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Department of Water Affairs and Forestry

Thukela Water Project Feasibility Study

Volume 4: Baseline Studies

A) Lake Baseline Study
B) Downstream, Aquatic and Riparian Ecosystems Baseline Study
C) Receiving Aquatic Ecosystems Baseline Study

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THUKELA WATER PROJECT FEASIBILITY STUDY

LAKE BASELINE STUDY

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SUMMARY

The two proposed lakes, Jana and Mielietuin, are part of the Thukela[1] Water Project. This study is one of several forming part of the feasibility study for the project. It sets out to investigate, at a scoping level, the consequences of creating a lake (lacustrine) environment on the Thukela and Bushman's Rivers. (It must be appreciated that the level of information in this report is appropriate for a scoping study, and needs to be extended for a full Environmental Impact Assessment (EIA) investigation). The first consideration is of the rivers that will be lost beneath the new impoundments.

Loss of river

Significant stretches of the Thukela, Klip and Bushman's Rivers will be lost by inundation under the proposed impoundments. Available information suggests that the parts of the rivers that will be transformed into standing waters are unexceptional and are replicated in the Thukela and Bushman's River valleys respectively. This does not mean, however, that their loss can be ignored. Instead concern must be raised of the ongoing loss of "ordinary" river reaches. Clearly, in the long-term, as further developments take place, these "ordinary" river reaches will become rare, as will the organisms that inhabit them. Only wise management of these rivers will allow these developments to be sustainable in the long-term. This project should contribute to a wider assessment of the implications of the loss of "ordinary" rivers on a national basis.

Damage due to construction activities

Clearly, there will be short-term impacts resulting from construction activities, with the primary problem being the ingress of fine rock sediments into the downstream river. Management plans to minimise this will need to be put in place during the next phases of the project.

Creation of a lacustrine (lake) environment

The two lakes that are formed are atypical of the natural habitats in the region and thus must have a large impact on the environment. It is incumbent on the developers and managers of these lakes to maximise the positive aspects of these lakes and to minimise the negative aspects, so that they are at least in harmony with the surrounding environment.

[1] Thukela is the correct spelling and is synonymous with Tugela.

A number of factors that will significantly affect the ecology of the prospective lakes are worth commenting on as they identify ways in which maximum benefits can be gained from the development:

Drawdown (A periodic reduction in lake water level with the exposure of mud around the perimeter)

Drawdown may take place frequently and has advantages for moulting aquatic birds and possibly contributes to the binding of phosphates into the sediment. The greatest consequence of drawdown is that it prevents the establishment of a permanent riparian zone around the perimeter of the lakes. This has positive consequences for human health (minimising bilharzia and malaria) but negative consequences for the ecosystem, e.g. habitat for fish, zooplankton, etc. It also reduces the capacity of the lake to purify the water as a healthy riparian zone enhances many of the purification processes. The use of water from the lakes will determine the extent of drawdown and thus the extent of the above consequences. It is recommended that serious consideration be given to the alternative outcomes so that these can be incorporated into the hydrological planning.

Physical and chemical conditions in the lakes

Management of the lakes and their catchments can radically affect the quality of the lakes and the services that they provide to society and the environment. Decisions will need to be made on what these services are and how the management of the catchments and lakes can achieve them. It is generally the case that lakes in the best possible condition (ecologically) will provide the best services. It is thus likely that efforts to maintain the best possible water quality in the lakes, under the circumstances, will be of greatest benefit. This report provides some indication, without having carried out extensive modelling, of the anticipated quality of the proposed lakes. Salient points are:

When first the lakes fill with water (3-5 years), nutrient and phytoplankton levels are expected to be high due to leaching from the drowned soils and rotting terrestrial vegetation. Leaching from coal deposits will also contribute nutrients although this is likely to be negligible. During this phase the water quality may be impaired and may contain high concentrations of algal toxins and taste and odour forming compounds.

In the longer term, the lakes are both expected to be moderately enriched with nutrients and will be classed as mesotrophic (i.e. for part of the year having “nuisance” numbers of algae producing toxins and taste and odour compounds). Lake Mielietuin is more potentially eutrophic (i.e. a larger part of the year having high “nuisance” algae).

It is imperative that steps are put into place to limit and reduce the current concentrations of nutrients that are coming out of the two catchments. This will include more stringent controls on effluent discharges so that they at least comply with Special Standards.

Thermal and chemical stratification will take place in the summer and mixing will take place in the early winter. There is some doubt as to whether winter mixing will extend to the bottom of these deep lakes. Should mixing be incomplete the chemical quality of the deep water will be peculiar. In summer the oxygen saturation of the bottom water is expected to fall to the anoxic level. This lack of oxygen means that a large part of the water body (i.e. the deep water) will be unable to support animal life below a certain depth (approximately 10m). It will also mean that nutrients, in particular phosphorus, will remain dissolved and will at times be available for algae growth. Note that this is a common situation in both natural and artificial deep-water lakes, which will have a significant affect on the downstream rivers. This affect is outlined in a second report by Dickens *et al.* (1999b).

Water related diseases (bilharzia, bacterial and malaria)

The only one of these pathogens that could become a problem in these lakes is bilharzia. As the lakes are unlikely to provide good habitat for the vector snails, this is unlikely to be an issue (this may change if alien aquatic weeds or healthy riparian vegetation develop). The lakes will have a positive benefit on water-borne bacterial diseases, as many of these do not survive passage through a large impoundment.

Plankton

Large zooplankton and phytoplankton populations will develop in the lake and serve as the base of a vibrant food chain. Excessive turbidity in the inflowing water may limit production in the upper regions but is unlikely to do so in the rest of the basins. As mentioned above, algae populations may become excessive at times, the only viable solution being to limit the input of nutrients from the catchments.

Aquatic birds

The lake will provide an increased habitat for many aquatic birds, particularly the fish-eating species.

Crocodiles

Crocodiles are present in the Thukela River upstream of Lake Jana. There is a remote possibility that they will colonise the lake, and possibly also Lake Mielietuin, which would be advantageous to the ecology and some aspects of tourism.

Fish

- The impoundments will be deep and will have minimal littoral habitat for fish around the edges. There will be no fish in the deoxygenated bottom waters.
- Unless drawdown of the lakes is minimised, riparian vegetation around the perimeter of the lakes will be minimal, which will reduce the habitat needed by many fish and will consequently negatively impact on the many advantages brought by a healthy fish population.
- From Lake Jana there will be zero to very limited access for fish to river breeding habitats as both of the rivers feeding the lake have major natural barriers just above the headwaters of the lake. This will mean that species such as scaly and labeo will be unable to spawn. This means that these fish will be uncommon in the lake. This is not an important issue as lakes are not their natural habitat, but it is unfortunate that these indigenous species will give way to exotic species. The impoundment will be dominated by exotic carp and catfish. Tilapia and exotic bass will form a minor component of the fish population.
- The barrier to upstream migration of fish from the downstream Thukela River, which will be caused by the Lake Jana dam wall, cannot be considered to be serious as impassable natural barriers exist on both the Thukela and Klip Rivers. Fishways are thus not a consideration for Lake Jana.
- Eels could become extinct in and above both impoundments if the impoundment walls are impassable to them (they breed in the sea, and travel upriver to mature, easily surmounting waterfalls and natural barriers). Removing this predator would have a negative impact on the upstream ecology although for the region as a whole the impacts would be less as these species are widespread. This issue can be easily mitigated through the provision of eelways. Consideration also needs to be given to the passage of large adult eels back downstream, and over the dam walls.
- A fish industry could be developed on both impoundments, and should be given consideration.
- The incidence of carp in the Thukela and Bushman's Rivers below the impoundments will rise but they are unlikely to thrive as they prefer slow-flowing waters. Where they occur they will have some impact on the river fauna.
- Three alien Orange River system fish species pose potential hybridisation and habitat competition threats to the scaly and Thukela labeo populations. This threat already exists as a result of the Pumping Scheme. Lake Jana dam wall will provide an

additional barrier to the downstream migration of these fish and so may help to alleviate this threat.

- Carp, catfish and the endemic scaly will dominate Lake Mielietuin. Bass will be a minor component of the population. Scaly will be able to breed in the Bushman's River upstream of the lake and from there grow to maturity in the lake. Tilapia could flourish if introduced. This is a useful angling and food species.
- Angling opportunities will be good, particularly on Lake Mielietuin, which will have higher nutrient concentrations.
- The effect of population fragmentation on the genetic structure of the scaly population by the Lake Mielietuin dam wall should be mitigated by occasional transfer of fish from below the dam to above. Construction of a fishway on a dam of this size, for the scaly population, should be considered but is not likely to be recommended.
- Eels have not yet been recorded in the Bushman's River but are likely to occur. This needs to be confirmed as does the need for any eelway over Lake Mielietuin dam wall.

Aquatic weeds

There appears to be little doubt that at some stage the impoundments will be subject to some form of infestation by alien weeds. Two of the major alien aquatic weeds (water hyacinth and parrots feather) already exist in the Lake Jana catchment. With an acknowledged seed bank (viable for up to 20 years!) it is likely that water hyacinth from the Colenso colony will establish itself in Lake Jana. If uncontrolled, the weeds would create major impacts on the aquatic environments in the respective lakes. All efforts should be made to locate and eradicate sources of the weeds within the respective catchments prior to the building of the impoundments. Once completed the lakes (and their catchments) should be routinely monitored for weeds, as should all "foreign" boats entering the lake. All new alien weed infestations should be either physically removed or chemically herbicided in a "zero tolerance" programme. A rigorously defined and comprehensive aquatic-weeds-control management plan, with a monitoring programme, should be in place before completion of the impoundments. The responsibility for the implementation and adherence to this management plan should be formally and explicitly laid at the door of a single management agency. Invasion by aquatic weeds would have the following negative impacts:

- Loss of littoral (lake margin) and open water habitat due to the invasion of weeds may have major impacts on all users by clogging the water surface, bays, abstractions, etc.
- Water quality (physico-chemical and biological) may be significantly affected as the weeds cut out light and oxygen, thus making the water anoxic, smelly and inhospitable.

- Evapotranspiration losses may be up to 40% greater than normal.
- Human health may be negatively impacted due to increased disease vectors associated with weed invasion (bilharzia, mosquitoes and possibly malaria).
- Drownings may increase in areas covered by aquatic weeds. Boating can become impossible.

