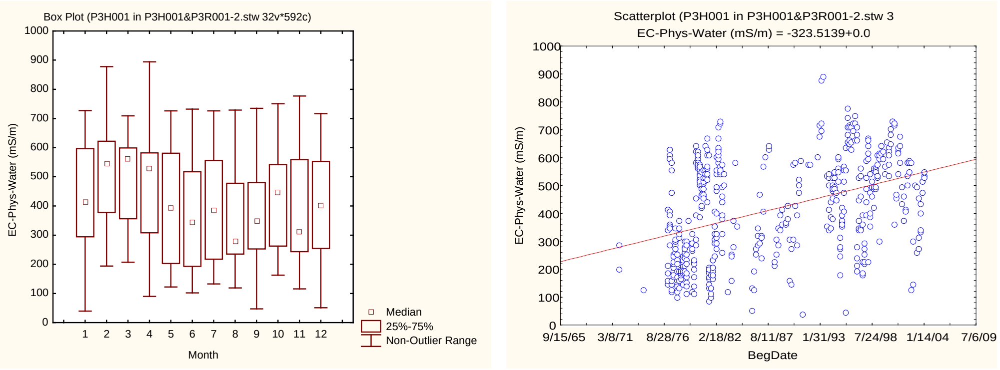

Figure 9a EC values for Site Q8 on the Kariega River

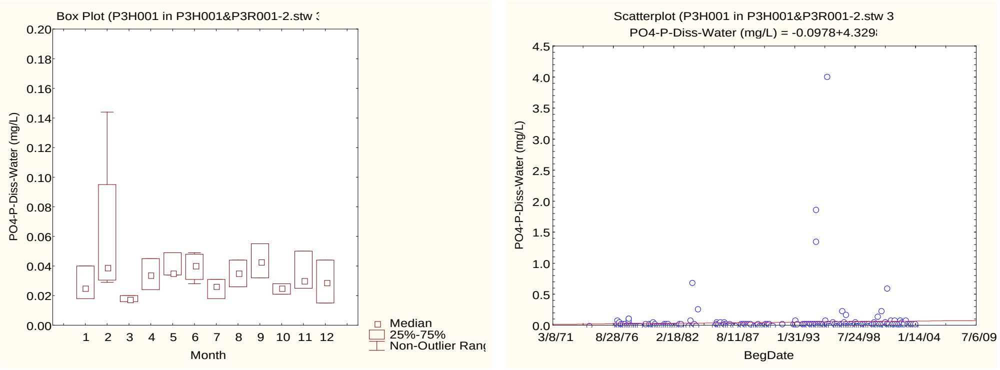

Figure 9b Phosphate values for Site Q8 on the Kariega River

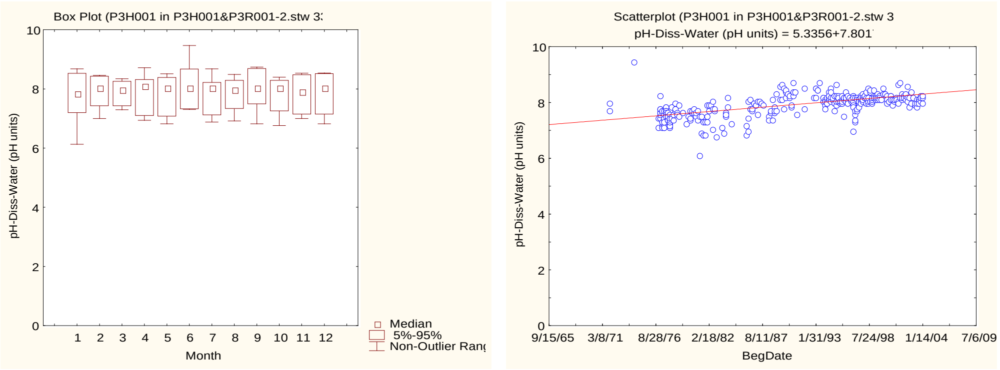

Figure 9c pH levels for Site Q8 on the Kariega River

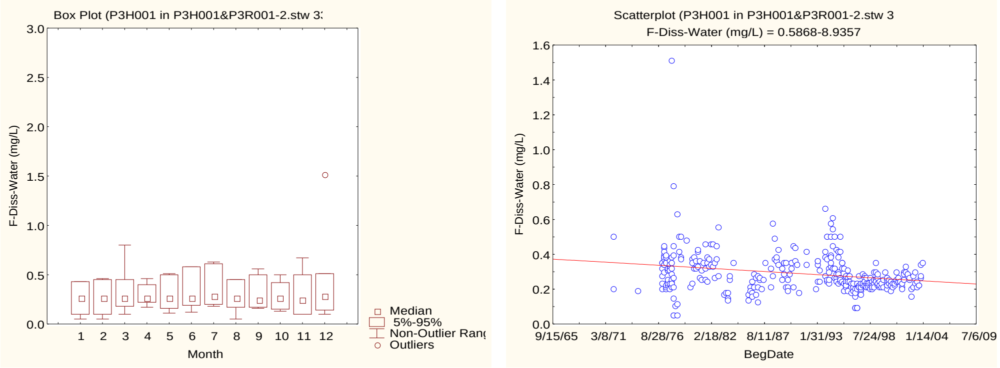

Figure 9d Fluoride concentrations (mg/l) for Site Q8 on the Kariega River

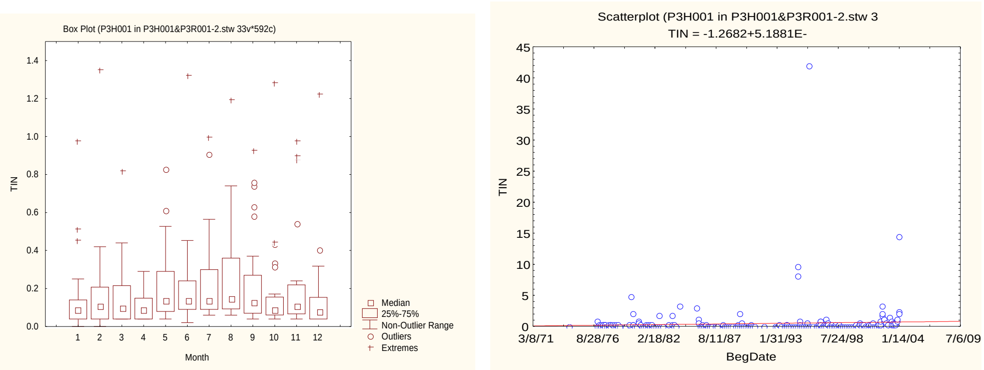

Figure 9e TIN (mg/l) for Site Q8 on the Kariega River

FLUORIDE

Domestic use

The fluoride concentration levels at this site are less than 1.0 mg/l throughout the year (Figure 9d), and there are no adverse health effects or tooth damage expected.

Irrigation

The fluoride concentrations in the water from this site will have no adverse effects on crops.

Livestock

The fluoride concentrations in the water from this site will have no adverse effects on livestock health.

Ecological status

Fluoride concentrations at this site are below 1.5 mg/l, and therefore within the natural boundary.

TIN (Total Inorganic Nitrogen)

Ecological status

This site has low TIN levels within the natural boundary, with little variation throughout the year (Figure 9e).

9. SITE Q15 (MILNER DAM)

ELECTRICAL CONDUCTIVITY

Domestic use

The EC values (Figure 10a) at this site are low and with the exception of August, fall within target quality range for domestic use, this being less than 70mS/m.

Irrigation

Water from this site is also suitable for agricultural purposes (irrigation) as EC values of less than 40mS/m ensure that salt sensitive crops are grown without yield decreases.

Livestock

Since EC values are all below 150mS/m this water would be completely safe for livestock watering purposes.

Ecological status

The EC levels on this site are within the target water quality range.

PHOSPHORUS

Ecological status

The Milner Dam is also situated in the New Years River in the upper reaches. The phosphate levels fluctuate around 0.02 mg/l (Figure 10b) with despite higher levels in July.

pH

Domestic use

The pH levels on this site are on the range 6.0-9.0 for most months in the year, except for January, February, October and December, where the pH range is less than 6.0 (Figure 10c). At the pH range between 6.0 and 9.0 no significant effects on health are expected, although there might be noticeable effects on taste at times. At pH levels between 4.0 and 6.0 there may be toxic effects associated with dissolved metals and the water may have a slightly sour taste.

Irrigation

At this site during February, March, October and December, the pH range is less than 6.5 (Figure 10c), and this may cause problems with foliar damage when crop foliage is wet and resulting in yield reduction or a decrease in the quality of marketable materials. There may also be problems with corrosion of metal and concrete in irrigation equipment. The same could be the case in January and May and June where the lower limits of the pH range are less than 6.5 (Figure 10c). In the other months, however, where the pH range is between 6.5 and 8.4, there will be no adverse effects on the crop yield and quality.

Ecological status

The pH on this site is within the good boundary, except in January where lower limit of the pH range is below 5.0, which is classified as poor.

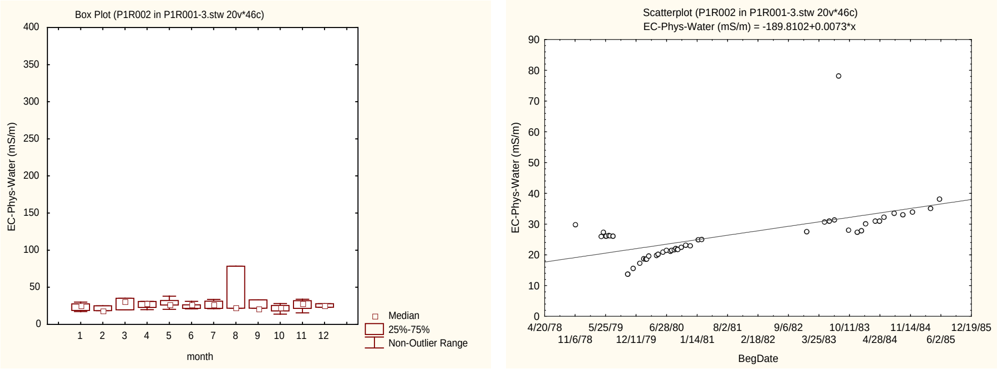

Figure 10a EC values for Site Q15 at Milner Dam

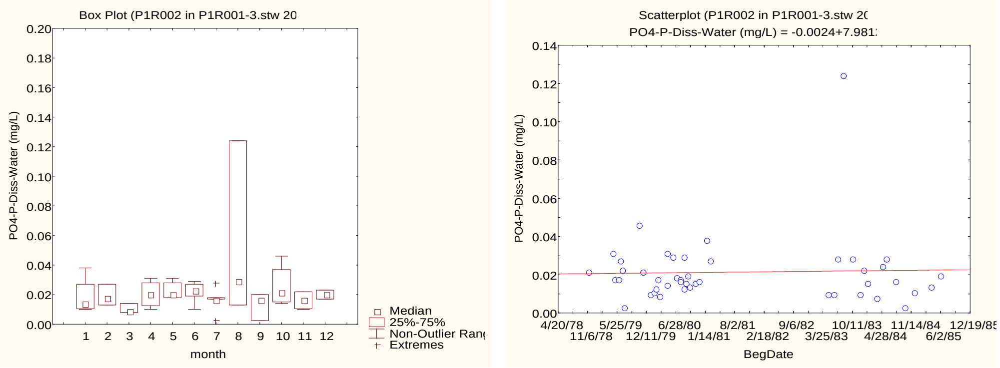

Figure 10b Phosphate values for Site Q15 at Milner Dam

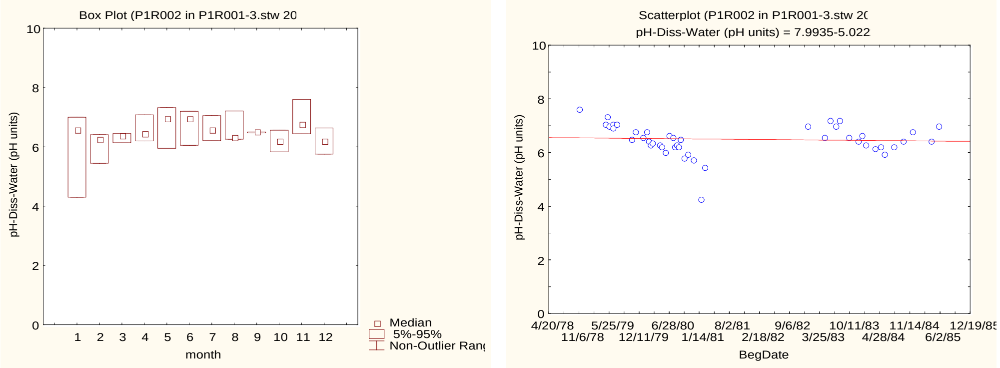

Figure 10c pH values for Site Q15 on Milner Dam

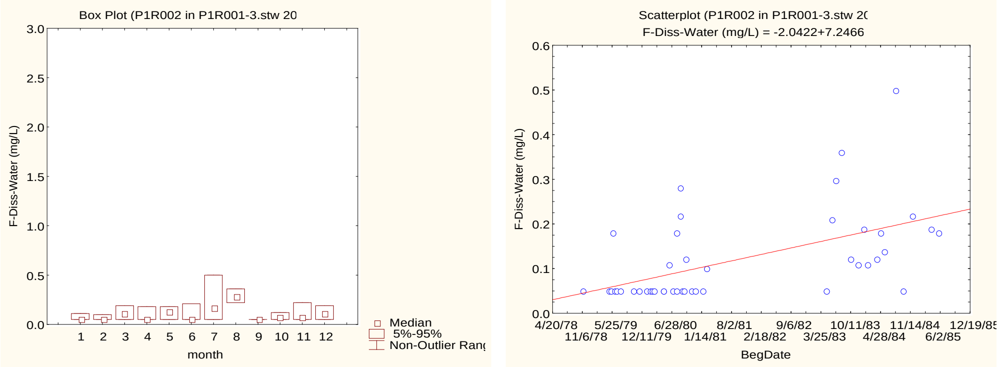

Figure 10d Fluoride concentrations (mg/l) for Site Q15 on Milner Dam

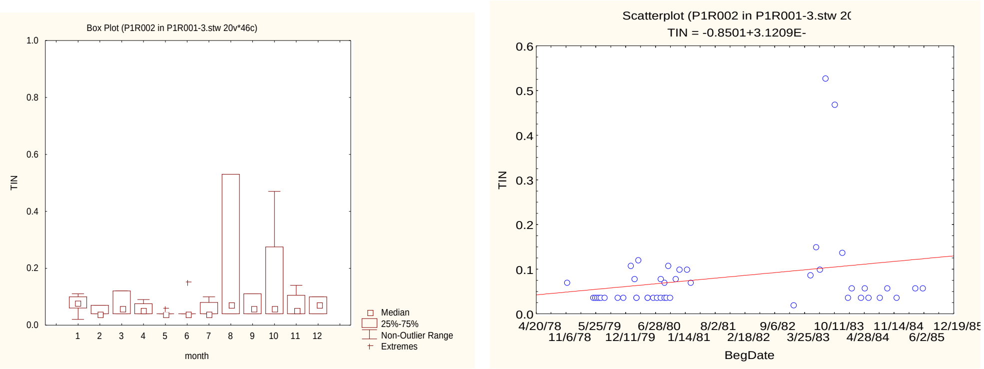

Figure 10e TIN (mg/l) for Site Q15 on Milner Dam

FLUORIDE

Domestic use

The fluoride concentration levels at this site are less than 1.0 mg/l throughout the year (Figure 10d), and there are no adverse health effects or tooth damage expected at this range.