Downstream water releases

As with any damming, and more so with deep impoundments such as those proposed, the quality of water released to the downstream river is substantially different to water normally found in a river, which will have some consequences for the downstream river environment. The main changes to the water come about through a reduction of silt and the elevated (sometimes toxic) concentrations of substances resulting from the lack of oxygen in the water when discharged from the bottom of the lake. Cold deep water releases also have a negative impact on the downstream environment. The consequences of these releases are the subject of a second report (Dickens *et al.,* 1999b).

Sustainability of the proposed developments

According to Dr Mark Everard (UK Environmental Agency and The Natural Step), one of the conditions of sustainable use of a resource is that "The physical basis for the productivity and diversity of nature must not be systematically diminished". This project will need to assess this matter, on the basis of a full EIA, to determine if this condition is being met. Clearly there will be some loss but this will, to some extent, be balanced by the provision of an alternative system (i.e. the two lakes). This alternative system will contribute in many respects to productivity and diversity, but only a detailed assessment will determine if there is a net loss or gain.

1 PURPOSE OF THIS DOCUMENT AND TERMS OF REFERENCE FOR THE STUDY

1.1 Structure of this document

This report starts with a review of the current situation, which serves to inform an assessment of the likely situation once the two impoundments are built. It is divided into the following sections:

- Brief introduction to the project and the terms of reference for this report.
- The current physical and biological make-up of the Thukela River and its catchment are described.
- From the known current characteristics, descriptions are given of the likely characteristics (water quality, populations of plants and animals and the overall environment) of the two impoundments. Some indication is also given of the anticipated quality of the water that will be released from the two lakes, but the impacts of this on the downstream river are the subject of the second report by Dickens *et al.* (1999b).
- Some likely impacts are listed, together with possible mitigations.
- Suggestions for monitoring these issues are made.
- The Appendices contain the full water quality and aquatic weeds reports, both of which have been incorporated into the main report. These are intended for the specialist and reflect the views of their authors. Conclusions in the main report do not necessarily reflect the views of the specialist authors.

1.2 Introduction and background

The Department of Water Affairs and Forestry (DWAF), as the responsible institution for the management of South Africa's water resources, has commissioned the Thukela Water Project Feasibility Study (TWPFS) with a view to further augmenting water supply to the Vaal River System from the Thukela River catchment.

The proposed scheme comprises two large impoundments, Lake Jana on the Thukela River and Lake Mielietuin on the Bushman's River, with linking aqueducts comprising either an open canal and/or a pipeline from the proposed lakes to the existing Drakensberg Pumped Storage Scheme.

1.3 Terms of reference for the study

The purpose of this Baseline Study was to determine the impacts which may arise as a consequence of the construction of impoundments on the Thukela and Bushman's Rivers, as proposed in the Thukela Water Project (TWP). This investigation was to address limnological issues such as the creation of new habitat, potential for invasion by alien species and shoreline establishment, as well as developing an understanding of the likely water quality characteristics of the impoundment. The latter aspect was also considered from the perspective of water releases in relation to the water quality requirements of downstream reaches. This Baseline Study was to have the following objectives:

1.3.1 Collation of available relevant information relating to the likely impacts of impoundments in relation to their effect on water quality, and the consequences and impacts of establishing a new lacustrine ecosystem.

1.3.2 Evaluation of the available water quality data and information for the Thukela system, with a view to developing a predictive understanding of the likely water quality and physico-chemical characteristics of the proposed impoundments.

1.3.3 Identification and description of issues and impacts which may arise as a consequence of these impoundments, particularly in relation to the potential for invasion by alien species (within the impoundment, upstream and downstream), the development of water quality problems within the impoundments (e.g. eutrophication) and the establishment of limnetic and littoral communities (Table 1.1).

1.3.4 On the basis of consideration of all techniques and data sources, an assessment of the impacts of the proposed TWP which may arise due to the creation of a lacustrine environment.

1.3.5 Opportunities for mitigation were to be identified, and where these are identified, impacts of the project before and after mitigation were to be stated.

1.3.6 Specific consideration was to be given to the identification of requirements for further investigation. Similarly, guidelines for both baseline (pre-impoundment) and post-impoundment monitoring were to be provided.

Table 1.1: Conventions for definitions and used in the description, evaluation and assessments of environmental impact

Category	Description or Definition
Type	A brief written statement, conveying what environmental aspect is impacted by a particular project activity or action, or policy or statutory provision.
Magnitude and Intensity	The severity of the impact
very high	- Complete disruption of process; death of all affected organisms; total demographic disruption
high	- Substantial process disruption, death of many affected organisms; substantial social disruption
moderate	- Real, measurable impact, which does not alter process or demography
low	- Small change, often only just measurable
no effect	- No measurable or observable effect
unknown	- Insufficient information available on which to base a judgement
Extent / Spatial Scales	The geographical extent or area over which the direct effects of the impact are discernible, i.e. the area within which natural systems or humans directly endure the effects of the impact.
international	- Southern Africa
national	- South Africa
regional	- KwaZulu-Natal and the Thukela catchment, the uThukela region
local	- dam basin, conveyance servitude, river reach, specific site locality
Duration	The term or time period over which the impact is expressed, **not** the time until the impact is expressed. Where necessary the latter must be specified separately.
short term	- up to 5 years (or construction phase only)
medium term	- 5 to 15 years (or early commissioning and operational phases)
long term	- > 15 years (or operational life)
Sign	Denotes the perceived effect of the impact on the affected area
positive (+)	beneficial impacts
negative (-)	impacts which are deleterious
Certainty	A measure of how sure, in the professional judgement of the assessor, that the impact will occur or that mitigatory activity will be effective
improbable	- low likelihood of the impact actually occurring
probable	- distinct possibility that the impact may occur
definite	- impact will occur regardless of prevention measures
Significance	An integration (i.e. opinion) of the type, magnitude, scale and duration of the impact. Judgements as to what constitutes a significant impact require consideration of both context and intensity. It is the assessor's best judgement of whether the impact is important or not within the broad context in which its direct effects are felt. (see Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823)
high	- Could (or should) block the project/policy; totally irreversible (-ve impact) or provides substantial and sustained benefits (+ve impact)
medium	- Impact requires detailed analysis and assessment, and often needs substantial mitigatory actions.
low	- Impact is real but not sufficient to alter the approach used. Probably no mitigation action necessary.

Some Explanations and Definitions

1 Environmental impact - An environmental change caused by some human act. (DEA 1992. *The Integrated Environmental Procedure*. Vol 5)

2 Environmental impact - Degree of change in an environment resulting from the effect of an activity on the environment whether discernable or undesirable. Impacts may be the direct consequence of an organisation's activities or may be indirectly caused by them. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

3 Affected environment - Those parts of the socio-economic and bio-physical environment impacted on by the development. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

4 Environmental issue - A concern felt by one or more parties about some existing, potential or perceived environmental impact. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

5 Environment - means the surroundings within which humans exist and that are made up of:
- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of (i) and (ii) and the interrelationships among and between them;
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being National Environmental Management Act No 107 of 1998).

6 Significance - (See Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823. Also in, DEA 1992. *The Integrated Environmental Procedure*. Vol 4)

7 Significance - "The definition of significance with regard to environmental effects is a key issue in EIA. It may relate *inter alia* to scale of the development. To sensitivity of location and to the nature of adverse effects." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 13).

8 Significance - "Once impacts have been predicted, there is a need to assess their relative significance. Criteria for significance include the magnitude and likelihood of the impact and its spatial and temporal extent, the likely degree of recovery of the affected environment, the value of the affected environment, the level of public concern, and political repercussions." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 124).

9 Significance -" The question of significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective - technical, conceptual or philosophical - the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant." (Beanlands, G. 1983. *An ecological Framework for Environmental Impact Assessments in Canada*. Institute for Resource and Environmental studies. Dalhausie University. Sections 7: 43)

10 Environment - Surroundings in which an organisation operates, including air, water, natural resources, flora, fauna, humans and their interrelation. (ISO 14001. 1996). Note - Surroundings in this context extend from within an organisation to the global system.

11 Environmental aspect - Element of an organisation's activities, products or services that can interact with the environment. (ISO 14001. 1996). Note - A significant environmental aspect is an environmental aspect that has a or can have a significant environmental impact.

12 Environmental impact - Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services. (ISO 14001. 1996).

1.4 Limitations and constraints

The overriding limitation on this project, was the short time allocation for the work and also that all field work was carried out during an inappropriate season. The specialists contributing to this report commenced work on the 16 August 1999 and the draft report was submitted on the 9 November 1999. All survey work was thus carried out in the late part of winter, prior to the first spring rains, which meant that river flows were low (exceptionally) and plants were still overwintering. Without the time or opportunity to properly survey the river environment, the conclusions, and in particular the suggested impacts, contained in this report must be treated as circumspect. *It needs also to be stressed that this report is part of an advanced scoping exercise, and will be followed up by a detailed Environmental Impact Assessment in the next phase of the project.*

1.4.1 Limitations to the lacustrine investigation

This report has had to be prepared within a very limited budget and time frame. Time did not permit an extensive literature search and no new data have been collected.

1.4.2 Limitations to the water quality investigation

To estimate the water quality likely to enter the proposed impoundments, the available chemical analysis data for five DWAF monitoring stations above the proposed impoundment sites were extracted. Two are above Lake Jana, one on the Thukela River at Thukela Drift/Colenso and the other on the Klip River at Ladysmith. For Lake Mielietuin, two sites are on the Little Bushman's River, one above and one at Estcourt, while the other is on the Bushman's River below Lake Wagondrift. More comprehensive data was available from the Umgeni Water site at Middledrift, which lies 185km below both the impoundment sites. This data was, nevertheless, used in the investigation.

The maximum frequency of analysis in the DWAF database was for EC (electrical conductivity) at an average of 3 samples per month, while for the other constituents the frequencies ranged from 0.9 to 2.4 per month, effectively being as little as monthly analyses. The frequencies of analyses, particularly for phosphate, nitrate and ammonia concentrations (the plant nutrients) are considered to be too low to adequately characterise water quality and evaluate pollutant loads. A weekly sampling frequency, particularly during the summer months, would be considered essential for this purpose. The paucity of the data was considered to be a severe limitation.