Irrigation

The fluoride concentrations in the water from this site will have no adverse effects on crops.

Livestock

The fluoride concentrations in the water from this site will have no adverse effects on livestock health.

Ecological status

The fluoride concentrations at this site are within the natural boundary.

TIN (Total Inorganic Nitrogen)

Ecological status

The TIN levels on this site are low and within the natural boundary with no variation throughout the year (Figure 10e).

10. SITE Q7 (NEW YEARS DAM)

ELECTRICAL CONDUCTIVITY

Domestic use

This site is located on the New Years River, close to the south-western boundary of the Municipality. The EC plot below (Figure 11a), shows that for the most part, EC values were 50mS/m and 100mS/m. According to DWAF guidelines, this water should not be likely to have any adverse health effects in the context of domestic use as EC values between 0 and 70mS/m form the target water quality range.

Irrigation

For agricultural use, EC values of less than or equal to 40mS/M are the DWAF target water quality range, at this for which values are higher than this, a 95% relative yield of moderately salt-sensitive crop could be grown.

Livestock

For livestock, any EC value less than 450mS/s is acceptable, except for pigs and poultry for which there may be a slight temporary decline in production.

Ecological status

Since the median EC values are all between 55 and 85mS/m, ecologically the site may be classified as fair. As there are maximum EC values higher than 85mS/m, individual salts were studied further.

PHOSPHORUS

Ecological status

The New Years dam is located in the lower reaches of the New Years River, just before this river joins Bushmans River. The concentration of phosphates is very low throughout the year (less than 0.2mg/l) (Figure11b). For this reason the river on this site can be considered as ‘fair’. However, there are extremes where phosphate levels increase, especially during wet seasons. This may be due to phosphates washed towards the river during runoff.

pH

Domestic use

The pH values at this site are between 6.0 and 9.0 throughout the year (Figure 11c), no significant effects on health occur, although there may be occasional effects on the taste of the water.

Irrigation

The pH range at this site is within the range 6.5-8.4 throughout the year (Figure 11c), no effects on crop foliage are expected although there may be slight problems with the clogging of drip irrigation systems.

Ecological status

The pH range at this site is within the good boundary

FLUORIDE

Domestic use

The fluoride concentration levels at this site are less than 1.0 mg/l throughout the year (Figure 11d), no adverse health effects or tooth damage are expected.

Irrigation

The fluoride concentrations in the water from this site will have no adverse effects on crops.

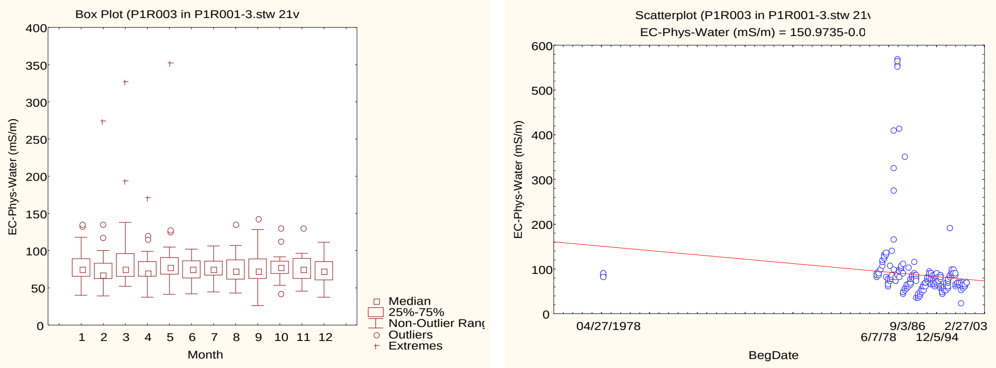

Figure 11a EC values for Site Q7 at New Years Dam.

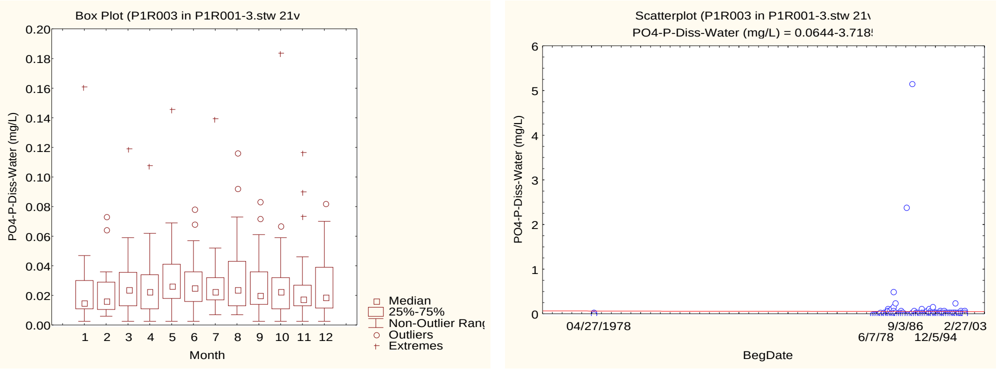

Figure 11b Phosphate values for Site Q7 at New Years Dam.

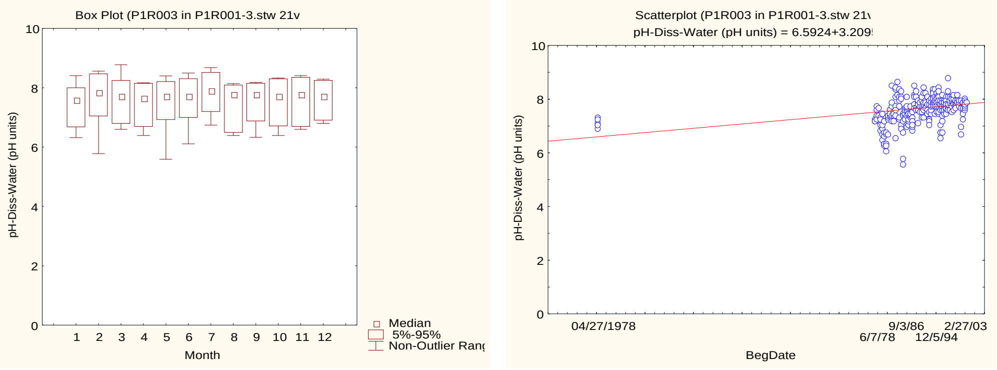

Figure 11c pH values for Site Q7 on New Years Dam

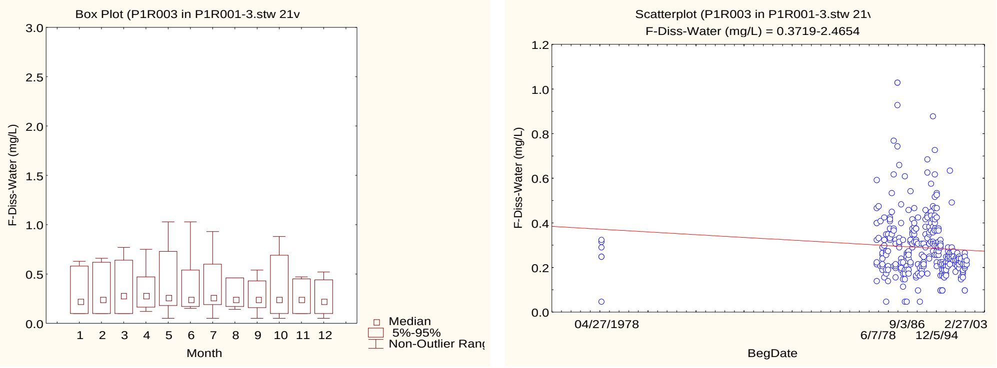

Figure 11d Fluoride concentrations (mg/l) for Site Q7 on New Years Dam

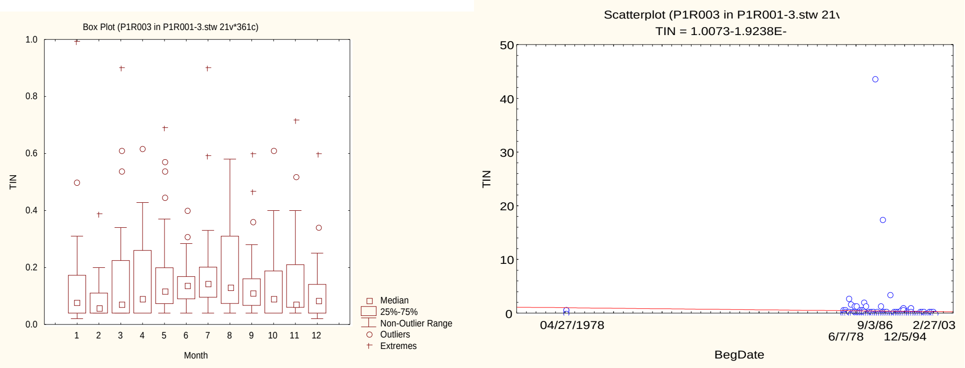

Figure 11e TIN (mg/l) for Site Q7 on New Years Dam

Livestock

The fluoride concentrations in the water from this site will have no adverse effects on livestock health.

Ecological status

Fluoride concentrations (Figure 11d) are within the natural boundary.

TIN (Total Inorganic Nitrogen)

Ecological status

The TIN concentrations on this site are within the natural boundary throughout the year (Figure 11e).

11. SITE Q5 (SETTLERS DAM)

ELECTRICAL CONDUCTIVITY

Domestic use

The EC values (Figure 12a) are much the same as those of the New Years Dam, with most of the values lying between approximately 50 and 100mS/m. The water at this site is thus safe for domestic use.

Irrigation

Most values are higher than 40mS/m meaning that the success of salt-sensitive crops cannot be assured. However, moderately salt-sensitive crops could be grown while using this water for irrigation.

Livestock

Having EC values lower than 100mS/m, no significant adverse effects should be expected.

Ecological status

This site may be classified as being fair for those periods when the EC values were between 55 and 85mS/m, but as the EC values exceeded 85 for much of the year individual salt concentrations were studied further.

PHOSPHORUS

Ecological status

The Setters Dam was constructed in the Kariega River. Phosphate levels are very low (Figure 12b), probably because the site is located in an area with low negative land-use impacts.

pH

Domestic use

The pH ranges at this site (Figure 12c) will have no significant adverse effects on health although there may be slight effects on the taste of the water.

Irrigation

For the first four months of the year the upper limit of the pH range is above 8.4 (Figure 12c), there may be problems with foliar damage affecting crop yield or visual quality of marketable products. There may also be problems with encrustation of irrigation pipes and clogging of drip irrigation systems.

Ecological status

The pH range at this site is within the good boundary.

FLUORIDE

Domestic use

Fluoride concentrations at this site are below 1.0mg/l, where no adverse effects are expected, for the most part of the year. In May, where fluoride concentrations go up to above 2.5 (Figure 12d), and the threshold for marked dental mottling with associated tooth damage due to softening of enamel is 1.5 mg/l. Above this concentration mottling and tooth damage will probably be noticeable in most continuous users of the water.

Irrigation

The fluoride concentrations at this site will have no adverse effects on crop yield, although for May fluoride concentrations are a bit higher than the rest of the year and these concentrations are acceptable for irrigation of fine textured neutral to alkaline soils.

Livestock

Fluoride concentrations at this site will have no adverse effects on ruminants throughout the year. In May, where fluoride concentrations go up to above 2.5mg/l, monogastrics may experience chronic effects associated with dental fluorosis in mature livestock. A decrease in feed and water intake and a decline in productivity may occur with continuous long-term exposure, but unlikely if exposure is short-term and feed concentrations are normal.

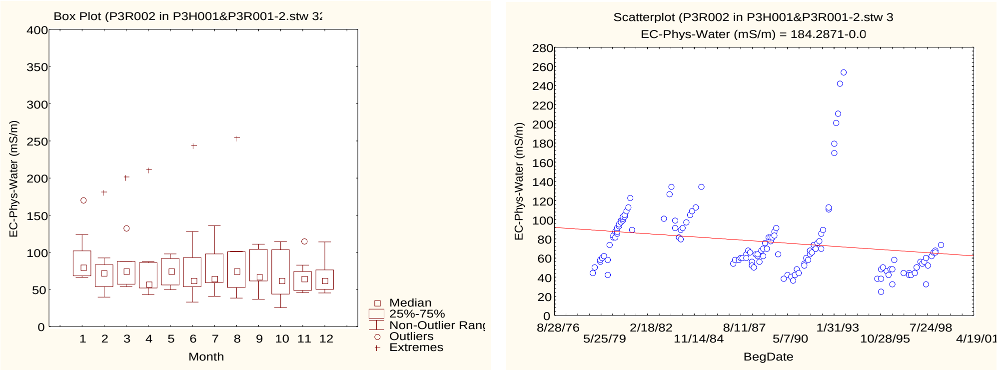

Figure 12a EC values for Site Q7 at Settlers Dam

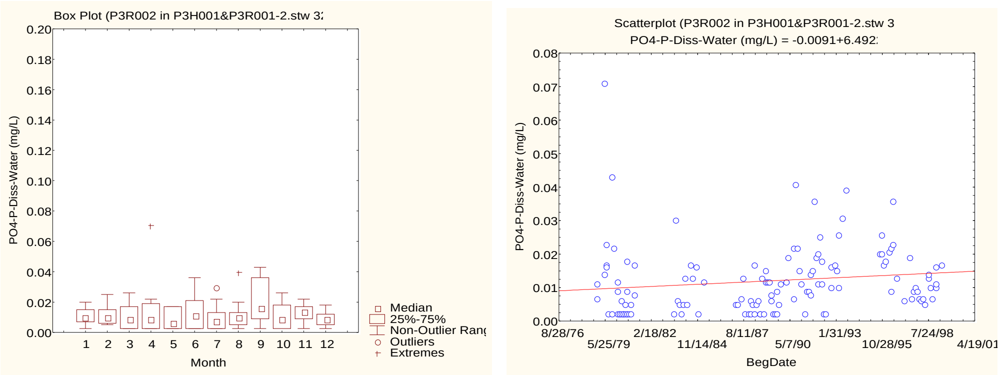

Figure 12b Phosphate values for Site Q5 on Settlers Dam

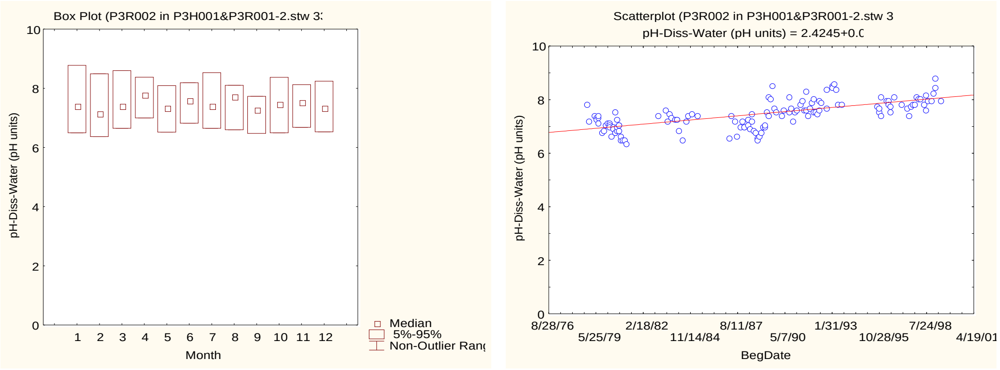

Figure 12c pH values for Site Q5 on Settlers Dam

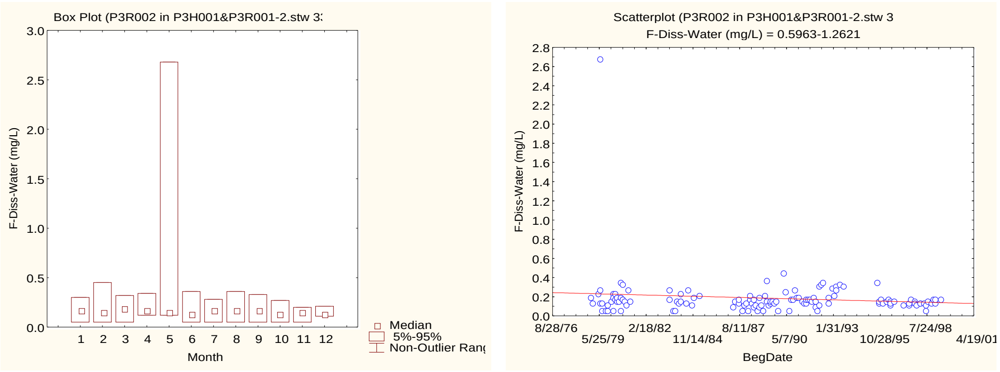

Figure 12d Fluoride concentrations for Site Q5 on Settlers Dam

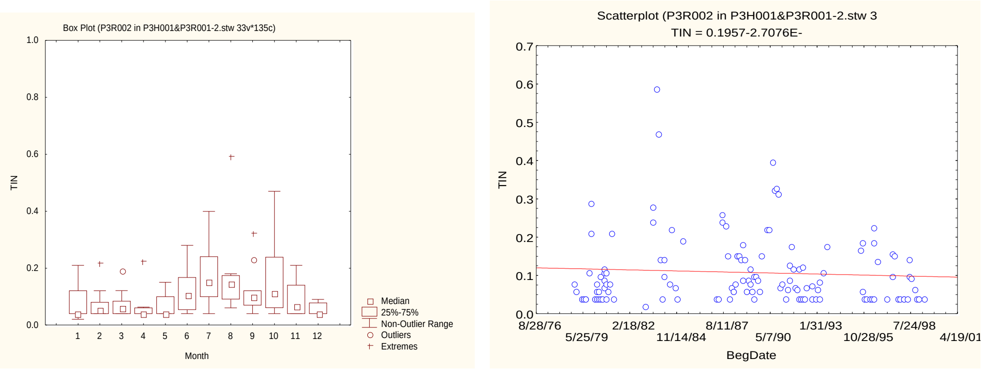

Figure 12e TIN (mg/l) for Site Q5 on Settlers Dam

Ecological status
Fluoride concentrations at this site are within the natural boundary, except for May where the fluoride concentrations are slightly above 2.5mg/l, and may be classified as fair.

TIN (Total Inorganic Nitrogen)
Ecological status
TIN levels on this site are within the natural boundary throughout the year (Figure 12e).

12. SITE Q17 (KOWIE RIVER)

ELECTRICAL CONDUCTIVITY

Domestic use

The EC levels in this site are in the region between 200 and 400 mS/m (Figure 13a). During the months where EC values are below 300mS/m water may have a salty taste, but there are no adverse health effects expected. When the EC values are above 300mS/m, water can be extremely salty and short-term consumption may cause probable disturbance of the body's salt balance.

Irrigation

Moderately salt-tolerant crops can be maintained with the EC levels on this site provided that a high-frequency irrigation system is used.

Livestock

EC levels from this site will have no adverse health effects on livestock, although there may be possible temporary reluctance to drink the water.

Ecological status

The EC values from this site are too high to use as an assessment criterion and individual salts were individually assessed.

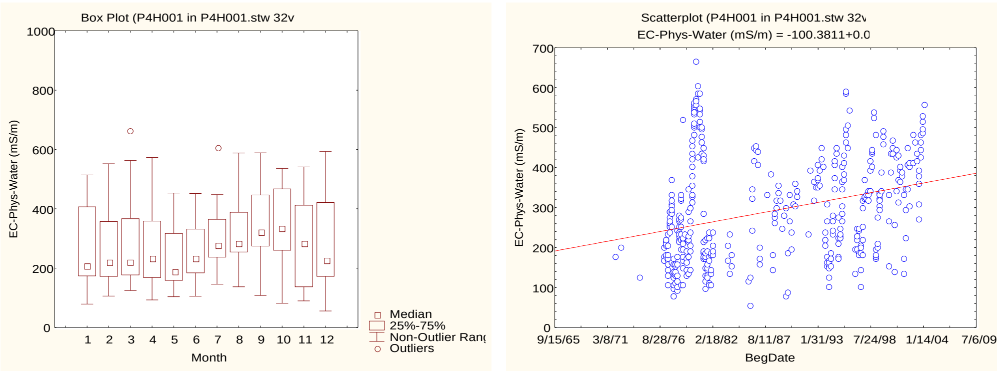

Figure 13a EC values for Site Q17 on the Kowie River

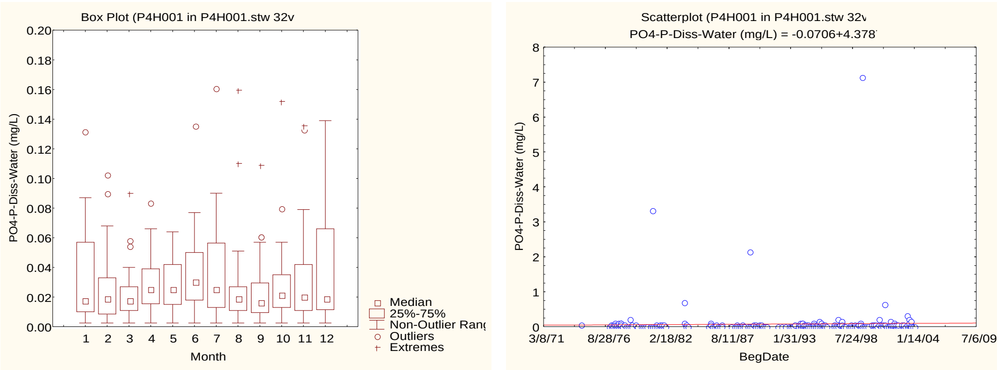

Figure 13b Phosphate values for Site Q17 on the Kowie River

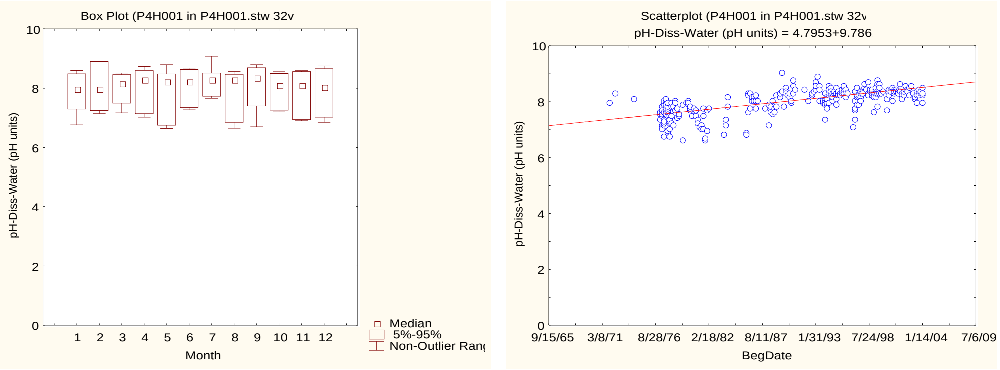

Figure 13c pH values for Site Q17 on the Kowie River

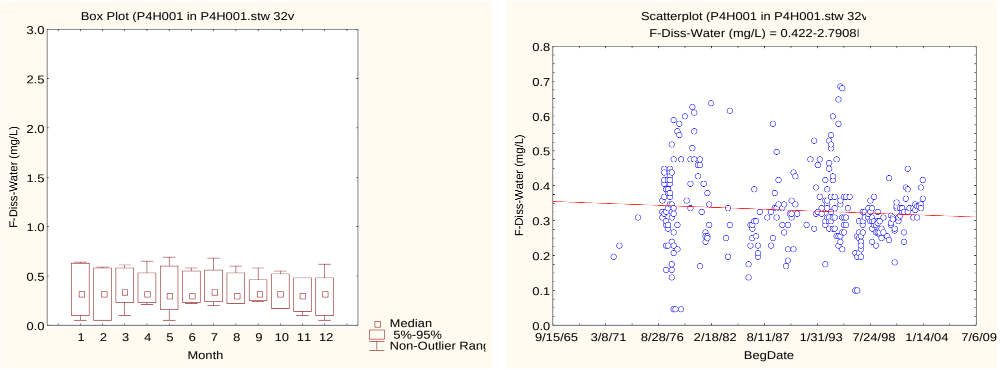

Figure 13d Fluoride concentrations (mg/l) for Site Q17 on the Kowie River

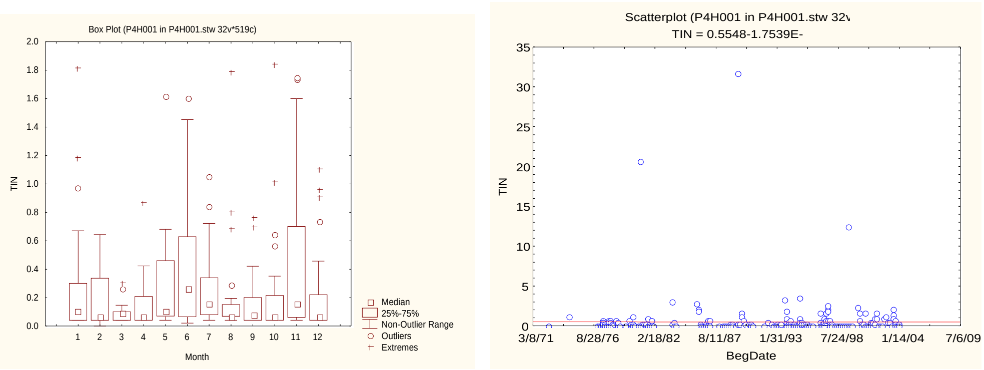

Figure 13e TIN (mg/l) for Site Q17 on the Kowie River

PHOSPHORUS

Ecological status

This site is within the good boundary for most of the year, except for the winter months (June and July) where median phosphate values are above 0.025mg/l (Figure 13b) and in the fair boundary.

pH

Domestic use

The pH levels on this site will have no adverse health effects (Figure 13c), although there may be occasional slight effects on the taste of the water.

Irrigation
The pH range on this site is not likely to have any effects on crop yield and quality (Figure 13c).

Ecological status
The pH range on this site is within the good boundary.

FLUORIDE
Domestic use
The fluoride concentrations on this site will have no adverse health effects (Figure 13d).

Irrigation
The fluoride concentrations water from this site will have no adverse effects on the crop yield and quality (Figure 13d).

Livestock
The fluoride levels on this site will have no adverse effects on livestock health.

Ecological status
The fluoride concentrations in this site are within the natural boundary.

APPENDIX 2: Pictorial details of the sites on the Bloukrans and Palmiet/Berg Rivers during September 2004.

Site B1. Section of non-canalized Bloukrans River below small road-bridge on Matthew Street, near Fort England Hospital. 33°18’47”S 26°32’29” E.

Site B2. Stream flowing out of the sewage farm (treated sewage effluent) into the Bloukrans River. 33°18’56”S 26°33’36” E.

Site B3. Section of Bloukrans River below farm-road bridge close to N2 highway bridge. 33°19’04”S 26°34’06” E

Site B4. Section of Bloukrans River below Railroad bridge and immediately below road bridge. 33°19’26”S 26°35’59” E.

Site B5. Section of Bloukrans River below weir on Mr. Duncan’s farm. 33°19’405”S 26°38’35” E.

Site B6, section of Bloukrans River at Blaawkrantz Pools (33°23’28”S 26°42’25” E) and
Site B7 Bloukrans River at the farm Luembe, downstream of extensive pineapple plantations 33° 27’27”S 26°41’36”E.

Sites were dry in May and September 2004 at time of sampling.

Site B8 below confluence of Berg and Palmiet Rivers, below N2 highway 33°22’18”S 26°28’35” E

APPENDIX 3: Detailed records of the SASS and ASPT scores for biotopes at each biomonitoring site from 2002 to 2004 (De Moor *et al*., 2002; Barber-James *et al*., 2003).

Table 15. SASS and ASPT scores for each biotope (stone and rock; all vegetation; and gravel, mud and sand) and total SASS and ASPT scores for each site, comparing all biomonitoring results over 2002 to 2004.