Analyses for total phosphorus, turbidity, suspended solids and bacteria (*E. coli*) were not conducted on any of the routine DWAF samples, which is considered to be a serious omission in characterising water quality in the catchments above the impoundments. Phosphorus, which is usually the driving force in determining algal populations in lakes, is strongly adsorbed onto sediment particles and is carried by rivers in this manner into lakes where it may become a nutrient for algal growth. Consequently, the fact that only analyses for soluble and not total phosphorus were performed, means that estimates of likely total phosphorus concentrations entering the lakes had to be made in order to suggest algal concentrations that would develop. Data on the relationship between soluble and total phosphorus concentrations for the inflow to another impoundment in KwaZulu-Natal was used for this purpose but, clearly, this method would be subjective and could lead to error. The lack of analyses for turbidity/suspended solids concentrations and bacteriological analyses, such as for *E. coli* means that estimating the extent of diffuse pollution to rivers from informal settlements without sanitation and sewage effluents is very limited.

1.4.3 Limitations to the faunal investigation

Limited data for fish populations already existed mostly in the database of the KwaZulu-Natal Nature Conservation Services (KZNNCS). The limited time available only enabled limited further collections at a time when the river was at its lowest level for some time. This meant that the distribution of fish was probably not representative of times when flows are more generous. The lack of data on fish in the Mielietuin impoundment area and the constraints of time necessitated a somewhat hurried survey of that river at only one site within that lake basin. Furthermore, the KZNNCS was only able to provide the services of Mr Mike Coke for the basic data and information provision, which necessitated the co-option of Dr Jim Cambray in the very late stages of the project to interpret the data.

The limited time available for invertebrate surveys has meant that only a part of the diversity of the river has been documented. The available historical data related to broad zones on a scale much larger than was useful for this investigation. Little site specific survey was done.

As a separate project, the KwaZulu-Natal Nature Conservation Services were contracted to investigate the biodiversity of the lake basins, both faunal and floral. This information was not available at the time of writing this report.

1.4.4 Limitations to the floral investigation

Loss of riparian vegetation due to inundation by the impoundment was not a part of this task but has been carried out by another team dealing with the biodiversity of the entire lake “footprint”.

1.4.5 Limitations to the aquatic weeds investigation

The principal limitation was inadequate time for this investigation to conduct a thorough survey for alien aquatic weeds throughout the respective catchments. This will be done in the forthcoming Environmental Impact Assessment phase of the project.

2 METHODS AND APPROACH

The main approach of this investigation deals with the creation of new lacustrine (lake) ecosystems. Data describing the present and historical water quality and fauna, are used to suggest the likely characteristics of the two proposed impoundments. An assessment of the acceptability of these new ecosystems proceeds from this.

A smaller part of the investigation was to gain some idea of the consequences of the loss of a considerable length of riverine ecosystem.

In all sections, the report thus presents the historical and current perspective, and then suggests the changes that may come about. Suggestions for mitigating these changes are then made, together with suggestions on how to monitor the situation over the years to come.

2.1 General overview

Due to the short time allowance for this investigation, the river in its current state was surveyed by helicopter, which allowed the whole team of specialists (excepting Dr Cambray) an aerial view of the proposed impoundments. This proved to be a valuable exercise.

2.2 Approach to establishing the "likely lacustrine environment"

The methods employed in this report have been to use the combined impressions of a team of specialists gained from the aerial survey, together with a broad knowledge based on many years of working with rivers and lakes. Supporting this was the information provided in the baseline studies on geomorphology, water quality, fish, invertebrates and the riparian zone, and the report by Oliff (1960a).

2.3 Approach to the water quality investigation

- To determine landuse in the catchments of the proposed impoundments which gives an indication of likely runoff water quality, as certain categories of landuse have greater potential to pollute water than others.
- To gather and evaluate existing water quality data for the rivers above and below the proposed impoundments from available sources (no new monitoring was carried out).
- To examine the data for historical trends to determine if constituent concentrations (levels of pollution) are changing or not.

- To use estimated phosphorus concentrations in the inflows to the lakes, together with physical data, to run an empirical model to suggest the algal concentrations likely to develop.
- To use existing data (Umgeni Water data) collected for lakes to estimate changes in water quality likely to take place through impoundment, and the quality likely to be released from different levels in the lakes.

The chemical data for 5 DWAF sampling sites in the catchments of the Jana and Mielietuin impoundments extending over a period ranging from 16 to 23 years were evaluated.

The constituents available were:

electrical conductivity	sum of nitrate and nitrite
total dissolved salts	sulphate
pH	phosphate
sodium	alkalinity
magnesium	silicon
calcium	potassium
fluoride	ammonium species
Chloride	

Additional chemical variables from the Umgeni Water site downstream at Middledrift were used, i.e. *E. coli*, turbudity, iron, manganese, algae total phosphorous and trace heavy metals.

The approach adopted was to perform percentile analyses on the data to determine its distribution, such as the medians and higher values; to plot the data as time series to show variation in concentrations; and perform trend analyses to show if water quality was deteriorating or improving with respect to the particular constituent. All data and graphs are presented in Appendix 1.

2.4 Approach to the faunal investigation

Historical data from the KZNNCS database on the fish of the upper Thukela River and from fishing competition catches in State lakes within the region, and information gathered from local anglers, was used to build up a picture of the current and past fish populations. Experience of the development of fish populations in State lakes in KwaZulu-Natal was used in estimating the potential populations of the proposed impoundments. In order to determine current populations of fish, an electroshocker and gillnets were used to sample fish in the rivers due to become part of the lake basins.

Fairly comprehensive surveys of the Thukela conducted in the 1950-60s, and also in 1985, provided useful data on the invertebrate populations. Limited sampling of the current populations also provided additional input. An assessment of the importance of these populations and the consequence of their loss was made. Lake ecosystems have little in common with the river ecosystems that currently exist, and few invertebrates live in both. It is likely that the lake ecosystems will develop an invertebrate population (including zooplankton which are infrequent inhabitants of the river ecosystem) that will reflect the quality of the water and the lentic habitat. Comprehensive reports in the literature describing lakes, not only in the Thukela but also neighbouring catchments, were used to give an indication of the biota that may develop.

2.5 Approach to the aquatic weeds investigation

- Identification of major aquatic weeds in the catchment.
- Ranking their importance as a threat.
- Consultation/communication with various key agencies/personnel.
  The following people and organisations were contacted and consulted to determine the current distribution and likely spread of these weeds:
  - Lesley Henderson (National Botanical Institute) - current distribution records;
  - Hugh Dixon-Paver (DWAF, KZN offices) - current distribution records;
  - Hendrik Bosman (DWAF, Head Office, Pretoria) - distribution records;
  - Carina Cilliers (Plant Protection Research Institute, Subdivision: Weeds, Pesticides and Herbicides) - distribution records, species, biological control and possible management strategies;
  - Mark Chutter (Afridev Consultants) - distribution records;
  - Rob Scott-Shaw and Mike Coke (KZNNCS) - distribution records.

3 STUDY AREA

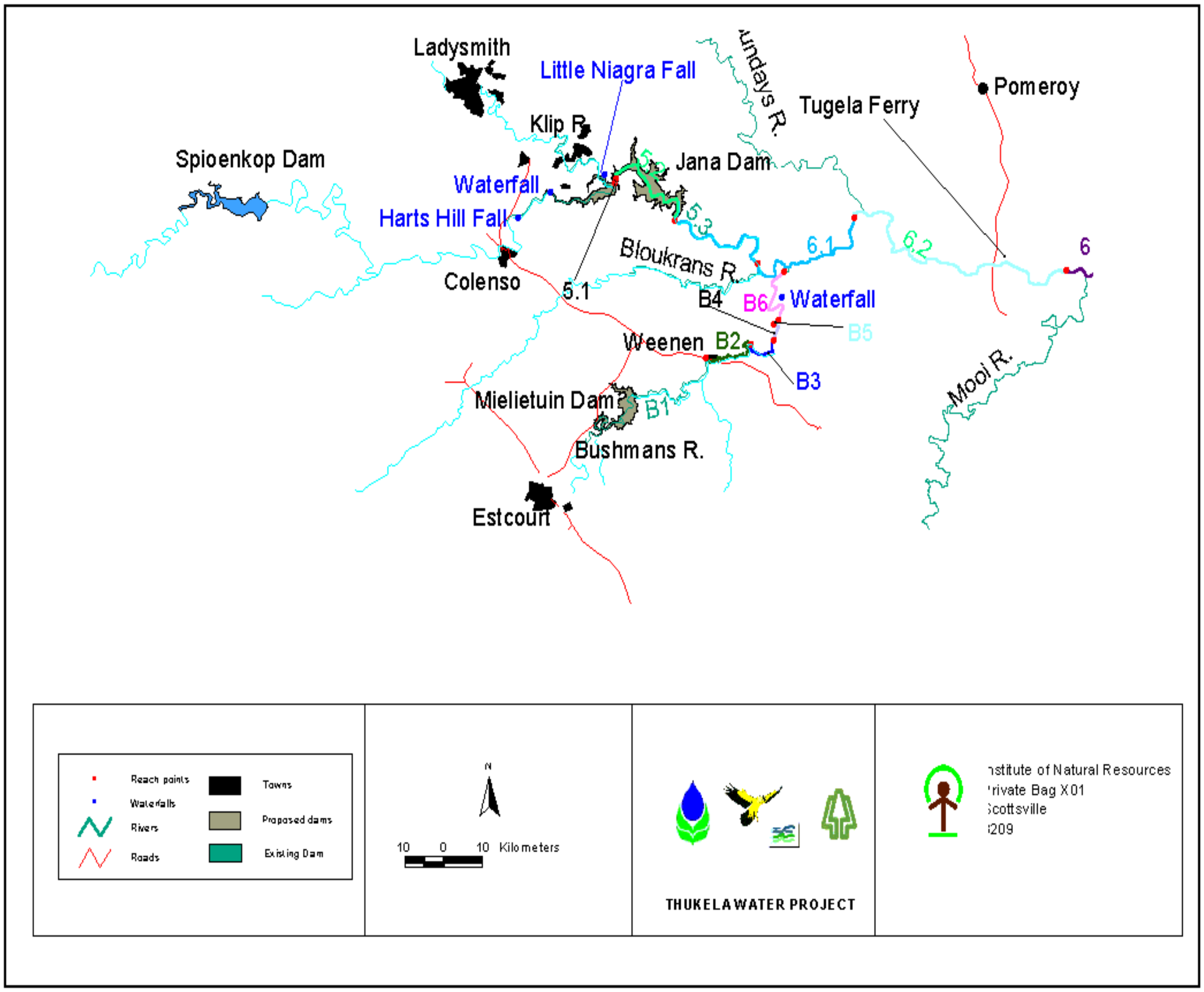

Figure 3.1: Locality map of the Thukela Water Project, depicts the study area

4 DESCRIPTION OF THE WATER QUALITY AND RIVERINE ENVIRONMENT IN THE PROPOSED INUNDATION AREAS

4.1 General overview

The inundation zone of Lake Jana will probably extend to just below the Ezakheni water abstraction weir, which is well below Harts Hill Falls. The gradient of the river within the inundation zone is steep and there are frequent rapids alternating with pools. On account of the deep incision of the river valley, for the most part there is no well-developed riparian zone with riparian zone trees.

The inundation zone of Lake Mielietuin lies in a reach of the river with alternating pools and rapids. The gradient of the river is moderate and there are riparian zones which support exotic trees (mainly poplars).

From available information there would appear to be no unique biotopes within the inundation zone of either impoundment. Oliff (1960a) did not find invertebrate taxa restricted to any parts of the rivers likely to be inundated.

Red Data Book species have not been found in the proposed inundation zones of the Jana and Mielietuin Lakes. Two endemic fish species, *Barbus natalensis* and *Labeo rubromaculatus*, are widespread in the Thukela River basin. The cascade, which lies at the foot of the Ezakheni abstraction weir, is a barrier to the upstream migration of all river fish except eels. The Little Niagara Falls, over which the Klip River plunges into Lake Jana are also a barrier to the upstream movement of all fish but not to eels.

While Lakes Woodstock and Spioenkop must trap large quantities of silt, the stored water is not silt free and the river water remains turbid all the year round.

4.2 Landuse in the catchments of Lakes Jana and Mielietuin

Apart from the underlying geology and soils in a catchment, which usually determines the mineral content of drainage water, landuse activities generally determine the bacterial, organic and nutrient concentrations in rivers. Landuse with high pollution potential are urban, industrial and agricultural uses. The landuse in the Lakes Jana and Mielietuin catchments were determined to make this assessment. Comments are as follows:

- The major landuse in the two catchments is unimproved grassland at 53% to 72% of the catchment areas respectively, which has a low pollution potential provided that the soil cover is not stripped bare by overgrazing. Information from a 1994 study

(WST Consortium) stated that the land in the Thukela and Bushman's Rivers was overstocked with livestock, ranging from 60% to 100% over the carrying capacity, which could be a threat to water quality through erosion.

- Agricultural land (all types) in the Lake Jana catchment is moderately high at 15.5% and thus the potential for erosion through poor farming practices and wash-off of applied fertilisers is present, but as the distribution of agriculture is mostly in the middle to upper catchment, there will be some amelioration of pollutants through in-stream processes before reaching the lake. The Lake Mielietuin catchment has far less agricultural land, just 4.6%, and therefore less pollution potential from this source.
- The Lake Mielietuin catchment has a greater proportion of urban land at 3.0% compared to only 0.6% for the Lake Jana catchment. The latter catchment has greater heavy industry but this is more extensively diluted. The WST Consortium study stated that urban informal settlements were growing rapidly in both catchments, which should be seen as a threat to water quality as there would not be any services in these areas.
- The immediate surround of both lakes is shrubland, thicket and bushland which is not seen as a threat to water quality and should be maintained as undeveloped areas.
- For the protection of water quality, developments in the lake catchments should be strictly controlled with sound planning principles in place. There should be good control of the discharge quality of effluents with a receiving water quality objective approach adopted. The apparent overstocking of the land with livestock should be investigated and a policy drawn up for the sustainable use of the land in the catchments.

4.3 Water quality in the catchments of Lakes Jana and Mielietuin

- The Thukela and Klip Rivers that will feed Lake Jana show good water quality with respect to their conservative *inorganic* constituent concentrations, which are unlikely to affect any user detrimentally. Details of these constituents are contained in Appendix 1.
- The phosphate-P concentrations of the Thukela and Klip Rivers (medians of 0.022 and 0.018mg/l) are a cause for concern as the levels will stimulate algal growth but without knowing the total phosphorus concentration the full impact cannot be assessed.
- The data for the Little Bushman's River that will feed Lake Mielietuin show the effects of pollution from the town with raised conductivity levels and associated ion concentrations, and the doubling of the phosphate-P concentration from 0.014 to

0.033mg/l at the 50th percentile. The trend line for phosphate-P for the river below the town shows rising concentrations, as well as high sporadic phosphate-P concentrations indicating pollution incidents. These concentrations will stimulate algal growth appreciably.

- The Bushman's River below Lake Wagendrift generally shows better water quality than the Little Bushman's River, but still the phosphate-P concentrations are high enough to support significant algal growth.
- For all the rivers feeding the two lakes, both sulphate and pH values show statistically significant upward trends over the monitoring period, but current levels are not problematic to any user in either catchment. The upward trend is of concern and must be monitored and addressed if necessary.
- Analyses for total phosphorus, turbidity, suspended solids and bacteria (*E. coli*) were not conducted on the DWAF samples, which is a serious omission in characterising water quality in the catchments above the lakes. Phosphorus which is usually the driving force in determining algal counts in lakes, is strongly adsorbed onto sediment particles and carried by rivers in this manner into lakes as a nutrient to stimulate algal growth. Consequently, the fact that only analyses for soluble and not total phosphorus were available meant that estimates of likely total phosphorus concentrations entering the lakes had to be made in order to suggest algal concentrations that would develop. The data were, therefore, severely limiting in this respect. Furthermore, circumstantial evidence suggests that bacterial and viral infections resulting from contaminated water are common. Again no evidence has been collected to support this. Faecal contamination of the water will need to be monitored in the next phase of the project.
- The inundation of coal deposits by the lakes is unlikely to have any affect on water quality. Only those seams of coal exposed at the surface would have any affect, but these are unlikely to be common.

4.3.1 Additional water quality data (extrapolated from Middledrift)

The water quality for an Umgeni Water site on the Thukela at Middledrift (185km below Lake Jana) was used as a general indication of water quality in the basin for those constituents which *were not included* in the DWAF analyses. It must be noted that additional impacts from tributaries (i.e. Mooi, Sundays and Buffalo Rivers), some of which are polluted, between the lake sites and Middledrift could be contributing to this data. In-stream processes would also be ameliorating the generally poorer water quality found near the towns which lie above the proposed lakes, so this data from Middledrift can be considered to be conservative.

Personal observation during the helicopter survey confirms this amelioration, as the water downstream of the lake sites in the lower part of the catchment became considerably clearer with less noticeable sewage odour. Comment on the data from Middledrift is as follows:

- The *E. coli* results show significant bacterial contamination with a 50th percentile value of 300 cells/100ml which is above the guidelines for full contact recreation (130 cells/100ml), livestock watering (200 cells/100ml) and clearly also for direct domestic use. The high 95th percentile value of 7990 cells/100ml shows severe bacterial pollution at times, which supports the concerns stated in Section 4.3. It is possible that such concentrations may be found in the rivers at the lake sites.
- An algal count of 4000 cells/ml at the 50th percentile shows that sufficient nutrient concentrations are present to support significant algal growth in the river, while a maximum count of over 25000 cells/100ml found represents algae at nuisance concentrations.
- The turbidity data indicate a very turbid system with a 50th percentile value of 103 NTU and a 95th of more than 4000 NTU. Iron and manganese concentrations associated with turbidity are also high and could enter the lakes and provide a store for release of the dissolved forms in the anoxic zones of the lakes.
- The data distribution for total phosphorus show high values, 0,082mg/l at the 50th percentile, which could support algal growth in the lakes.
- From the analysis of 8 samples for toxic trace metals, two results each were above the detection limits for copper, zinc and mercury and one result each for arsenic and nickel. There were no positive results for cadmium, chromium, lead, silver and antimony. It can be concluded that the trace metals are not regularly present in the river and when found are at low concentrations. They may exceed the aquatic life guidelines but not those for other water uses. This is an issue that needs to be investigated in the next phase of the project.

In the forthcoming EIA phase of the project, all of these issues will need to be monitored in sites more relevant to this project. <u>Note that more detailed information is contained in Appendix 1 of this report.</u>

4.4 General river environment

In the Jana Lake basin, the Thukela River lies in a deep, rocky valley in which it forms large, deep pools separated by extensive boulder or bedrock riffles and rapids. Riparian vegetation comprises mostly rushes, *Scirpus* sp., and a few patches of waterweed, *Potamogeton crispus*, develop in the quiet backwaters during low-flow periods. There is, thus, a wide diversity of habitats available for fish. The river is fairly turbulent and remains moderately turbid even in the winter low-flow periods.

In the Mielietuin Lake basin, the Bushman's River lies in a moderately deep valley cut into shale rock where it forms predominantly long, slow-flowing pools separated by short areas of cobble or bedrock riffle. The enriched water is fairly turbid and produces large quantities of filamentous algae which coats the substrate and clogs backwaters, particularly in low-flow periods. Similarly, it favours a dense growth of semi-aquatic watercress, which forms mats along the banks in the slower-flowing reaches. Riverine vegetation comprises largely rushes, *Scirpus* sp. Although the instream habitat is varied, it holds relatively few fish species.

4.5 Fish historically and currently present in the Thukela and Bushman's Rivers and due to be inundated by the two lakes

The fish species present and their distribution in the two rivers are listed in Table 4.1. Only nine species natural to the area have been recorded, while a further eight are exotic (this includes some species introduced from other parts of South Africa).

The scaly, *Barbus natalensis*, is endemic to KwaZulu-Natal and the Thukela labeo, *Labeo rubromaculatus*, is endemic to the Thukela River system. There are no known Red Data fish species in the study area.

In the Jana Lake basin scaly, two labeo species and catfish predominate in the Thukela River fish population. Eels and a few tilapia are present and carp are very occasionally caught by anglers. Small *Barbus* species occur, but are usually limited to tribuatries and backwaters.

In the Mielietuin Lake basin scaly have historically been the predominant fish species present. However, in recent years introduced catfish have become common. Although not a river fish, carp have been able to invade the Bushman's River in increasing numbers, probably due to the attenuation of floods by Lake Wagendrift. Eels (probably), *Barbus* minnows and bass are present but form a minor part of the population.