SASS Scores Per Biotope, and Site Totals (September 04)

Site	Stone & Rock	All vegetation	Gravel, Sand, Mud	Total
B1	11		12	23
B2	22	12	6	40
B3	21	31	27	79
B4	32	13	32	77
B5	43	57	31	131
B6				
B7				
B8	26	15	34	75
B9				

ASPT Scores Per Biotope, and Site Totals (September 04)

Site	Stone & Rock	All Vegetation	Gravel, Sand, Mud	Total
B1	2.2		3.0	2.5
B2	4.4	2.4	2.0	3.1
B3	5.3	5.1	5.4	5.3
B4	4.6	4.4	4.0	4.3
B5	4.3	5.2	3.4	4.4
B6				
B7				
B8	4.3	3.8	4.3	4.2
B9				

SASS Scores Per Biotope. and Site Totals (May 04)

Site	Stone & Rock	All Vegetation	Gravel, Sand, Mud	Total
B1	36	22	20	50
B3	46	27	40	60
B4	51	23	60	77
B5	35	48	30	81
B6				
B7				
B8	86	37	34	89
B9	0	27	0	27

ASPT Scores Per Biotope, & Site Totals (May 04)

Site	Stone & Rock	All vegetation	Gravel, Sand, Mud	Total
B1	5.1	3.1	4.0	4.5
B3	5.1	3.8	5.0	5.0
B4	4.6	3.8	5.5	4.5
B5	5.0	4.0	3.8	4.5
B6				
B7				
B8	5.1	4.6	3.7	4.9
B9	0	4.5	0	4.5

SASS Scores Per Biotope, and Site Totals (September 03)

Site	Stone & Rock	All Vegetation	Gravel, Sand, Mud	Total
B1	25			25
B2	14			14
B3	23			23
B4	34	31		51
B5	42			42
B6	81	69		120
B7	50			50
B8				
B9				

ASPT Scores per Biotope, and Site Totals (September 03)

Site	Stone & Rock	All Vegetation	Gravel, Sand, Mud	Total
B1	3.6			3.6
B2	3.5			3.5
B3	3.8			3.8
B4	4.9	5.2		5.6
B5	4.7			4.7
B6	6.2	5.8		5.7
B7	5.0			5.0
B8				
B9				

SASS Scores per Biotope, and Site Totals (November 02)

Site	Stone & Rock	All Vegetation	Gravel, Sand, Mud	Total
B1	13			13
B2				
B3	22	17		32
B4	29	31		42
B5	57	44		60
B6	95	50		97
B7				
B8				
B9				

ASPT Scores Per Biotope, and Site Totals (November 02)

Site	Stone & Current	All Vegetation	Gravel, Sand, Mud	Total
B1	2.6			2.6
B2				
B3	3.1	0.8		3.6
B4	5.8	3.4		4.2
B5	6.3	4.9		5.0
B6	6.3	5.6		6.1
B7				
B8				
B9				

APPENDIX 4

Quoting from Palmer *et al.* (2004): in order to ascertain which water quality monitoring points and relevant data are to be used for Reference Condition assessment (*i.e.* not impacted by point source or agricultural run-off) and which data are to be used for Present Ecological State assessment:

- Ecological Water Requirements (river) assessments for water quality require that an assessment be made of Reference condition. This is to benchmark the default boundary values provided in the methods for the categories and determine whether natural background levels are different from those values provided. In the event that they are, the values in the benchmark tables need to be recalibrated so that an accurate assessment of the Present Ecological State can be undertaken.
- However, data obtained from DWAF water quality monitoring points can be used to determine both Reference Condition and Present Ecological State. The confidence level of the assessment is determined by the sample size and the method discussed within Jooste and Rossouw (2002) and Palmer *et al.* (2004b) describes a statistical procedure to calculate this.
  - Data obtained from DWAF water quality monitoring points that have been operational for several decades may be appropriate for Reference Condition assessment. This can be ascertained by plotting the concentrations of appropriate water quality variables over time and determining whether there is a detectable trend over time. If there is a trend, the earlier part of the record may be appropriate for Reference Condition determination (i.e. pre-impact data) while the more recent data record may be appropriate for a Present Ecological State assessment.
  - There may be a water quality monitoring point upstream of any impacts in the resource unit that may be suitable for Reference Condition assessment. In this case, the more recent data record can be used.
  - Assess whether it is necessary, and appropriate, to use water quality data from dam outflow.

2 DISTRIBUTION OF WETLANDS IN MAKANA

Weideman, C., Kirby, D., Zingel, T. and Connellan, B.

2.1 EXECUTIVE SUMMARY

Wetlands provide a multitude of valuable functions and services, both ecological and socio-economic in nature. Their value is of particular significance in drier climates, where they act to regulate and prolong stream flows, increasing the length of time that water is available in the catchment. They are similarly instrumental in water purification, agricultural production, drought relief, and the provision of harvestable resources. Consequently, their loss should be viewed in a serious light.

South Africa has lost 50% of the wetlands in the last century. The highest rates of loss have occurred within the semi-arid regions of the inland margin zones, which comprises Makana municipality. The lack of information regarding the spatial distribution and classification of wetlands in the country has been identified as the major obstacle to the development of conservation strategies at national, provincial and local levels.

This study, in line with a drive to compile a national wetland database by a subsidiary of the Department of Environmental Affairs and Tourism, the South African Wetlands Conservation Programme, attempts to provide a basis to facilitate the development of a wetland inventory. By digitally modelling the predicted distribution of wetlands within the Makana municipality, Eastern Cape, and providing an assessment of the risks facing wetlands in the region based on the prevailing land-cover and the land-use pressures they imply, a platform for further inventory work is established and an indication of priority areas provided.

Modelling predicted the potential wetland distribution to occur largely in areas associated with low land-use pressures, such as bushland and thicket, grassland and fynbos. High-risk land-uses, such as intensive cultivation and grazing, and urbanisation comprised a significantly lower proportion of the modelled distribution. Thus, although situated in an area traditionally assumed to be a high risk in terms of wetland loss, the low intensity land-use practices prevalent mean that Makana municipality is probably exempt from this assumption.

There was evidence of erosional degradation of wetlands on commonage areas due to subsistence grazing, facilitated by the ease of access to these areas by subsistence farmers. Currently, no policy is maintained by the municipality regarding wetland use on commonage areas, and a framework needs to be developed regarding sustainable use of wetland resources.

Alien vegetation encroachment has been identified as a major cause of wetland destruction, although the extent of encroachment is undetermined due to lack of data. Cooperation by wetland conservation bodies with the Department of Water Affairs and Forestry should shed light on the nature of threats facing wetlands in the region.

Endorheic pans in the south of the municipality seem to be experiencing extended and uncharacteristic levels of desiccation. Whether this is due to climatic factors or catchment management practices is not known, but close monitoring of potential drivers of this situation should be undertaken.

Threats facing wetlands occur on a catchment-wide basis, and thus may originate from outside Makana’s boundaries. Catchment management practices need to be studied on a wider

scale than attempted in the scope of this project. It is possible that, although water abstraction and land-use pressures within modelled distribution were found to be negligible, collectively they may represent a threat to wetland health on a catchment-wide basis.

2.2 INTRODUCTION

It is estimated that there has been a 50% loss of wetlands in South Africa (Kotze *et al.*, 1995 cited in Cowan, 1995), with some of the greatest loss occurring in the inland margin areas, encompassing the Makana municipality. South Africa is known to be a water-poor country, with a consequently lower natural wetland extent and smaller individual wetlands (Kotze *et al.*, 1995 cited in Cowan, 1995). This paucity of natural wetland distribution means that the implications of loss of wetlands are severe. It has been noted that the effects of wetland loss include decreased agricultural productivity, poorer water quality, less reliable water supplies, increased incidence and severity of flooding and increased threat to wildlife resources (Breen and Begg, 1989). In response to worldwide natural wetland losses, the Ramsar convention, ratified in 1971, bound all signatories, including South Africa, to include wetland conservation as a national policy and to promote sound wetland utilization. These commitments have largely not been met.

In South Africa, the lack of spatial information regarding wetland distribution and abundance has been identified as the major obstacle to development, implementation and monitoring of wetland conservation strategies at national, provincial and local levels (Dini and Cowan, no date). It has been recognised that the generation of information on the distribution and status of South African wetlands is a priority, and the South African Wetlands Conservation Programme (SAWCP) of the Department of Environmental Affairs and Tourism (DEAT) has been tasked with developing a national wetlands inventory, which is currently in progress.

Although a number of mapping projects have been previously undertaken in various parts of the country, there have been inconsistencies that the national inventory as proposed by DEAT, aims to address. In line with the objectives of SAWCP, this project provides a basis for further work on a national wetlands inventory by establishing, within limits, the extent of wetland distribution in the Makana municipality, Eastern Cape, classifying wetlands according to a standardized inventory being developed by SAWCP, and determining the nature of threats to wetland health.

2.2.1 Wetland functions

Wetlands have long been acknowledged as being key natural habitats of exceptionally high diversity and productivity (Ramsar, 2001), providing a range of invaluable services to humankind. Unfortunately, the nature of these services has largely been poorly defined and understood in the past. The services include tangible benefits such as:

- regulation of catchment drainage and river flow,
- flood peak reduction,
- drought relief,
- water purification and waste assimilation and
- soil erosion protection and sediment accretion.

Wetlands also provide socioeconomic benefits, such as opportunities for recreation and education, harvestable resources and facilitation of agricultural production (Begg, 2001).

Regulation of catchment drainage and riverflow

Although the relationship between groundwater and wetlands is complicated (Ramsar, 2001b), wetlands act to absorb water, regulating its release into the catchment, thereby prolonging riverflows (Begg, 2001). This makes water available for use during drier periods in catchments which, in the absence of wetlands, otherwise would have released their water into the drainage system far more rapidly.

Flood peak reduction

Related to their tendency to regulate water flow is the ability of wetlands to mitigate the effects of floods (Begg, 2001). Catchments without wetlands have a reduced capacity to buffer flash flood events, and suffer greater damage than those catchments well buffered with wetlands. Wetland basins, not already filled to capacity, both reduce flood peaks and slowly release floodwaters to downstream areas, providing a steady flow of clean, useable water.

Drought relief

The value of wetlands as water reservoirs is emphasized in arid areas, where the relationship between water storage and streamflow are vital (Begg 2001). During droughts, or dry seasons, pressure on fresh water resources means that plants, animals, and humans may be heavily reliant on the water storage capacity of wetlands. Wetlands are of particular significance to subsistence or small scale commercial rural communities, in the South African context, during periods of drought (DEAT). Their elevated water regimes provide grazing and limited cultivation, and allow rural families to supplement their livelihoods in situations in which survival would otherwise be difficult. In South Africa, it is felt that the Department of Agriculture does not recognize this value to small communities and therefore does not support the sustainable use of wetlands.

Water purification and waste assimilation

Wetlands are often referred to as ‘nature’s kidneys’ as they act as natural filters, playing an important part in the improvement of water quality (Begg, 2001). High levels of particulate matter and nutrients such as phosphorous and nitrogen, are trapped and absorbed by wetland plants and soils, effectively improving the quality of water leaving the wetland. This filtering process is very important as it prevents eutrophication further downstream, a process that leads to rapid plant and algal growth followed by depleted oxygen levels that affects other species. Many wetland plants also have the capacity to remove toxic substances that originate from pesticides, industrial discharges and mining activities (Ramsar, 2001d). It is for this reason that the water leaving a wetland is often cleaner than that entering it, thereby ensuring protection for downstream habitats.

Protection from soil erosion and sediment accretion

Wetlands act as very effective sediment traps in the natural environment. The dense plant cover that characterises many wetlands fulfils an important role by intercepting overland flow, thereby reducing the erosive power of the flow and removing excess sediments from the water. This accretion of sediments and nutrients results in the formation of very fertile patches of land, as well as reducing the amount of siltation occurring downstream.

Protection of wildlife

Wetlands in general are home to a high diversity of species. Although freshwater ecosystems cover only 1% of the Earth’s surface, they hold more than 40% of the world’s plant species and 12% of all animal species (Ramsar, 2001). Wetlands are also significant areas of genetic diversity, holding strains of many commercially important plants (Begg, 2001). For example, the wild rice varieties found in many wetlands continue to be an invaluable source of new genetic material for developing disease-resistant strains of commercial rice (Ramsar, 2001). Conserving this biodiversity for future generations is therefore essential.

Recreation, tourism and cultural values
The natural beauty and diversity of animal and plant life in wetlands makes them ideal tourist locations. Hunting, wildlife watching, and educational outings, are all recreational activities that wetlands provide (Begg 2001). While the cultural value of wetlands is relatively poorly documented, there are many instances where wetlands have been shown to provide significant religious, historical, archaeological, or other cultural values for local communities, representing a part of a nation's heritage (Ramsar, 2001f).

Agricultural production
Wetlands provide a variety of benefits in the form of products that can be exploited for human use (Ramsar, 2001a). The economic importance of crops and pastures grown on wetland soils is substantial, with conservative estimates showing that hay production from wetlands is in the region of 10-15 tons ha^{-1} yr^{-1} in South Africa (Begg 2001). Other products from wetlands include fibre for textile and paper making, timber for construction, fuelwood, medicines and tannins used to treat leather (Ramsar 2001a).

2.2.2 Proposed South African wetland classification system

Wetlands have been described according to various definitions, and in an attempt to standardise an inventory system, it has been necessary to develop a commonly accepted classification system which incorporates a consistent definition. The Cowardin classification system (Cowardin *et al.,* 1979) used by the United States National Wetland Inventory and accepted as the most comprehensive and versatile (Finlayson and van der Valk, 1995), describes wetlands as **"***lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water***".** In order to be classified as a wetland, at least one of the following criteria must be met: the land must at least periodically support hydrophytic plants; the substrate must be largely undrained hydric soil or, alternatively, the substrate is non-soil, and is saturated with or covered by shallow water periodically during the growing season. The Ramsar definition of wetlands, adopted by the Convention on Wetlands to which South Africa is a signatory, further defines wetlands as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres***"** (Ramsar Convention Bureau, 1997)**,** which is consistent with Cowardin (*et al., 1979*)'s deepwater definition. These definitions aggregate a range of landscape features which perform similar functions under a collective and broad term, from periodically dry pans, to permanently submerged, deepwater habitats.

DEAT has adopted the Cowardin classification system, with minor modifications, for South African purposes. The Cowardin system differs from other classification systems in that it classifies wetland types according to the determinants of wetland diversity, with the definitions and taxa having an ecological basis (Cowardin and Golet, 1995). It is nevertheless designed to facilitate mapping and inventory and is therefore equally useful in decision-making involving wetland conservation, management and utilization (Dini *et al.*, 1998).