Table 4.1: Fish species and distribution in the Thukela and Bushman's Rivers above Lakes Jana and Mielietuin impoundment sites

Scientific Name	Common Name	Status	Thukela River Distribution				Bushman's River Distribution	
			Lake Kilburn	Lake Spioenkop	Colenso	Lake Jana Basin	Lake Wagendrift	Lake Mielietuin Basin
Anguilla mossambica	longfin eel			+	+	+	?	?
Barbus aeneus	smallmouth yellowfish	alien	+					
Barbus anoplus	chubbyhead barb		+	+	+			
Barbus natalensis	scaly	endemic	+	+	+	+	+	+
Barbus trimaculatus	threespot barb					+		
Carassius auratus	goldfish	alien			+			
Cyprinus carpio	carp	alien	+	+	+	+	+	+
Labeo capensis	Orange River mudfish	alien	+					
Labeo molybdinus	leaden labeo					+		
Labeo rubromaculatus	Thukela labeo	endemic	+	+	+	+		
Labeo umbratus	moggel	alien	+					
Amphilius natalensis	Natal mountain catfish		+			+		
Clarias gariepinus	sharptooth catfish		+	+	+	+	+	+
Lepomis macrochirus	bluegill	alien		+			+	
Micropterus dolomieu	smallmouth bass	alien					+	
Micropterus salmoides	largemouth bass	alien		+			+	
Oreochromis mossambicus	Mozambique tilapia			+		+		

In the Thukela River the cascade below the Ezakheni water abstraction weir and the Little Niagara Falls on the Klip River mark the upstream limits of the natural distribution of *Clarias gariepinus*. This species has, however, been illegally introduced into Lake Spioenkop above Colenso in recent years, from where it has invaded the entire upper Thukela River region. It has also been illegally introduced into the Klip River in the Ladysmith area. Three alien fish species from the Orange River system, *Barbus aeneus*, *Labeo capensis* and *L. umbratus* have invaded Lake Kilburn in the extreme headwaters of the Thukela River via the Drakensberg Pumped Storage Scheme pipeline, despite the enormous altitude difference and whirling turbines. They pose possible hybridisation and habitat competition threats to *Barbus natalensis* and *Labeo rubromaculatus* throughout the Thukela River and particularly in the proposed impoundments. Bass, bluegill and carp have been introduced into Lake Spioenkop for angling purposes. Carp are now common in the very slow-flowing reaches of the Thukela above Colenso and are also very occasionally caught in the more turbulent Jana Lake basin area. Fast-flowing river conditions, however, do not suit them. Bass are limited almost exclusively to Lake Spioenkop and to farm impoundments.

In the Bushman's River, the Bushman's Falls below Weenen and below the proposed Lake Mielietuin, mark the upstream limit of the natural distribution of *Clarias gariepinus,* although here too it has recently been illegally introduced into Lake Wagendrift and has subsequently invaded the middle reaches of the river. Carp were introduced into Lake Wagendrift for angling purposes and have also invaded the middle reaches of the river. Specimens were found in the river at Weenen Nature Reserve as early as 1986. The bass and bluegill introduced into Lake Wagendrift for angling purposes have tended not to invade the river below the impoundment.

4.6 Invertebrates historically and currently in the Thukela and Bushman's Rivers above the two impoundment sites

Inundation of the two river reaches by the two lakes will bring about an almost total change in the invertebrate populations. Certain species will not survive and so will be lost to the immediate area. The consequence of this can only be weighed against the rarity of the species and of the habitats that they reside in and whether alternative sites will cater for their contribution to biodiversity.

The invertebrate data currently available is not sufficiently detailed to enable a discussion about specific sites as most of the reporting has been done in relation to the river zones described by Oliff (1960a). Conclusions are, therefore, of a general nature, as Lake Jana falls into the rejuvenated zone (Zone 6 - Oliff, 1960) which extends on the Thukela River from

Harts Hill (just above the inflow to Lake Jana) to Ngobevu several kilometres downstream. Lake Mielietuin also falls into this rejuvenation zone on the Bushman's River although this river was never delineated into zones.

A more detailed report on the invertebrates in the Thukela and Bushman's Rivers is presented in a report on the downstream river (Dickens *et al.*, 1999b). It is sufficient to say at this stage that the data does not suggest that there will be any major consequence of loss of these two stretches of river habitat to inundation. The KwaZulu-Natal Nature Conservation Services have been tasked with assessing the biodiversity of the lake areas but this information was not available at the time of writing this report.

Information from a report on the upstream Spioenkop reservoir (Hart, 1999) has been noted. Productivity in this lake was suppressed by the high turbidity levels experienced, a phenomenon unlikely to persist in the downstream Lake Jana or to be a problem in Lake Milietuin. The fauna found in Spioenkop, predominantly turbid water species of zooplankton, are thus unlikely to be repeated in the new lakes. The littoral zoobenthos in Spioenkop was dominated by insect larvae, in particular Ephemeroptera and Chironomidae. Of note was that most of these organisms were found several metres from the shore. Diversity and abundance was greater on rocky substrates. The bivalve mollusc, *Unio caffer*, was found along the shoreline.

4.7 Crocodiles

Crocodiles already exist in the Thukela River and have been seen as high as the confluence of the Thukela and Little Thukela Rivers. During the helicopter survey, a very large specimen was seen from the air near Middledrift, downstream of the dams.

4.8 Summary of issues related to the current water quality and environment

- The catchments of both lakes have a low pollution potential provided that the soil cover is not stripped bare by overgrazing. Overstocking is already a severe problem, particularly in the Jana catchment, and will have an impact on water quality.
- Urban informal settlements are growing rapidly in both catchments, which should be seen as a threat to water quality.
- The moderately high phosphate-P concentrations of the Thukela and Klip, as well as the Bushman's Rivers are a cause for concern, as the levels will stimulate algal growth in Lakes Jana and Mielietuin respectively. Trend graphs indicate that the situation is worsening. Algal populations will at times develop nuisance proportions (offensive and toxic species of algae) in the lakes. It is important to note that after construction

of these dams, control of pollution discharges from the towns upstream of the dams will become a priority and the respective towns will probably be required by regulations to reduce their discharges.

- The upward trend of pH, sulphate and conductivity in the rivers is of concern and must be monitored and addressed if necessary. These are not important aspects at present.
- It is probable that the rivers feeding the proposed dams experience elevated bacterial pollution at times.
- The Thukela in particular is a very turbid system despite the two large sediment traps upstream in the form of Woodstock and Spioenkop Dams. This is an indication of the severity of the overgrazing in the catchment. Iron and manganese concentrations associated with turbidity are also high and could enter the lakes and provide a store for release of the dissolved forms in the anoxic zones of the lakes.
- From available information, there would appear to be no unique river biotopes within the inundation zone of either impoundment. Likewise, there do not appear to be any remarkable species that would be lost by the impoundment of the rivers.
- Red Data Book species have not been found in the proposed inundation zones of the Jana and Mielietuin Lakes although two endemic fish species are widespread in the Thukela River basin. Natural barriers to fish migration occur on all of the rivers entering the lakes, which means that the barrier affect of the dams will be lessened.

5 ANTICIPATED PHYSICAL AND WATER QUALITY CHARACTERISTICS OF THE TWO IMPOUNDMENTS AND DOWNSTREAM RELEASES

To estimate the water quality likely to develop in the lakes, use had to be made of data gathered for existing lakes where good databases were available and the assumption was made that similar changes in the proposed lakes would take place. Three types of water quality pertinent to this study were evaluated, namely the water quality for the inflow, the lake surface close to the impoundment wall which would represent the aerobic zone and, lastly, the bottom water which would be anoxic and represent bottom water release. Details of this investigation appear in Appendix 1.

The water quality of the two lakes is likely to go through two phase shifts, changing from an initial unstable phase, to a longer term more stable phase. In summary these are:

- Short term trophic state

Provided that there is no dramatic change in population density and landuse in the catchments of the lakes (unlikely), resulting in increased phosphorus loads on the lakes, it is expected that there will be a temporary (3 to 4 years duration) elevation of the trophic status of the lakes as they fill. This would be due to nutrients leached out of the newly inundated basin and the decay of the terrestrial plant life presently covering the basin. There may also be a small but minor contribution from the leaching of coal deposits. Algal populations would be expected to be greater in the early life of the lakes than they would be later.

- Long term trophic state

Phosphorus levels in the water flowing into the lakes are sufficiently high to suggest that the lakes will be at least mesotrophic. The tropic status of the lakes, as reflected in the algal populations, will be governed by light availability, in other words by the turbidity of the stored water. Turbidity will be higher in the inflow regions becoming progressively clearer towards the impoundment walls. Fortunately, much nutrient also diminishes as the water moves closer towards the impoundment walls. Higher concentrations of nutrient in the Bushman’s River suggest that the Lake Mielietuin is likely to be more eutrophic than Lake Jana.

Comments on the anticipated water quality in the impoundments are as follows.

5.1 Algal growth

To estimate the likely algal concentrations that will develop in the proposed Jana and Mielietuin Lakes, an empirical model using mean total phosphorus inflow concentrations and lake residence times was employed. Only the soluble phosphorus concentrations (phosphate-P) were available and consequently the total phosphorus concentrations had to be estimated from a derived relationship for another lake system in KwaZulu-Natal. The river phosphorus concentrations were weighted according to their respective catchment areas to arrive at the mean inflow concentrations. Outputs of the model were as follows:

- For the proposed Lake Jana, a mean chlorophyll *a* concentration of 6,08µg/l, a peak of 17,32µg/l and translated to algal counts (725 cells/ml per µg/l chlorophyll *a*) a mean of 4410 cells/ml and a peak of 12 560 cells/ml.
- For Lake Mielietuin, a mean chlorophyll *a* concentration of 6,70µg/l, a peak of 19,32µg/l and translated to algal counts a mean of 4860 cells/ml and a peak of 14000 cells/ml.
- The mean algal counts are relatively high and the peak counts could be considered as blooms, which could create nuisance conditions at times if the development tends towards blue-green algal species (nuisance conditions occur when numbers and species of algae cause the water to become toxic or permeated by foul smelling and tasting chemical compounds. The water becomes expensive to treat, the lake environment becomes noxious and fish and other animals may die from toxin poisoning. The lake also becomes unacceptable from a recreational and tourism point of view). Only more extensive modelling will determine the proportion of the year that these blooms will develop, but it is likely to be less than 10%.
- Populations of algae in the impoundments will be significantly different to those found in the rivers. While most of the algae in the river would be attached to the substrate, the algae in the impoundment would be planktonic and would comprise largely different species.