The development of a standardized classification system proposed by DEAT (and supported in this project), will aid in determining the effects of wetland loss on biotic diversity (Kotze *et al.*, 1995 cited in Cowan, 1995). This will supply information regarding size and location of wetlands, as well as wetland type, and therefore its associated biotic communities. This will ensure allow an adequate representation of the different wetland habitats for conservation. Until such an inventory exists, it is impossible to assess the urgency of protection of the different wetland systems.

Under the proposed South African classification system, wetlands are classified according to a hierarchical structure reflecting their physical and ecological diversity. The structure progresses from systems, at the most basic level, to subsystems, and finally class, at the most definitive level. Each step in the hierarchy describes specific aspects of wetland characteristics:

- *Systems*: wetlands influenced by similar hydrologic, geomorphologic, chemical or biological factors,
- *Subsystems*: reflect hydrologic conditions within Systems,
- *Classes*: describe the appearance of the wetland based on vegetation structure and composition, or the substrate where vegetation is absent (Dini *et al*, 1998).

According to this hierarchy, six different wetland systems occur in South Africa: marine, estuarine, riverine, lacustrine, palustrine and endorheic. The most commonly occurring systems in Makana municipality are riverine, palustrine and endorheic. Estuarine and marine systems are obviously excluded, while lacustrine systems typically consist of deepwater habitat and, apart from man-made structures, are uncharacteristic of the semi-arid conditions of the Eastern Cape. While riverine systems occur directly in association with river channels, endorheic and palustrine wetlands may occur independently of rivers (not necessarily so in the case of palustrine wetlands). The latter two systems were considered most suitable for modelling purposes in this project, being associated with more or less unique characteristic landforms and processes, and are consequently relatively easier to predict digitally. In addition, river channels, and thus riverine wetlands, experience mandatory protection by law, with no development allowed within a given distance from the channel (Haigh, pers. comm., 2004). They were therefore not considered a priority in terms of protection status assessment.

While definition of some wetland types has been controversial, endorheic pans are relatively easily defined ecosystems (Cowan, 1995). They typically consist of a shallow circular basin structure, having no obvious surface feed or discharge. Palustrine wetlands, in contrast, are dependent on groundwater, particularly its intersection with the land surface, and include wetlands traditionally called marshes, swamps, bogs, fens and vleis.

2.2.3 Wetland formation

Wetlands exist as a result of the interplay between land and water (Williams, 1990), giving wetlands characteristics of both. Although wetland systems differ significantly in the landscape features with which they are associated and the environmental drivers which result in their formation, they all have this feature in common. The intersection of the land surface by water may occur due to a number of reasons such as the periodic overflowing of rivers in valley bottoms or floodplains, tectonic uplift or landslip, occasional tidal inundation caused by land subsidence or unusual climatic events, deposition of sediments in estuaries or deltas, the impediment of drainage due to impervious lower sediments, and particularly, by the rising of the water table above the land surface level. All these events may result in the formation of standing water resulting in waterlogged soils, and hence wetlands.

Each of the wetland systems outlined in the proposed South African wetland classification system is associated with more or less unique landscapes. Formation of the different systems requires the complex interaction of a number of biophysical drivers, which vary between wetland systems. For the two wetland systems which are the focus of this project, endorheic pans and palustrine wetlands, the differences are considerable.

Endorheic pans

Four environmental factors namely: bedrock, drainage, slope and climate are involved in the formation of endorheic pans (Le Roux, 1978). It is the interaction of climate, availability of geologically susceptible surfaces, disturbances of the surface by animals and by soil weathering, the lack of integrated drainage systems (for example, streams and rivers), and deflational processes including wind, which determine pan formation and persistence. According to Goudie and Thomas (1985), the most obvious association is with areas of poor drainage. Rainfall in these areas results in the formation of static pools, which initiate the development of pans. Usually, pans occur in areas receiving less than 500 mm precipitation annually and above 1000 mm mean annual free surface evaporation loss. This is significant because it is the drying up of these pools, leaving the soils exposed and not bound by protective vegetation, which allows wind to scour out a basin. This results in their characteristic circular shape formed by swirling winds. Wind erosion is particularly important in the dry season, when soil is dry and the vegetation is also dry and sparse. When pans are inundated, wind action plays a role in agitation and mixing of water, sediment and suspended particles.

The contribution of mammals to the formation of pans is considerable, especially in the drier areas (Parris 1984). Excessive grazing at seasonal water holes, leading to trampling of vegetation around the edges of the pan, exposes them to the erosive abilities of wind action. Erosion of the interior of the pan by animals walking through it adds to the deepening and widening, helping to maintain their basins.

Endorheic pans characteristically occur in areas of average slope of less than one degree, having poor drainage (Le Roux, 1978). Their distribution is not entirely determined by substrate, and may occur in sandy soils, where leaching of clay into the bases of the depressions results in their impermeable nature. Generally, they are independent of groundwater, instead being fed by lateral surface flow occurring as a result of the impermeable substrates.

Palustrine wetlands

These are fundamentally different in nature from endorheic pans. Their distribution occurs as a result of the interaction of climate, groundwater, soils, geology and geomorphology. Palustrine wetlands may occur shoreward of river channels, lakes or estuaries, on river floodplains, in isolated catchments or on slopes (Dini *et al.*, 1998). Essentially, they are situated where the water table, or groundwater, for whatever reason, intersects with the land surface. The intersection of land and water may be due to geological or geomorphological features, and generally involves the interaction of permeable and impermeable rock strata (Illgner, pers. comm., 2004). Infiltration of water through permeable strata is channeled at the interface with impermeable strata. If infiltration or channeled groundwater flow is interrupted by a geological feature, such as a doloritic intrusion, this water pools at the land surface, and a wetland results. Similarly, groundwater may be discharged as hill side seeps, and palustrine wetlands may occur in this way anywhere along the slope continuum, from crest to valley bottom, within the general landscape. They are therefore intimately associated with groundwater supply.

It can be assumed that any force, natural or anthropogenic, which interferes with the normal functioning of any of the processes involved in wetland formation and maintenance may be considered to constitute a threat to their existence. This threat normally comes in the form of changes to the hydrological regime in some way, often resulting in a lowering of the water table, or structural changes to the wetland itself (Illgner, pers. comm., 2004).

2.2.4 Threats to wetlands

According to Kotze *et al.* (1995, cited in Cowan, 1995) wetland loss results from both on-site activities (activities within the wetland itself) and off-site activities (activities occurring away from the wetland, but within the catchment). On-site activities which have been responsible for a majority of wetland loss in South Africa are agricultural and urban development, erosional degradation and dam construction. Erosional degradation usually results from poor grazing management. There are other on-site activities which result in wetland loss, including road construction, afforestation, dumping of solid and toxic waste, and mining, although these activities have not had a severe effect on wetland loss.

Off-site activities with the most significant effects on wetland loss are those that disrupt the flow regime of the catchment drainage system for example, the construction of dams or water abstraction. Similarly, activities that increase erosion in upper catchment areas resulting in increased sediment deposition in wetlands are also responsible for significant loss. These may include overgrazing practices and injudicious cultivation practices (Kotze *et al.,* 1995 cited in Cowan, 1995).

Primary causes of wetland loss vary between regions according to the different land-use pressures and the vulnerability of local wetlands to disturbance (Kotze *et al.,* 1995 cited in Cowan, 1995). In semi-arid regions of the inland margin zone (regions lying between the edge of the plateau and the eastern and southern coasts), which includes Makana, wetlands show high susceptibility to water erosion, and erosional degradation is generally thought to be the major cause of wetland loss. This often occurs as a result of poor land management practices, for example, heavy grazing pressure. Over-utilization of grazing areas in the catchment reduces vegetation cover and causes soil compaction, increasing run-off peaks and causing the animals to utilize wetland areas more intensively, ultimately leading to erosional degradation.

Semi-arid regions of the inland margin zone are known to have experienced some of the highest rates of wetland loss (Kotze *et al.,* 1995 cited in Cowan, 1995), because of their susceptibility to erosion. However, in areas within these regions with low human population densities and little pressure on the land, wetland loss may nevertheless be minimal.

In the context of the objectives of the South African Wetlands Conservation Programme, our research aimed to establish a baseline wetlands inventory for the Makana municipality in the Eastern Cape, by providing:

- a predictive digital model of potential wetland distribution,
- geographic coordinates and satellite imagery of confirmed wetlands in Makana,
- identified according the South African classification system
- a database of farms and land cover on which wetland distribution is predicted to occur.

On the basis of these data, the project further aims to assess the current status of wetland protection in the municipality and identify specific potential threats according to land-use within the predicted distribution.

2.3 METHODS

2.3.1 Modelling

The model of predicted wetland distribution was produced using Idrisi 32 GIS software, and was initially based upon five environmental variables: monthly temperature and rainfall, slope, elevation and Normalised Difference Vegetation Index (NDVI). NDVI provides a scale against which measurement of actively growing vegetation is possible (Palmer, 2004). The model was built using values obtained from 15 wetlands throughout the Makana municipality. The choice of environmental variables used in generating the model was limited by the availability of data at sufficient resolution. All variables were employed for which adequate data exist and those which statistical testing revealed to be insignificant were rejected.

Potential wetland areas were identified by examining 1: 50 000 topographic maps and 1: 10 000 aerial photographs. Low gradient grassland regions, points of origin of rivers and tributaries, and river valleys were considered to be areas indicative of potential wetland presence. These regions were ground-truthed to determine actual wetland presence.

Geographic coordinates were obtained for each of the 15 wetlands (Garmin GPS II plus, Olathe, KS, USA), and, depending on size and shape of particular wetlands (for example: round endorheic pan, or linear riverine wetland), two to four readings were recorded per site. The coordinates were positioned on the relevant digital terrain models, associated with monthly rainfall and temperature, slope, elevation and NDVI, respectively, generating values for each coordinate for the five variables. Areas known to contain no wetlands were arbitrarily selected, and nine coordinates representing wetland absence were similarly positioned on the relevant terrain models, thereby generating values for each environmental variable in the same manner.

The values thus obtained for monthly rainfall and temperature, slope and elevation, were analysed using discriminant function analysis (Statistica version 6.1) to identify the variables for which “presence” and “absence” values were most significantly different. This results in a weighting: the standardised canonical discrimination coefficient. The greater the contribution by the respective variable to the discrimination between groups, the greater is the standardized coefficient (Poulsen and French, no date). Each of the values for each environmental variable was multiplied by the respective standardised coefficient, with the variables in which discrimination between groups was most significant (and therefore generating the largest coefficient) consequently having most influence on the model. These new values were then used to generate separate models for predicted wetland distribution according to monthly temperature, and slope and elevation, highlighting digital terrain layers representing the range of values obtained for wetland “presence” data.

The values obtained from the digital terrain model for NDVI were analysed separately, and as only one set of variables was being tested, discriminant function analysis was not used. Instead, a means and standard deviation for wetland “presence” data (Statistica version 6.1) was obtained. Digital terrain layers representing values within this deviation were highlighted in order to produce a model of predicted wetland distribution based on NDVI.

The three resulting models generated according to monthly temperature, slope and elevation, and NDVI, were finally cross-classified in order to refine predicted distribution. This resulted in a single digital model which predicted wetland distribution at four layers:

- zero predicted, zero presence;
- presence predicted according to slope and elevation;
- presence predicted according to NDVI, and
- presence predicted according to slope, elevation and NDVI

The coordinates obtained for confirmed wetlands were overlaid on a digital satellite image of Makana in order to illustrate their position spatially. The predictive model was then taken to CSS (Conservation Support Services), Grahamstown, and converted to Arcview GIS format. By overlaying land cover maps (National Land Cover 2000), it was possible to extract data regarding the variety of land uses and vegetation types covered by the predicted wetland distribution, according to our model. These were expressed as hectares per land cover category, as well as converted to percentages of total predicted wetland cover. Furthermore, data were generated pertaining to the farms within Makana included in the wetland distribution, and a list of farm names compiled.

2.3.2 Model limitations

It is important that accuracy and significance of the predictive model is not exaggerated. There are a number of limitations inherent to modelling in general and this project in particular, notably:

- lack of data availability at adequate resolution
- inability to account for underlying geology
- attempting to predict complex interactions in digital format
- predicting distribution for different wetland systems associated with unique
- landscapes within a single model

Data availability

A major determinant of wetland distribution is soil type (Williams, 1990), for example, clay soils of low permeability retain water at the surface which promotes the formation of wetlands. Soil data for Makana of sufficient resolution for the purposes of modelling at this scale do not exist at present.

Geology

Similarly, modelling of climatic and surface features ignores the effect of subterranean geology on the formation of wetlands. The geology of the Eastern Cape plays a fundamental role in the hydrology of the area (Haigh, 2004). In the Eastern Cape, the uppermost rock strata are composed of the impure sandstones and shales of the Baviaanskloof Formations, reaching up to 150 m in thickness. The interaction of permeable and impermeable rock strata plays an important role in influencing where wetlands may form on the landscape (Illgner, pers. comm., 2004). Generally, the infiltration of water through permeable surface strata, such as sandstones, is halted at the convergence with less permeable rock, such as shales. This results in the movement of water along this convergence. If this water is forced to the surface, for example, by an intruding dyke or sill, the water table will intersect with the surface and a wetland will result. The mountain catchment areas of the Eastern Cape occur in two parallel ranges, collectively called the Cape Fold Belt, running in an east-west direction (Haigh, 2004). Their effect on drainage and hydrology is clearly visible on the predictive model, with distribution showing an east-west orientation. However, it was not possible to include the effects of underlying geology into the predictive model, and this is a considerable disadvantage in attempting to predict where wetlands may occur on the landscape. Local geology and its influence on hydrology is critical in determining wetland distribution.

Modelling complex interactions

Wetland distribution occurs as a result of the interaction of different biophysical factors (Cowan, 1995), generally including bedrock, drainage, slope and climate. For example, rainfall on areas of poor drainage and impermeable soils, affected by the underlying geology and topography and specific evaporation rates, may or may not result in the formation of wetlands, depending on the presence of one or all of these factors to varying degrees. Thus, the interaction of these variables in determining wetland distribution is complex, and difficult to predict via the medium of digital modelling. Presently, the predictive model generated in this project simply highlights areas of NDVI, slope and elevation values which approximate those measured in 15 confirmed wetlands. Because these values for wetland presence and absence could be discriminated between, modelling suggests that these variables are somehow significant in determining wetland distribution. This, in essence, is the significance of the model.

Drawbacks of producing one model to account for all wetland types

Another factor which the model fails to take into account is the wide variety of landscape types which give rise to different classes of wetlands. Each of the broad wetland systems is associated with a suite of rather different environmental drivers. In producing the model, data for environmental variables associated with the different wetland systems (endorheic pans and palustrine wetlands) were not differentiated between, and the model is therefore broadly predicting distribution of various classes of wetlands which, in reality, specifically occur in association with unique landscape types. Endorheic pans, for example, typically occur in areas characterised by a lack of integrated drainage, impermeable substrates, annual rainfall below 500 mm and an average slope of less than one degree (Cowan, 1995). They do not seem to be reliant on groundwater, rather being fed by shallow lateral flow on top of these impermeable substrates (Partridge, 2001). Palustrine wetlands, on the other hand, are associated with points of groundwater discharge at valley heads, along footslopes, or where a geological feature, such as a dolerite dyke, obstructs drainage (Partridge, 2001). Generally, they may occur anywhere along the topographical continuum between crest and valley bottom where groundwater intersects the land surface.

Ideally, because of the vast difference in the nature of the associated landscapes, the distribution of the different wetland systems should have been predicted separately. For this, however, it would be necessary that a greater number of wetland sites be visited in order to generate enough data on which to base independent models.

2.4 RESULTS

Ground-truthing the potential wetland areas identified on aerial photographs and topographic maps revealed 16 wetlands, 15 of which were used in producing the model. Overlaying these coordinates (Table 3.1) on a digital satellite image of Makana (Figure 3.1) revealed an aggregation of five wetlands around Grahamstown, one endorheic, and four palustrine (numbers 1, 2, 3, 4, 5 in Table 1), two palustrine wetlands on the N2 to East London (numbers 6 and 7), four endorheic pans near Seven Fountains, numbers (8, 9, 10, and 11), two palustrine wetlands near Riebeck East (numbers 12 and 13), and two endorheic pans near Southwell (numbers 14 and 15). Interestingly, all endorheic pans occurred at latitudes south of 33.40000 S, apart from the one (number 1) at the shooting range outside Grahamstown. The remainder, all palustrine systems, occurred north of this latitude. This perhaps infers a difference in the nature of the bedrock, drainage and climate in the regions north and south of this general latitude.

Discriminant function analysis revealed no significant discrimination between monthly rainfall for wetland “presence” and “absence” values. Discrimination was possible, however, between temperature, slope and elevation values, and standardised canonical discrimination coefficients were generated which reflected the contribution of the respective variable to the significance of discrimination between groups. These coefficients were 0.30000 (temperature), 1.00211 (slope), and 0.04527 (elevation). Applying these coefficients to the values obtained for the above environmental variables resulted in the generation of two models, predicting wetland presence according to temperature (mean: 351.9052 ± standard deviation: 88.0994) (F: 14.81; p<0.001) (Figure 3.2), and slope and elevation (mean: 24.9045 ± standard deviation: 8.6308) (F: 248.05; p< 0.001) (Figure 3.3).

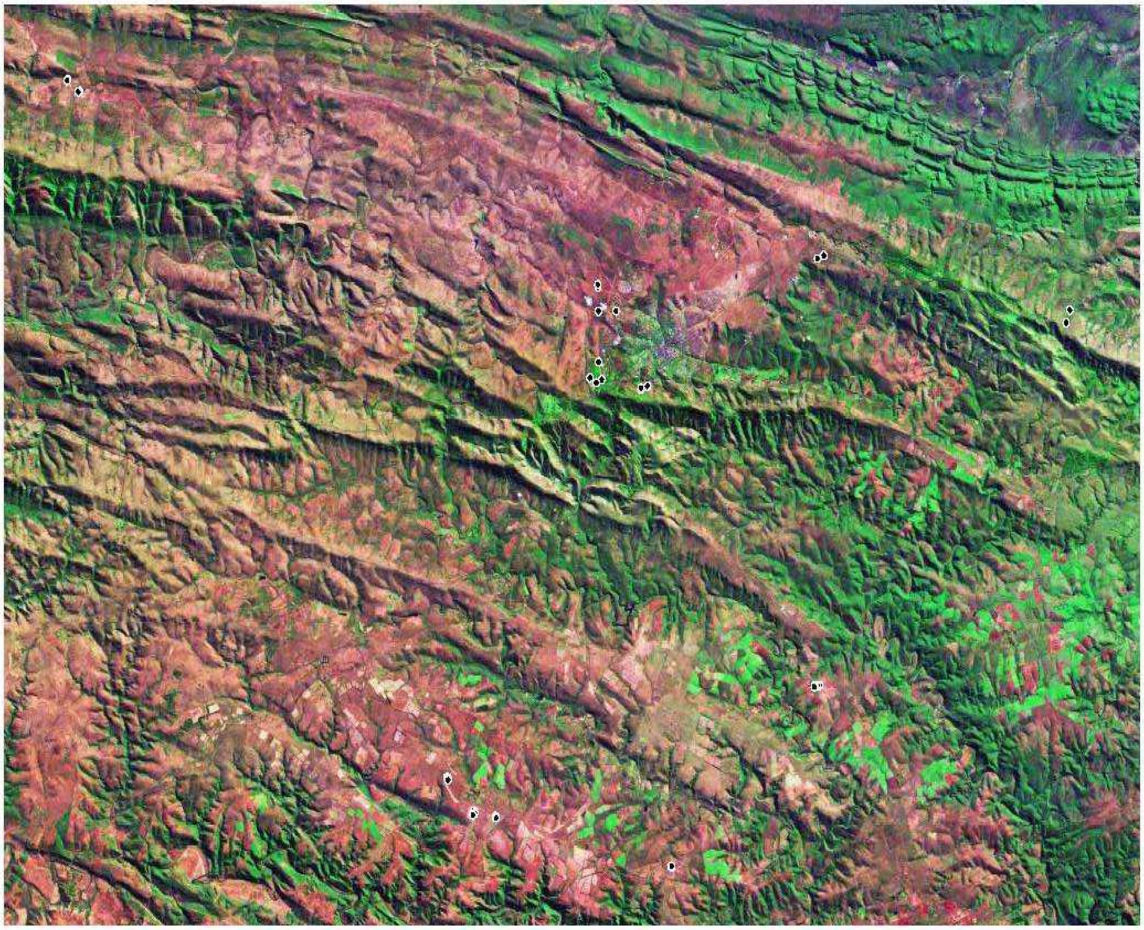

Figure 3.1: Confirmed wetland presence in Makana. Each point represents a single GPS coordinate, thus one wetland may be represented by a number of points. Similarly, where wetlands occur in close proximity, more than one wetland may be represented by what appears to be one point.

Table 3.1: Geographic coordinates of known wetlands in Makana

	Location	**Latitude**	**Longitude**	**system**	
	Grahamstown				
1	Shooting range	33.29430S 33.28459S 33.28366S	026.48879E 026.48853E 026.48842E	Endorheic pan	
2	Prison/Industrial area	33.32164S 33.32281S 33.32097S 33.31452S	026.49054E 026.48728E 026.48348E 026.48869E	Palustrine	valley bottom seep, slope<1º
3	Joza	33.29430S	026.49917		
4	Settlers Monument (1)	33.32476S 33.32433S	026.51744E 026.51756E	Palustrine	foot slope seep, slope>5º
5	Settlers Monument (2)	33. 32554S 33.32512S	026.51379E 026.51392E	Palustrine	foot slope seep, slope>5º
	East London road (N2)				
6	Coombs view	33.29976S 33.29472	026.76695 026.76933	Palustrine	foot slope seep, 1º<slope<5º
7	Moss farm	33.27240S 33.27377S	026.62299E 026.61903E	Palustrine	valley bottom seep, slope<1º
	Seven Fountains				
8	Farmerfield farm (road 343)	33.51668S 33.51662S 33.51633S	026.53086E 026.53125E 026.53115E	Endorheic pan	
9	Hope Fountainfarm (1)	33.49593S 33.49635S 33.49668S	026.42633E 026.42626E 026.42664E	Endorheic pan	
10	Hope Fountainfarm (2)	33.49385S 33.49473S 33.49557S	026.41333E 026.41381E 026.41265E	Endorheic pan	
11	Scheepers farm	33.48022S 33.48044S 33.48139S	026.39736E 026.39798E 026.39805E	Endorheic pan	
	Riebeck East				
12	Shenfield farm	33.20468S 33.20509S	026.18090E 026.18009E	Palustrine	valley bottom seep, slope<1º
13	George pole	33.19995S 33.20043S	026.17382E 026.17355E	Palustrine	floodplain, slope 0°
	Southwell road				
14	Endwell farm (1)	33.44466S 33.44451S 33.44312S	026.61956E 026.61804E 026.61832E	Endorheic pan	
15	Endwell farm (2)	33.44444S 33.44443S 33.44492S	026.61721E 026.61665E 026.61654E	Endorheic pan	

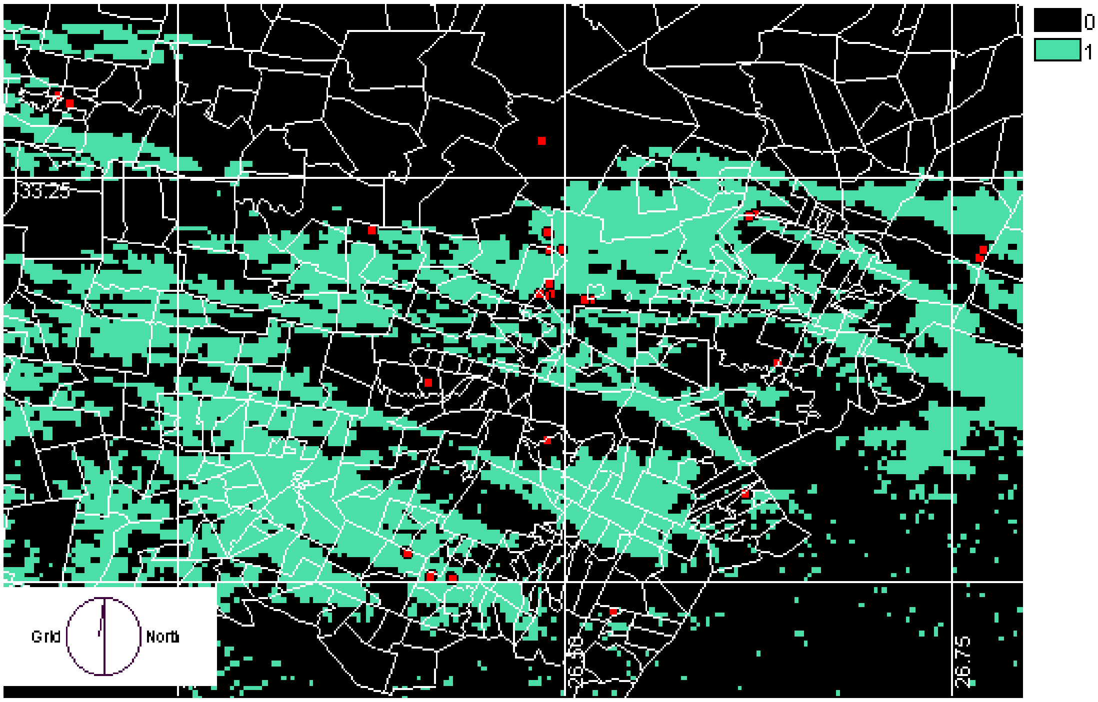

Figure 3.2: Predicted wetland presence (green) according to temperature (1 = absent)

Values obtained for NDVI for wetland presence and absence were tested separately, obtaining a mean and standard deviation. The mean for confirmed wetlands was 0.362296 ± standard deviation: 0.125564; means for wetland absence was 0.089307 ± standard deviation: 0.035864 (F: 50.11; p<0.001). Highlighting digital terrain layers representing values within the deviation for confirmed wetlands resulted in a model predicting wetland presence according to NDVI.

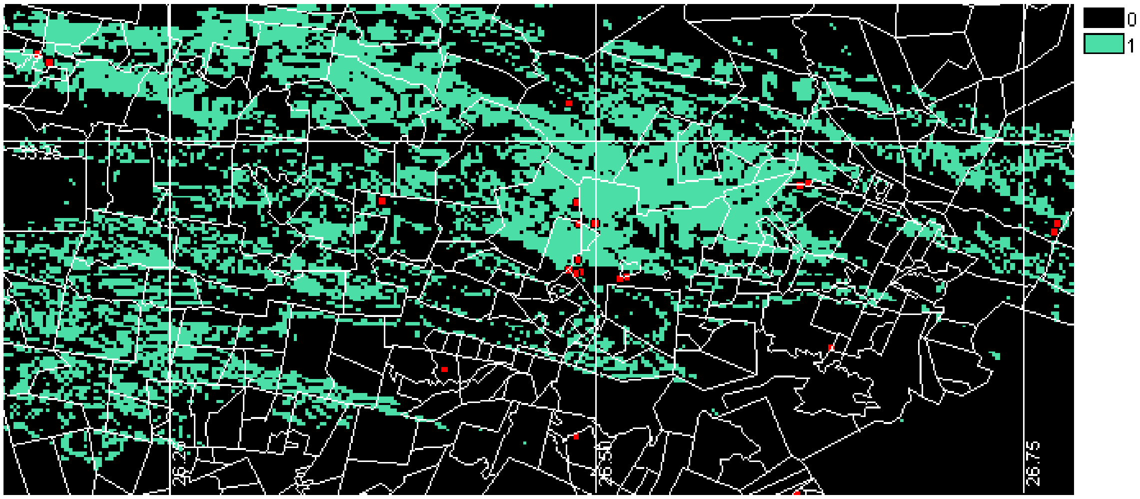

Figure 3.3: Predicted wetland presence (green) according to slope and elevation

Cross-referencing these three models refines the accuracy of the model, predicting presence according to a number of variables rather than just one. It was found that the model predicting wetland presence according to temperature did not correlate satisfactorily, and was therefore rejected for the final model. The resulting model (Figure 3.4) predicts wetland distribution according to slope, elevation and NDVI. Modelled distribution (Figure 3.4) occurs in an east-west oriented band, more or less following the geology of the Cape Fold Belt, between 33.60000S in the south and 33.20000S in the north. The area identified as potential wetland distribution covers a total of 23064 hectares (Table 2).