5.2 Turbidity

- The lake surface water turbidities will be far lower than normal river turbidities due to sedimentation of the silt particles. As an example, the median inflow turbidity to Lake Inanda is 15 NTU, while that of the lake basin in the vicinity of the wall was just 3 NTU and, consequently, when surface water releases are being made the river will be clearer with less particulate matter than before. The median turbidity of the Thukela River at Middledrift, which approximates the inflow to the lakes, was 103 NTU (elevated by high turbidities during spate events). Most of this sediment will nevertheless settle out in the lake basin and, due to the great depths, is unlikely to be re-suspended by wind and wave action. The inflowing turbidity will help to suppress algal growth near the inflow. Reduced turbidity in the discharge from the impoundment wall will affect the supply of fine sediments required downstream by some organisms.

- Hart (1999) raised with some concern the prevalence of high turbidities in Lake Spioenkop, upstream of Jana Dam. His concern was that this turbidity persisted despite the settling capacity of Spioenkop and the upstream Woodstock Dam. The clay fraction contributing to this turbidity must be of a very small size and may contribute more turbidity to Lake Jana than anticipated. Nevertheless, because of the water depth, the longer retention time, and the more convoluted terrain with less wind, it is anticipated that this turbidity will settle in Jana, resulting in the clean water discussed above.
- When bottom water is released on a monthly basis, as part of a mechanical requirement for maintaining the valves/gates, the turbidities will rise in the rivers compensating partially for the loss of variability currently experienced, but still will not reach the naturally experienced pulses of very high values. Impoundment releases are unlikely to be able to mimic the turbidity of natural river water.

5.3 Iron and manganese

- The lake water surface iron and manganese concentrations will be lower than those naturally occurring in the rivers by a factor of about 2, and consequently when surface water is discharged the rivers will be deprived of these constituents. This will be more than compensated for by bottom water releases.
- When bottom anoxic water is released, high concentrations of reduced dissolved iron and manganese will be introduced into the ecosystem with potentially harmful effects as aquatic guideline criteria will be exceeded. The data evaluated suggest that dissolved iron concentrations, which should not vary by more than 10% of the background value, will be orders of magnitude higher. For dissolved manganese the data suggest that the target guideline concentration will be exceeded by the 30th percentile (70% of the time), the chronic effect value at the 50th percentile (50% of the time) and the acute effect value at the 95th percentile (5% of the time). The discharge of bottom water will result in drastic changes in the concentrations of iron and manganese in the rivers, which could prove toxic to many species of plant and animal.
- The only mitigatory step that can be taken would be to ensure that dilution and oxidation of the iron takes place in the tailponds of the impoundments before

overflow to the rivers. Unlike iron, which is relatively easily oxidised, there will not be rapid oxidation and precipitation of manganese as the process is extremely slow. This will mean that the problem will persist down river.

5.4 *E. coli* (measure of faecal contamination)

- The data evaluated suggest that there will be a great improvement in the bacterial water quality in the lakes by orders of magnitude, and consequently this is a positive effect of impoundment. Data for Lake Inanda showed that at the 90^{th} percentile, lake surface counts of *E. coli* were just over 10 cells/100ml while river inflow was over 1000 cells/100ml. The data also show that when bottom water releases are made there will be little difference in concentrations.

5.5 pH

- The pH values of the surface water (to approximately 10m depth) are unlikely to be very different to those of the natural regime for the rivers and, therefore, surface release of water from the lakes will not change the natural regime.
- Bottom water, which will be anoxic, is likely to have lower pH values than the natural by between 0.5 and 1 pH units due to anaerobic processes taking place. Release of bottom water is potentially harmful to the ecosystem as the aquatic guideline limit of a maximum change of 0.5 pH units will be exceeded, especially when there are rapid changes from surface spill to scour or *vice versa*.
- The only mitigatory step to raise the pH is blending with the surface or tailpond water, but it would take more high pH water than low pH water to effectively raise pH as it is a logarithmic value. As an example, it would take 3 times as much pH 8 water mixed with one volume of pH 7 water to raise the pH to 7.5.

5.6 Ammonia

Free ammonia is the form of ammonium species which is toxic to aquatic life. The percent of free ammonia relative to the total concentration present is dependent on an equilibrium controlled by pH and temperature. High ammonium concentrations are usually produced in the anoxic zones in lakes and, therefore, release of bottom water is potentially toxic to aquatic life. The data examined for other KwaZulu-Natal lakes showed:

- That there were much higher total ammonia concentrations in the bottom water than in the inflow or surface water.
- That when the total ammonium species concentrations were used to calculate free ammonia concentrations at a pH of 8.0 and temperature of $25^{o}C$ (possible temperature

of downstream river), the bottom water exceeded the target aquatic guideline concentration at the 55th percentile and the chronic effect value at about the 75th percentile. This means that 45% of releases would be harmful and 25% very harmful to the ecosystem.

- The only mitigatory step that could be taken would be to ensure the release of as much surface water as possible, together with the monthly bottom water releases.

5.7 Temperature

In order to gain some idea of the likely temperature regime for the two lakes, data for two other KwaZulu-Natal lakes showed the following:

- That the lakes are likely to be stratified in summer with a warm surface layer of approximately 10m.
- That, when stratified, the deeper lake (42m) had more stable and lower temperatures than the shallower lake (16m). The inference is that the very much deeper Jana (135-190m) and Mielietuin (75-105m) lakes will have stable low bottom temperatures that will be discharged.
- While lake mixing and turnover does occur for both the lakes studied, isothermal conditions in the deeper lake only occurred for about 2 months of the year, while in the shallower lake, for 4 months. The indication is that the depth of the Jana and Mielietuin Lakes may result in them being strongly stratified with a potential to discharge cold water for most of the year.
- That the maximum temperature differences between surface and bottom water occurred in January/February and were about 10^{o}C. If prevailing in the Jana and Mielietuin Lakes, there will be a considerable shock to the ecosystem when the monthly bottom water releases take place (an engineering requirement to service the release valves or gates). The guidelines for aquatic life state that sudden temperature changes should not exceed 2^{o}C.
- Comparing lake inflow temperatures to those at different levels in the lake showed that in summer, surface and 6m depth temperatures could be warmer than river temperatures by up to 5^{o}C, while bottom temperatures could be up to 13^{o}C colder. Consequently, the natural temperature regimes for the rivers will be greatly disturbed by impoundment discharges. In mitigation, the depth of discharge from the lakes could be selected to most closely match the natural temperature of the river. In winter, the situation can be reversed, with temperatures in the lake, and thus potentially in the discharge, being 5^{o}C higher than the natural river.

5.8 Dissolved oxygen

- Data from the KwaZulu-Natal lakes indicated that dissolved oxygen concentrations in the Jana and Mielietuin Lakes would be depleted below 4mg/l, which is recognised as the lower limit for aquatic life, at about the 8 to 10m water depths and below. These patterns were also seen for lakes in Gauteng. Below this depth dissolved oxygen concentrations gradually declined to zero. There is little doubt that the bottom releases for the Jana and Mielietuin Lakes will be completely anoxic and potentially detrimental to the ecosystem.
- The great depth of the Jana and Mielietuin Lakes may prevent mixing and turnover in the lakes, thus ensuring that discharges will be anoxic all year round. If turnover does occur, it is likely to be for a short period.
- For mitigation of the releases of anoxic bottom water, the release mechanism should be such that the water is rapidly re-oxygenated, which spraying the water into the tailponds below the impoundments can bring about. This mechanism is used at Lake Albert Falls in KwaZulu-Natal and measurement has shown that near saturation concentrations are quickly reached in the receiving pond.

5.9 Downstream releases

At the time of writing this report, the design of the two dam walls had not been finalised although some basic features were available. It is likely that both of the dams will have a multiple level abstraction tower discharging to the downstream river. Designs of this type have become the norm as the beneficial affects on the downstream river are appreciated. Many of these affects are discussed above but more detail is contained in the report on the downstream river (Dickens *et al.*, 1999b) where most of the impacts will be experienced.

Also unavailable at the time of writing was detail describing the tailponds at the base of particularly Jana dam. It is anticipated that this tailpond will have a wall approximately 35m high, so will form a substantial structure in its own right. Nevertheless, the volume of the tailpond will be fairly small, as will the retention time, although one suggestion was that the pond would often be empty and would only come into operation during high flows. The tailpond could have a number of positive impacts as described below:

- It could be designed to act as a buffer to minimise the sudden changes in flow resulting from the test operation of the dam valves, thus protecting the downstream river from these impacts.

- Mixing of scour and surface water discharged from the lake will be accomplished in the tailpond. This will ameliorate several negative water quality impacts as described above.
- If kept full, the stilling pond will help to ameliorate the poor water quality from scour discharges, i.e. temperatures and oxygen will rise, and metals will be oxidised before release to the river.
- Water spilled over a high crest can become supersaturated with gases, in particular nitrogen, which can be problematic to fauna downstream. A tailpond would allow these gases to dissipate.

6 LIKELY INHABITANTS OF THE TWO IMPOUNDMENTS

6.1 Fish

6.1.1 Lake Jana

This will be a deep, steep-sided impoundment with minimal littoral habitat. It will probably remain fairly turbid throughout the year in its headwater regions but will be clearer near the wall. It is likely that at the full supply level the water will rise halfway up the face of the Little Niagara Falls on the Klip River, but will not permit the passage of fish up the remaining height of the falls and into the river. It is also likely that on the Thukela River arm of the lake, the headwaters will reach the foot of the cascade situated below the Ezakheni water abstraction weir. This will mean that fish will not have access to river on either arm of the lake, which will have consequences for riverine-spawning fish species such as *Barbus natalensis, Labeo rubromaculatus* and *L. molybdinus*. These species will not be able to breed while using the lake as a refuge. Since there are many suitable breeding areas for these fish in the river above the impoundment, providing these are kept free of dense algal growth and silt, their populations above the lake are unlikely to be affected. Those riverine fish that wash down into the lake will thrive mainly in the headwater regions but will not breed. Their populations will thus be artificial and small.

The impoundment will probably become populated mainly by carp, which will muddy the water in the impoundment and, as such, reduce water quality. *Clarias gariepinus* (barbel) are likely to do well in the impoundment as they can breed in the shallow, flooded marginal vegetation formed in summer when the lake level rises. *Oreochromis mossambicus* may also flourish around the margins of the impoundment. *Labeo molybdinus* and *Barbus anoplus* could become minor components of the population. The minnow, *Barbus trimaculatus*, may do well in the flooded, sheltered bays of the impoundment, especially during the early years of impoundment. Bass and bluegill may increase but will be confined to the less turbid parts of the lake (nearer to the wall). Eels, which breed at sea, could vanish from the impoundment and the entire upper region of the Thukela and its tributaries if the impoundment wall proves impassable to them. It is, therefore, important to construct eelways to enable elvers to move from the sea upstream and to overcome the impoundment walls. However, once the eels mature they need to be able to safely negotiate all barriers as they return to the sea to spawn. This downstream migration needs to be considered.