Following conversion to Arcview format, data were generated regarding land cover included within the predicted distribution (National Land Cover 2000). This revealed that 17 different land-use categories were included within the modelled distribution (Figure 3.5). Predicted wetland distribution occurred largely (94.8%) within low-intensity land-use areas (shrubland and low fynbos, thicket and bushland, and unimproved grassland) (Table 3.2), with areas constituting high risk to wetlands, including urban areas (2.1%) and areas of commercial cultivation (1.4%), constituting a significantly lower proportion of potential wetland distribution.

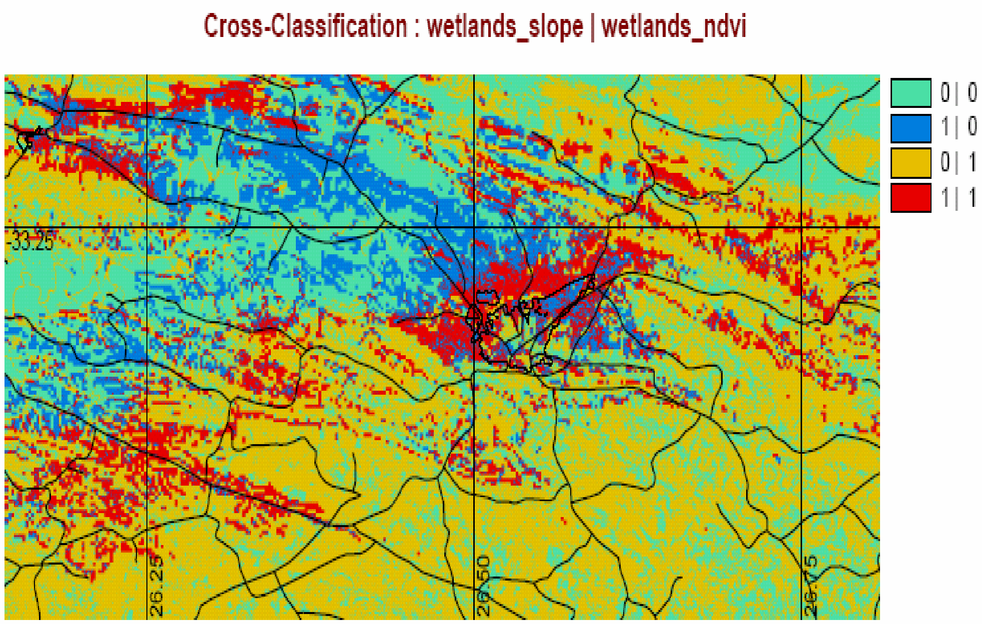

Figure 3.4: Predicted wetland distribution in Makana. Presence predicted according to slope and elevation (blue), NDVI (yellow), slope, elevation and NDVI (red). Roads indicated in black.

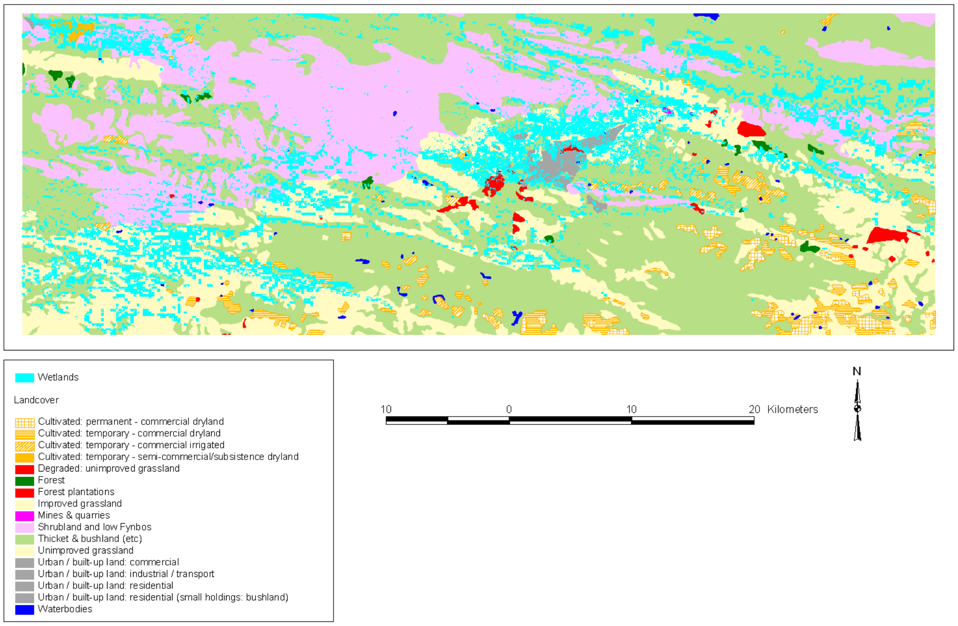

Figure 3.5: Land cover within Makana municipality included within predicted wetland distribution (blue)

Table 3.2: Land cover included within predicted wetland distribution in Makana

Description	**Area (ha)**	**% area**
Cultivated: permanent - commercial dryland	0.6	0.0
Cultivated: temporary - commercial dryland	128.1	0.5
Cultivated: temporary - commercial irrigated	93.8	0.4
Cultivated: temporary - semi-commercial/subsistence dryland	135.9	0.5
Degraded: unimproved grassland	12.5	0.0
Forest	67.6	0.2
Forest plantations	89.6	0.3
Improved grassland	94.6	0.4
Mines & quarries	16.5	0.07
Shrubland and low Fynbos	3540.1	15.3
Thicket & bushland (etc)	11117.9	48.2
Unimproved grassland	7232.2	31.3
Urban / built-up land: commercial	21.0	0.09
Urban / built-up land: industrial / transport	17.2	0.07
Urban / built-up land: residential	459.2	1.9
Urban / built-up land: residential (small holdings: bushland)	11.9	0.05
Waterbodies	24.2	0.1
Conserved area	1125.0	4.7
Total	23063.7	99.8

The data generated regarding the distribution of modelled wetlands over farms in Makana revealed that a total of 197 farms included potential wetlands within their borders (Appendix 1). No data were available regarding the nature of farming practices relevant to each farm.

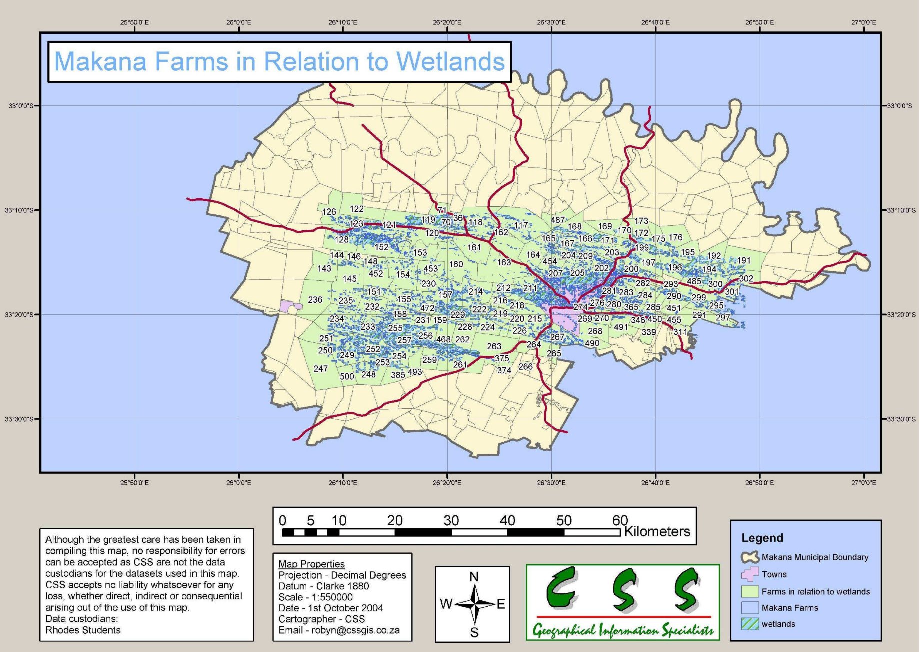

Figure 3.6: Makana farm boundaries overlaid on modelled wetland distribution (blue).

2.5 DISCUSSION

The final predictive model indicates potential wetland distribution within Makana, based on slope, elevation and NDVI, over a total area of about 23064 hectares (Table 3.2), a majority of which (94.8%) occurs within shrubland and low fynbos, thicket and bushland, and unimproved grassland. It should be recognised, however, that little of this predicted distribution will comprise of actual wetlands, and that wetland distribution may not necessarily occur in the proportions indicated by the land-cover overlay. For example, while the model predicts that 4.7% (Table 3.2) of potential wetland distribution occurs within conserved areas, this 4.7% of potential wetland area may be uncommonly rich in actual wetland presence. Likewise, while 48.2% (Table 3.2) of distribution is predicted to occur in thicket and bushland, actual wetland presence may be uncharacteristically sparse. The figures generated by the land-cover model can therefore only be used as a guide in quantifying distribution. In addition, the accuracy of the predictive modelling, by means of ground-truthing, remains to be tested.

2.5.1 Interpretation of land cover in terms of threats to wetlands

Figure 3.5 supplies information regarding land-cover, however, it is lacking in that it does not provide a clear indication of land-use, which is an important factor influencing the assessment of potential threats to wetlands. It does not differentiate, for example, between gazing lands and game farms, or the type of grazing which occurs. These all have implications in determining the intensity of land-use and land-use pressures occurring on a given farm or area, which are the major drivers of wetland loss (Kotze *et al*., 1995 cited in Cowan, 1995). Nevertheless, the description of the different cultivation practices in existence is fairly comprehensive, and assessment of the intensity of land-use based on these descriptions can be inferred. In addition, land-cover descriptions provided such as "urban/built-up land", "mines and quarries", "forest plantations" and "degraded, unimproved grassland" are fairly unambiguous as to the land-use pressures in existence in an area, and the nature of the threat posed to local wetlands. Similarly, land-cover descriptions such as "shrubland and low fynbos", "thicket and bushland" and "unimproved grassland" infer areas of land-use not subjected to intensive pressures or alteration.

Kotze *et al*. (1995, cited in Cowan, 1995) indicate that two broad activity types affect wetland loss: on-site and off-site activities. The former include activities which directly affect wetland structure and functioning. These activities occur largely *in situ*, and include urban and agricultural development (resulting in erosional degradation, water abstraction and structural damage to the wetlands themselves), and dam construction; to a lesser extent, road construction, afforestation, mining, and dumping of solid and toxic waste. The latter include *ex situ* activities that result in the alteration of the flow regime of catchment drainage, which is responsible for maintaining wetlands in terms of the timing of their water supply requirements and the biota they support. Similarly, activities which increase erosion in wetland catchments, resulting in the accretion of sediments in the wetlands, are also contributors to wetland destruction.

On-site threats

On-site threats in the context of the Makana municipality would not appear to constitute any significant risks to wetlands, according to modelled potential distribution. Urban development, in all its forms, comprises a mere 2.1% of predicted distribution (Table 3.2), while agricultural development, as it relates to cultivation, comprises only 1.4%. Urban development calls for the draining and reclamation of wetlands, as well as the threats of effluent discharge into nearby water courses, and ultimately, wetlands themselves. Agricultural development could be expected to cause wetland loss by causing structural damage to the wetlands themselves, as well as lowering the water table. This effect is compounded if cultivation is irrigated, and if cultivation is permanent (year round) as opposed to temporary in nature. The climate and soils in the Makana region are largely unsuitable for intensive cultivation (Illgner, pers. comm., 2004), thus the threat posed by this category of land-use is generally considered to be minimal.

Similarly, water bodies constitute only 0.1% (24.2 ha) of predicted wetland distribution and would therefore not appear to pose a significant risk to wetlands in their capacity as an on-site threat (by flooding wetlands, causing homogenisation and destruction of habitat of wetland biota and reducing the ability of the wetland to function normally). Although the land-cover model does not distinguish between natural and man-made water bodies, the figure provides a general indication of the extent of damming. In a semi-arid region such as Makana, the extent of natural water bodies may be expected to be limited, and thus the water bodies that occur on the model are likely to be due largely to man-made dams.

Despite the negligible proportion of dammed areas within modelled wetland distribution, dams pose a risk in their capacity as an off-site risk by altering the flow regime of catchment drainage. Dams change the character of catchment discharge, resulting in regulated, continuous flow downstream of the dam, rather than the seasonally varied flow regime experienced under natural conditions (O'Keeffe, pers. comm., 2004). Water discharged from dams is often also warmer than normal as a result of solar heating while impounded. The effects of changed flow regimes and warmer water impact negatively on natural systems which are highly adapted and dependent on specific hydrological requirements. These effects are far reaching within a catchment, and dams which occur outside the extent of predicted wetland distribution, or Makana itself, may nevertheless constitute a threat.

Other risk categories identified by Kotze *et al*. (1995 cited in Cowan, 1995) as on-site threats, including mining (mining and quarries: 0.07%) (Table 3.2) and forest plantations (0.3%), are similarly minor components of total predicted wetland distribution, and, as such, would appear not to pose any significant threats to wetlands in Makana.

Off-site threats

The risk of off-site activities can only be controlled by sound management practices at the scale of the entire catchment. Off-site threats result in alteration of the flow regime of catchment drainage, and sediment accretion within wetlands themselves as a consequence of erosional degradation higher up in the catchment. Apart from the effects of damming, alluded to earlier, off-site threats include water abstraction and poor land management practices such as overgrazing.

Water abstraction may be expected to be high in regions with high levels of urban development or commercial cultivation, especially irrigated cultivation. Table 2 indicates that both these land-cover categories constitute small percentages of total predicted wetland distribution (2.1% and 1.4%, respectively, irrigated: 0.4%). Again, the extent of these activities outside the context of Makana needs to be determined, as the effects are far reaching within a given catchment.

Kotze *et al*. (1995 cited in Cowan, 1995) indicate that in the semi-arid areas of the inland margin zone, which includes Makana, erosional degradation is the primary cause of wetland loss. This is because of the erosivity of the rainfall and the erodibility of the soils typical of wetlands in this region. In areas where heavy utilization of natural grazing occurs, vegetation cover is denuded and soil compaction results. This limits the amount of infiltration of rainfall and run-off peaks are increased, which act on unprotected soils to result in erosion. In addition, animals are consequently forced to utilize wetland areas more intensively as grazing. Overgrazing therefore poses both on-site threats (by causing intensive use of wetland areas by grazers, resulting in on-site erosion), and off-site threats (by causing increased erosion in the upper catchment and accretion of sediments in wetlands).