Populations of *Amphilius natalensis* that have been found in the river, prefer well-oxygenated, swiftly flowing water over a cobble substrate. This species will obviously decrease and may disappear from the impoundment as their habitat is flooded.

Genetically, the impoundment wall will continue to isolate fish populations by preventing downriver fish from moving to the upper reaches. As natural barriers exist on both the Thukela and Klip Rivers, just upstream of the impoundment wall, this barrier effect will be maintained by the wall. No attempts to move fish to above the barriers should be considered.

6.1.2 Lake Mielietuin

This will be a fairly deep lake with moderately steeply-sloping earth and shale banks. Its water will be moderately enriched, encouraging the growth of algae and semi-aquatic plants in the shallows.

The impoundment will probably become populated by carp, which will muddy the water in the impoundment and, as such, reduce water quality. *Clarias gariepinus* is likely to do well in the impoundment as they can breed in the shallow, flooded marginal vegetation, as well as undertake spawning migrations up the inflowing river. *Barbus natalensis* will have to migrate out of the impoundment for spawning migrations. If there are suitable spawning grounds near the impoundment, then the larval and juveniles will have abundant food in the impoundment and their populations should increase depending on the predation level by alien bass. Since the water will be much warmer than that of Lake Wagendrift, *Oreochromis mossambicus* could successfully be introduced, or might invade from farm impoundments in the catchment although it is thought that they are scarce here. However, if water levels fluctuate rapidly their breeding habits would be disturbed, preventing the development of a large population. Populations of the alien predator, *Micropterus salmoides* (bass), are likely to do well and will negatively impact on the young of the indigenous species. Bluegill may flourish if turbidities are low.

No eels were collected but their presence or absence needs to be confirmed. If eels are found to be present, then unless an eelway is installed on the impoundment wall, eels will disappear from the impoundment, as well as from the upstream river as their juveniles (elvers) upstream migration will be seriously impacted. It is, therefore, important to consider the construction of eelways to enable elvers to overcome the dam wall. However, once the eels mature they need to be able to safely negotiate all barriers as they return to the sea to spawn. This downstream migration needs to be considered.

6.2 Aquatic weeds

The following aquatic weeds were identified as possible/probable threats to both the proposed Jana and Meiletuin Lakes: *Eichhornia crassipes* (water hyacinth); *Salvinia molesta (*salvinia

or Kariba weed); *Myriophyllum aquaticum* (parrots feather); *Pistia stratiotes* (water lettuce); and *Azolla filiculoides* (red water fern).
These weeds are ranked in terms of their perceived likelihood of invasion and, hence, threat to the proposed lakes.

The following primarily indigenous aquatic weeds may also cause problems, particularly immediately after inundation of the lakes and until some form of equilibrium is established: *Azolla pinnata; Ceratophyllum demersum; Lagarosiphon major; Lemna* sp.*; Ludiwigisa stolonifera*; *Nymphaea caerulea* (water lily); *Nymphoides indica* subsp. *occidentalis*; (floating heart); *P. pectinatus*; *Potamogeton schweinfurthii; Spirodella* sp.*; Wolffia arhizza;* and the exotic, *Arundo donax.*

Of these weeds, water hyacinth and parrots feather have both been positively identified as occurring at least in Lake Jana catchment - parrots feather, in the impoundment of the Ezakheni abstraction weir (south of Ladysmith and almost at the head of Lake Jana), and water hyacinth, at the Eskom power station barrage on the Thukela River at Colenso, as well as in a farm dam east of Lake Spioenkop but west of the N3 highway (just before the N11 offramp from the N3). As yet, there are no available reports of any of these weeds in the Little Bushman's River and, hence, the immediate potential for invasion in the proposed Mielietuin impoundment is lower than in the Jana impoundment. Because of higher nutrient concentrations, an invasion of Mielietuin would be more problematic.

Given the nature of these invasive aquatic weeds and the increasing numbers of records for their occurrence throughout the country, there is a reasonable likelihood that all the five major weeds will eventually find their way into these proposed lake systems. The implications of this are presented in the next chapter.

6.3 Algae

As described in the previous chapter, algae populations will be moderately abundant and may at times tend towards problematic blue-green species. Algal populations will be most problematic during the first few years after filling of the dams and it is during this time that severe nuisance populations can be expected. Thereafter, nuisance conditions will be limited to short periods, usually during late summer. These problematic algae can be toxic to fish, wildlife and humans, and also give unpleasant taste and odour to the water. It can be expected that Mielietuin will experience more severe conditions than Jana.

After the lakes have "matured", diversity of algae will increase and will reflect the nutrient conditions in the water. Besides the periodic incidents with blue-green algae, diatoms such as *Melosira* will be abundant in winter, with a mixture of other diatoms, green algae and blue-green algae during summer. The moderately abundant populations will support zooplankton populations, which in turn will provide food for fish.

6.4 Zooplankton

Zooplankton populations are likely to be substantial and will play an important role in controlling the algal populations. A lack of a secure habitat, such as aquatic weed, can limit their ability to reproduce and so limit their effectiveness. The species that develop in this new environment will reflect the water quality conditions, with more cladocerans and cyclopoid copepods developing if eutrophication increases. It is probable that the populations prevalent in the upstream Lake Spioenkop will not persist in the less turbid Lake Jana, but will be replaced by species reflective of a more stable impoundment.

6.5 Invertebrates

The Lake Jana site appears to be the upper limit of the distribution of *Macrobrachium* crayfish. These will not survive above the impoundment/s as they have a need for the marine environment to complete their life cycle. The populations of other invertebrates that develop in the impoundments will be substantially different and more cosmopolitan than those found in the rivers they will replace. Bilharzia and its mollusc host may survive in both impoundments, especially if there is abundant vegetation. There is some potential for nuisance swarms of the adult forms of some aquatic insects, such as mayflies and caddisflies, which may swarm, especially around the dam walls if lights are showing.

Hart (1999) reported on the presence of mainly insect species in the littoral zone of Lake Spioenkop upstream of Lake Jana. Diversity was greater on rocky substrates, with higher numbers a few metres from the shore. Rock will be a common habitat in Jana in particular, so should support fairly extensive populations of Ephemeroptera (mayflies). Mayflies, in particular, are an important food source for fish.

6.6 Riparian vegetation

Sandbanks from deposited silt will begin to develop in the inflow regions of the lakes, supporting beds of reeds, such as *Phragmites*, although these reedbeds will be disturbed by high flood events. Fluctuating water levels in the lake will limit the distribution of reeds and other riparian vegetation around the edges of the lakes. The rate and magnitude of water level change will determine whether this vegetation survives or if the margins of the lake become a barren mud-bank. The implications of this are discussed in the next chapter. Submerged aquatic vegetation is unlikely to be abundant due to the great depths of both lakes.

6.7 Birds

Both lakes will become a modest habitat for various waterfowl and piscivorous (fish eating) birds, although if only sparse riparian vegetation develops, then breeding sites will be severely limited. Dead trees protruding from the lake surface will provide a significant and important habitat for many species, such as cormorants.

6.8 Crocodile

Both lakes may be occupied by the crocodiles that exist in the river. They will naturally take up residence in both lakes where they could multiply although breeding habitat would be less than suitable in the steep sided impoundments. Experience from Lake Inanda has been that the crocodiles seem to prefer the river below the impoundment to the lake itself (*pers. com*. Ross Howett, Msinsi Holdings). This may be due to problems with catching fish in the expanse of the lake that would be easier below the impoundment wall where fish often congregate. The presence of these major predators in the lakes would be advantageous to the ecology of the area and also to tourism. There are, however, likely to be some dissenters.

7 IMPACTS RESULTING FROM THE TWO IMPOUNDMENTS

It must be appreciated that these impacts suggested below are based on a superficial assessment of the catchments and the dams. It is anticipated that impacts that are more comprehensive will be determined during the full EIA process. Table 7.1 at the end of this chapter gives summary of these impacts.

Overall, the two river ecosystems will be changed from river ecosystems to standing water, lacustrine ecosystems. The major concerns arising from this situation are the importance of the existing river due to be inundated (in other words what is going to be lost) and the type or quality of the new lacustrine ecosystem which will be formed.

7.1 Loss of river

Present information suggests that the ecosystems that will be lost beneath the new lakes are replicated elsewhere and are not of special ecological importance. This does not mean, however, that their loss can be ignored. Instead, concern must be raised for the ongoing loss of “ordinary” river reaches. Clearly, in the long-term, as further developments take place, these “ordinary” river reaches will become rare, as will the organisms that inhabit them. Only wise management of these rivers will allow these developments to be sustainable in the long-term. This project should contribute to a wider assessment of the implications of the loss of “ordinary” rivers on a national basis. The loss of the continuum aspect of the river is also an important issue as the wall and lake will form an impassable barrier to many organisms. This issue is discussed in more detail in Dickens *et al.* (1999b).

7.2 Damage due to construction activities

Significant impacts could be experienced during the construction phase of both lakes. This would relate mainly to impacts due to excessive turbidity from earth/rock works and oil from machinery. Leaching from concrete works could also have an impact on pH and water quality. The fine sediments, in particular, emanating from rock works can have a severe impact on rivers by coating the river substrate with inhospitable ooze. This would affect all life in the river for some distance downstream. Small quantities of oil are less of a problem in a flowing river but will impact on the biota by coating the substrate with an impervious and toxic layer. These impacts will need to be minimised in consultation with planners during the design phase of the project and should form part of the EIA.

7.3 Creation of a lacustrine (lake) environment

The creation of a lacustrine or lake environment in the upper Thukela River basin is a large impact as it creates an ecosystem that is alien to the region. The move from a flowing river ecosystem, to a deep-water lake, is extreme. Conditions in the lakes will differ significantly from those found in the river, with the consequence that few of the ecosystem processes and inhabitants will be able to survive the transition. Given that the two stretches of river due to be inundated by the two lakes are unremarkable and are replicated elsewhere, it is the formation of two large ecosystems alien to the region that is the major impact. This need not be a negative impact, however, as the opportunity exists to assist the development of these ecosystems towards something of value, although not natural. In order to do this, some idea of the likely water quality that will be found in the two lakes is presented in Chapter 5. Various aspects of this water quality will in turn have impacts on the lake environments themselves, and on the downstream river environment. In addition, the lake will support animal and plant populations that will be unnatural to the region. Depending on many issues, the development of these can be influenced to be more harmonious with the natural environment, and thus more useful to society.