However, the normally high rates of wetland loss expected in the semi-arid inland margin due to erosional degradation are sometimes not experienced in the presence of certain mitigating factors (Kotze *et al*., 1995 cited in Cowan, 1995). In areas where human populations, and the associated land-use pressures, such as grazing, cultivation and urban development, are low, wetland loss due to erosional degradation is relatively lower than expected. This would appear to be the situation in Makana. The land-cover model (Figure 5) indicates that a large majority of predicted wetland distribution (94.8%) (Table 2) occurs in land-cover areas which indicate low-intensity use and alteration, such as shrubland and low fynbos (15.3%), thicket and bushland (48.2%), and unimproved grassland (31.3%). As stated earlier, levels of urban development and intensive cultivation, land-uses which result in water abstraction and may lead to erosional degradation, are also negligible. Susceptibility to erosional degradation is therefore perhaps not as high as it is in other semi-arid regions of the inland margin zone.

What needs to be considered, however, is the use of commonage areas for grazing by rural subsistence farmers, and especially the proximity and ease of access of these areas to rural subsistence farmers. Modelled wetland distribution occurs within two types of land ownership: common property and private property, which has important implications for the different management practices applied (Kotze *et al.*, 1995 cited in Cowan, 1995). In private areas, there is the potential that deliberate wetland loss may occur due to land development, while in commonage areas, loss is primarily due to erosional degradation as a result of poor or inappropriate management. Evidence of this exists in wetlands occurring in commonage areas around Grahamstown. The palustrine wetland occurring in the industrial area adjacent to Grahamstown (number 2 in Table 1) is exposed to grazing by rural subsistence farmers (Handek, pers. comm., 2004), and is visibly degraded, showing signs of erosion (Haigh, pers. comm., 2004). In comparison, the palustrine wetlands occurring in the commonage areas behind the Settlers Monument (numbers 4 and 5, Table 1), being less accessible to subsistence farmers (McGregor, pers. comm., 2004), show no evidence of erosional degradation. Data regarding the extent of predicted wetland distribution occurring within commonage areas were unfortunately unavailable.

2.5.2 The effects of alien invasive plants on wetland health

Although data for levels of invasion by alien vegetation are incomplete and it was not possible to assess the urgency of the threat they pose, they have been identified as constituting a significant threat to wetlands in Makana (Illgner, pers. comm., 2004). Alien vegetation utilizes far higher amounts of water than native species, which results in lowering of the water table. Water is rapidly absorbed and released into the atmosphere by evapo-transpiration, and is consequently lost to the catchment (Working for Water, 2001). Significantly, they also alter the flow duration and flow regime of catchment drainage, reducing dry season flows proportionately more drastically than wet season flows (Working for Water, 2001). This usually has serious implications for wetland functioning and its associated biota, both of which are adapted to specific hydrological regimes (O'Keeffe, pers. comm., 2004).

Because they are naturally adapted to high water regimes, alien invasives thrive in the relatively moister conditions of local wetlands, often out-competing and excluding indigenous species. This results in decreased biodiversity of wetland ecosystems. In addition, alien vegetation has been shown to compromise the stability of catchment soils, especially following a fire event. Studies in the Cape peninsula comparing soil erosion in areas under fynbos with that under alien vegetation after burning have shown that, following the first rains, up to 100 m^3 soil per hectare is lost in the latter, while the former show insignificant erosion. This constitutes a significant threat in terms of erosional degradation, leading to *ex situ* sediment accretion in wetlands further down in the catchment. Thus, by changing the hydrological regime, lowering the water table, reducing biodiversity and facilitating the erosion of catchments and sedimentation of wetlands, aliens comprise both on-site and off-site risks to wetlands in a given catchment. In response to the multitude of environmental concerns presented by the encroachment of alien invasives, the Department of Water Affairs and Forestry initiated the Working for Water project in 1995 (Working for Water, 2001), which is chiefly concerned with the eradication of alien vegetation, both on a local and national scale.

It should be noted at this point that, while the term "wetland loss" implies a sense of permanency, rehabilitation of wetlands is possible, although sometimes requiring the use of substantial engineering structures in severe cases (Kotze *et al*., 1995 cited in Cowan, 1995). A wetland is considered "lost" if it has been degraded to the extent that it has compromised a significant proportion of its functional values. Such wetlands may be described as "relict". Most wetlands are readily rehabilitated if the original hydrological regimes are reinstated.

2.6 CONCLUSIONS

The purpose of the predictive model generated as a result of this work was to establish a platform on which to base further work on the compilation of a national inventory. It potentially saves time and resources by providing a guide in directing the initial steps in locating wetland distribution in Makana. It functions by identifying areas of NDVI, slope and elevation, which, based on the location of 15 confirmed wetlands, are known to favour wetland formation, and as such, should not be considered a failsafe predictor of wetland distribution.

It is presented with the admission of several limitations, namely:

- the omission, in its generation, of certain variables known to be of significance in determining wetland existence due to lack of data, notably soils;
- its inability to account for sub-surface factors influencing wetland formation;
- the limited ability to predict complex biophysical interactions involved in determining wetland distribution, and
- its attempt to predict occurrence within a single model of a number of different wetland types which, in reality, are associated with unique landscapes and processes.

Nevertheless, it is based on sound principles and, according to initial ground-truthing exercises, appears to broadly reflect areas noted for confirmed wetland presence. Its accuracy remains to be tested, however.

Bearing these limitations in mind, the predictive model was used to identify the land-use pressures which threaten wetland health and function in Makana. It was consequently determined that modelled wetland distribution comprised largely of land-cover categories which are associated with low intensity use and alteration, including shrubland and low fynbos, thicket and bushland, and grassland. Land-cover categories which have been identified as high risk to wetlands, including urban development, intensive cultivation and grazing and man-made dams comprised a fairly insignificant proportion of predicted wetland distribution by comparison.

Consequently, although it occurs within the semi-arid regions of the inland margin, identified as being one of the areas experiencing the highest rates of wetland loss in the country due to erosional degradation, Makana is probably exempted from this general assumption because of the low levels of land-use intensity which prevail. Nevertheless, erosional degradation has been noted to occur in wetlands situated in commonage areas subjected to subsistence grazing. This appears to be facilitated by the proximity and ease of access to these areas by subsistence farmers. Unfortunately, the extent of wetland distribution occurring within commonage areas has not been determined, but further studies perhaps need to assess the relationship between wetland distribution on commonage areas, the values they represent to rural communities and the land-use intensities applied by rural subsistence users, influenced by proximity. The municipality currently maintains no policy regarding the subsistence use of wetlands in commonage areas (Handek, pers. comm, 2004) and a framework needs to be developed outlining sustainable use of wetlands goods and services.

The risk to wetlands posed by alien encroachment was not determined in this project, due to lack of data, but it has been identified as a significant threat in Makana. The effects of alien encroachment are far-reaching within a given catchment, having both *in situ* and *ex situ* implications for wetland health. The Working for Water initiative is actively working to eradicate the threat of alien invasives, and close cooperation of wetland conservation bodies with this department should provide a powerful tool in the development of a wetland inventory, as well as assessment of the nature of threats facing wetlands, both in Makana and nationally.

It has been stressed that threats to wetlands are not only *in situ,* but that activities throughout the catchment impact on wetland health; wetlands essentially bear the brunt of all poor management activities within a catchment. For this reason, while examining the land-uses encompassed within the modelled wetland distribution may provide an indication of the types of land-use pressures they are experiencing, the full implications of catchment use for wetlands needs to be assessed at a larger scale. While threats to wetlands identified within the scope of this project seem minimal (disregarding the undetermined risk posed by alien infestation), activities at the larger scale may be having major impacts on the health of wetlands in Makana. Personal communications with farmers indicate that endorheic wetlands in the southern extents of the municipality, notably those located around Seven Fountains, have experienced extended periods of desiccation, showing no seasonal inundation characteristic of these systems. The underlying drivers, whether climatic or due to some nature of catchment management practice should perhaps be closely observed. The combined effect of catchment water abstraction and damming both within Makana and beyond its boundaries may be significant enough to endanger wetland health in Makana.

2.7 RECOMMENDATIONS

Makana is not especially rich in wetlands, having no wetlands of international significance according to the Ramsar Convention (Ramsar 2001), nevertheless, collectively, the value of the services and functions they perform are of no less importance. While ecological functions are well established and generally applicable, it would be of benefit to determine the full extent of socio-economic benefits extracted by users from wetlands, as it applies to Makana. A policy needs to be formulated outlining a framework for the sustainable use of wetlands in commonage areas, which seem to be experiencing a degree of pressure from subsistence users, depending on their proximity and accessibility to users.

Generally, however, wetlands in Makana seem to be experiencing little pressure from land-use activities. Nevertheless, endorheic pans in the more southerly areas of the municipality appear to be experiencing extended and uncharacteristic periods of desiccation. Whether this is due to climatic factors or land management practices is unknown. The potential drivers of this perhaps need to be closely monitored.

While the extent of alien encroachment in the municipality is undetermined, the ecological risks that these pose to wetlands, both on a local and catchment-wide scale, are well established, and this should be monitored closely.

Most significantly, it needs to be recognised that the findings discussed in this project regarding the status of protection of wetlands in Makana, if used in isolation, are insufficient on which to base management decisions. Threats which face wetlands, by their nature, are those that act on a catchment-wide scale, and activities throughout entire catchments need to be monitored in order to assess the risks to wetlands in Makana. While these findings show high risk activities occurring within predicted wetland distribution are low, the combined effects of these practices throughout the entire catchments may be sufficient to compromise wetland functioning.

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Appendix 1. List of farms falling within predicted wetland distribution

Farm name	**Farm number**
LOMBARDY	36
BERG PLAATS	70
LOUIS HOPE	71
HOUNSLOW	117
VAN DER MERWES KRAAL	118
FARM 133	119
VAALE KRANS	120
PALMIET FONTEYN	121
FARM 136	122
OUTSPAN	123
GROOT FONTEIN	126
MOOYE MEISJES FONTEYN	128
JOUBERTS KRAAL	143
HEBRON ANNEX	144
MEYERS KRAAL	145
MOOI MEISJES FONTEIN ANNEX	146
MEYERS KRAAL ANNEX	148
ROODE KRANTZ	151
ASSAGAI BOOM	152
DOORNTJES	153
SMOERFONTEIN	154
STONEHAM	155
HIGHLANDS ANNEX	156
PALMIETFONTEIN	157
FROME	158
STONEHAM ANNEX	159
HILTON	160
BRACK KLOOF	161
DRAAI FARM	162
TABLE HILL	163
BURNT KRAAL	164
FARM 190	165
FARM 191	166
FARM 192	167
FARM 193	168
FARM 194	169
FARM 195	170
FARM 196	171
FARM 197	172
FARM 197	173
FARM 199	175
FARM 200	176
SPITZKOP	191
FARM 218	192
FARM 220	194
FARM 221	195
GOVERNORS KOP	196
COLLINGHAM	197
TEMPE ANNEX	198
COLLINGHAM OUTSPAN	199

THE ORCHARDS	200
COLLINGHAM TOWERS	201
TEMPE	202
TEMPE	203
FARM 242	204
BRAKKEFONTEIN	205
LITTLE SAXFOLD	206
IJSTER KOP	207
HILL THORN	208
ANNEX THORN PARK	209
FARM 248	210
ZYFER FONTEYN	211
FARM 250	212
SLAAIKRAAL OUTSPAN	213
KRUISFONTEIN	214
FARM 253	215
COLDSTREAM	216
FARM 255	217
FARM 255	218
GEELHOUTBOOM	219
FARM 257	220
FARM 258	221
FARM 258	222
FARM 259	223
FARM 260	224
FARM 261	225
BERG PLAATS	226
BALTRASNA ANNEX	227
HAARTEBEEST PAD ANNEX	228
MILL RIVER	229
DOORFONTEIN	230
HIGHLANDS	231
SPITS KOP	232
ZUURKLOOF	233
HOFFMANS KLOOF	234
WITTEKLIP	235
NEW YEARS DRIFT	236
SIDBURY PARK	247
KOMGA	248
WELCOME WOOD	249
EUREKA	250
SWEET KLOOF	251
SYDNEYS HOPE	252
SIDBURY TOLL OUTSPAN	253
ASSEGAAI BUSH	254
BOEKENHOUT FONTEIN	255
CARELS RUST	256
FARM 299	257
FARM 300	259
MELVILLE PARK	261
HARTEBEEST PAD	262
CARIEGA	263
PALMIET RIVER	264

Farm name	**Farm number**
FARM 306	265
FARM 307	266
GLENSTONE	267
314/1	268
FARM 315	269
MOUNT PLEASANT	270
GOOSEBERRY	271
FAIREWOOD	272
FARM 320	273
FARM 321	274
BURNETTS GRANT	276
FARM 324	277
FARM 326	278
DONKERBOSCH OUTSPAN	279
BELMONT	280
FARM 333	281
GROBBELERS KLOOF	282
GLETWYN	283
FARM 336	284
BEGGARS BUSH	285
NEW ESSEX	286
LE CATEAU	287
TRENTHAM PARK	290
PIGOT PARK	291
FARM 353	293
FARM 354	294
FARM 355	295
FARM 355	296
FARM 356	297
ANNEX GREENHILLS	298
GREEN HILLS	299
STONY VALE	300
KOMSFOUNTAIN	301
GILEAD	301
BRENTHOEK	311
FARM 372	317
FARM 382	329
FARM 383	330
FARM 385	333
FARM 386	335
FARM 388	336
FARM 389	337
FARM 389	338
RADWAY GREEN	339
394/2	340
FARM 395	341
FARM 397	342
FARM 408	343
MELROSE WEST	344
BANANA GROVE	345
ROCKDALE	346
MELROSE	347

Farm name	Farm number
MELROSE	349
FARM 416	351
LOWER MELROSE	352
FARM 418	353
FARM 418	354
FARM 419	355
FARM 419	356
FARM 420	357
FARM 423	358
FARM 425	359
FARM 437	360
FARM 442	361
FARM 443	362
FARM 443	363
FARM 444	364
WILLOW GLEN	365
WILLOW GLEN	366
WILLOW GLEN	367
WILLOW GLEN	368
FARM 469	374
FARM 470	375
BIRCHWOOD PARK	385
NEW MELROSE	450
WILLOW PARK	451
ROODEKRANTZ	452
THORN KLOOF	453
BURNT KRAAL	454
FARM 580	455
ALLANDALE	456
MINIPLAAS	457
LOLDANI	464
FABERS KRAAL	468
FARM 598	472
FARM 599	473
FARM 599	475
FARM 410	483
FARM 615	485
FARM 615	487
KLIPDRIFT	490