The important issues that will affect the nature of the two lakes and thus the overall impact of their development are presented below:

7.3.1 Drawdown

The volume of water stored in the respective lakes will vary with time and there may at times be a large drawdown zone where extensive mud-banks around the perimeter of the lakes become exposed. Consequences of such a drawdown are both positive and negative. Negative consequences include inconvenience for recreation but most importantly, the suppression of healthy riparian vegetation around the margins of the lakes. Riparian vegetation requires permanently moist soil, so will be unable to survive when the water level drops excessively. Riparian vegetation is important for the lake ecosystem, as the base of the plants provide refuge for a host of organisms, from algae to insects to fish, all of which make for a healthier ecosystem. Reducing the lake margins to a barren mud zone eliminates many of these organisms. The consequences of this are a poorer biodiversity, poorer ecosystem functioning, poorer processing and removal of substances from the water, and consequently a poorer environment. This can result in rampant populations of survivor species, including phytoplankton, which can develop into nuisance numbers in the absence of their natural grazers.

On the positive side, a lack of riparian vegetation would mean fewer habitats for bilharzia snails and mosquitoes, and consequently a lesser chance of infectious diseases. Other positive aspects include the provision of refuge for moulting waterfowl and consolidation of silt accompanied probably by the chemical binding of phosphates into the sediment. (Phosphate binding appeared to happen during a prolonged drought at Lake Hartebeespoort).

7.3.2 Physical and chemical conditions in the lakes

The quality of water in the two lakes will differ from that found in the rivers they are replacing as the long retention of the water in the lakes allows for a number of processes to occur that alter the typical river water. The resulting water quality will affect the formation of the lake ecosystems to become either harmonious with the region or degraded and problematic. Those factors that will contribute to the resulting condition of the lakes and, thus, need to be considered in the EIA and planning stages, are described below:

- The lake surface water turbidity will be far lower than current river turbidity due to sedimentation of the silt particles in the upper reaches of the lakes. Current river turbidity, on the other hand, due to poor catchment practices, is probably worse than it would be in the natural state. Nevertheless, clearer water in the lake allows algae to flourish and alters the predator-prey relationship of a number of organisms.
- Iron and manganese concentrations will fluctuate, from deficient in surface waters during summer, to potentially toxic during winter destratification and in scour water releases to the downstream river. Little can be done about this in a deep-water lake as the mitigatory options are expensive and difficult (i.e. aeration of the hypolimnion).
- Various processes that take place in lakes will ensure that nutrient concentrations (phosphorus and nitrogen) will decrease, the former binding with the sediments and the latter moving into the atmosphere. In this way, lakes serve to reduce the nutrient contamination of the downstream river. On the other hand, because of the clear water and mild growing conditions, these low concentrations of nutrients can produce growths of algae not seen in rivers. For this reason, nutrient input into the lakes needs to be curbed as much as possible. This will have consequences for the management of wastewater in the towns upstream of both lakes, a factor that must be taken into account during planning.
- There will be a great improvement in the bacterial water quality in the lakes, by orders of magnitude. This is a positive effect of impoundment.
- Comparing lake inflow temperatures to those at different levels in the lake show that in summer, surface and 6m depth temperatures could be warmer than the river by up

to 5°C, while bottom temperatures could be up to 13°C colder. The higher and more stable surface temperatures during summer must have implications for organisms that inhabit the lakes, and contributes to the greater productivity of the lakes compared to the river. This contributes in turn to the purification of the river water.

- The water body will stratify with respect to temperature and oxygen in the summer and the stratification will break down in the winter. In summer, the oxygen saturation of the hypolimnetic water will drop, probably to a completely anoxic condition. The characteristics of anoxic hypolimnetic water includes changes in pH, the formation of free ammonia and increased concentrations of dissolved iron and manganese. The consequences of this to the lakes are that all of the water below ~10m depth will be inaccessible to most animal life. This is a common situation in artificial and natural deep-water lakes, but is exacerbated by the input of nutrients and organic substances (i.e. pollution) into the lakes. The greatest impact of this anoxic water is on the downstream river but this is discussed in Dickens *et al*. (1999b).
- Silt may be expected to precipitate on the bottom of both lakes, the coarser particles nearer to the inflow. Over a period of time the inflow to the lake may come to resemble a mud flat and reed marsh colonised by riparian plants. The frequency and rate of drawdown of the lakes will govern the extent of the riparian and aquatic vegetation. The formation of these reed marshes can only benefit the lake ecosystem.

7.3.3 Water related diseases (bacterial, bilharzia and malaria)

There should be little concern for the stimulation of bacterial diseases such as typhoid, cholera and dysentery as bacterial populations decline rapidly in lakes and are unlikely to be found in downstream water releases. Lakes are not usually focal points for the spread of malaria as they do not provide good mosquito breeding habitat, but bilharzia infections frequently do happen in lakes. Infection usually takes place near the margin of the water where vector snails may be abundant in fringing vegetation. The spread of bilharzia in lakes is therefore closely related to the availability of snail habitat and the drawdown-induced paucity of the riparian zone is therefore important in limiting vector snail habitat. Lake Roodepoort, near Pretoria, has a stable water level and a well-developed fringe of aquatic vegetation. People are frequently infected with bilharzia there. As mentioned above, the elimination of a riparian zone has other ecological consequences. Choices may need to be made between the two.

7.3.4 Plankton

Large zooplankton and phytoplankton populations will develop in the lake and serve as a base of the fish food chain. Numbers of algae in both lakes are likely to be moderately high and will reach nuisance conditions at times, especially through the production of blue-green algae. These algae produce toxins and offensive taste and odour compounds that make the water not only difficult to treat for potable water purposes but also harmful to the rest of the fauna and flora in the lakes.

7.3.5 Fish

The relative abundance of the fish species in the lakes will differ from that in the present rivers, with populations of standing water species increasing. It is expected that the riverine species will not thrive in Lake Jana but may do well in Lake Mielietuin where they will tend to be more common near the river inflows than elsewhere in the lake. It cannot be expected that the fish populations in the lakes will mirror the rivers that they replace as the habitats in the two are fundamentally different. While some indigenous fish will thrive, others will disappear from the lakes. Unfortunately, exotic fish are more adapted to these lake habitats, and will thrive at the expense of the indigenous fish. Fortunately, this dominance will not affect the upstream rivers, and only to a minor extent the downstream rivers (carp, in particular, will wash over the lake dam walls and their numbers will increase in the rivers - but only marginally), which means that the impacts will be largely confined to the artificial impoundments.

Eels are a different issue to the rest of the fish as they are not confined by natural or unnatural barriers in the rivers. They could disappear from the entire upper uThukela Region if the Lake Jana dam wall proves impassable to them (no eels were found in the Bushman's River although they are likely to occur there). The provision of eelways on both dam walls is considered important as the loss of these important predators from the entire catchment upstream of the two lakes must have ecological implications. It must first be established, however, that eels do occur in the Bushman's River.

As described in Chapter 6, the impoundment dam walls will be barriers to fish migration. On the Thukela River this is not considered to be a problem as natural barriers to migration already exist. Fishways are thus not likely to be a consideration. On the Bushman's River, some fragmentation of the fish population will occur but no species are dependent on migrating to the upstream river in order to reproduce. A natural barrier to migration also occurs some distance downstream of the dam. Consequently, occasional transfers of fish from downstream to above the lake will alleviate this problem. A fishway on Lake Mielietuin is thus unlikely to be necessary.

7.3.6 Aquatic birds

The lakes will provide an increased habitat for many aquatic birds, particularly the piscivorous (fish eating) species, as well as waterfowl and waders. These species will be opportunists, making the most of what is for them an unusual habitat. Waterfowl will not do well unless there is cover provided by riparian vegetation. The development of these populations represents a positive support of indigenous fauna, although in an unnatural situation.

7.3.7 Crocodiles

Crocodiles may colonise both lakes, although they are unlikely to thrive due to limited breeding habitat around the lakes and that they tend to prefer river habitats. Crocodiles would have positive implications for both the ecology and tourism.

7.3.8 Aquatic weeds

As described in Chapter 6, if given a chance, alien aquatic weeds are likely to thrive in the lakes. The literature and local experience indicates that, if left uncontrolled, they will have innumerable impacts for man and the environment, such as:

- Causing direct obstruction to navigation (and hence also recreational access).
- Increasing water loss from the lakes by evapotranspiration (24-40% above normal).
- By blocking abstraction structures and pumps, and checking waterflow in irrigation/transport aqueducts (significant as the project is likely to use pipelines or canals to transport the water to the existing Lake Kilburn). The canals will also serve to spread the plants (as fragments or seeds) to the Vaal River catchment;
- Should aquatic weeds come to cover the lakes, the depth at which the water becomes anoxic could rise to within a meter or two of the surface. The anoxic conditions would break the food chain and lower the productivity of the lakes through the loss of fish and plankton. It would also mean that downstream water releases would be primarily anoxic, thus being of unsatisfactory quality.
- Although the quality of water provided by the lakes, as a potable water supply, would be significantly degraded by the weeds, this would be rectified during the long passage to the Vaal River.
- Water temperatures, pH, bicarbonate alkalinity, and dissolved oxygen content (often to zero) are lowered. The water becomes inhospitable to other organisms and offensive to people.
- Free carbon dioxide content, B.O.D, and nutrient levels increase.

- Causing drastic changes in plant and animal communities of freshwater environments (particularly fish kills).
- Serving as agents for the dispersion and incidence of several deadly diseases (schistosomiasis (bilharzia), cholera and possibly malaria).

It is imperative that every effort is made to eradicate the aquatic weeds already in the catchment of at least Lake Jana, prior to construction, and that controls are implemented to ensure that they do not re-infest the area.

Besides the factors mentioned above, the presence of a surface cover of aquatic weed cancels out any positive benefits resulting from the creation of a lake ecosystem.

Table 7.1: Impacts resulting from the Jana and Mielietuin Dams

(Note: Impacts on the downstream river are recorded in Dickens *et al*., 1999)

Generic impact	Effect	Cause	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance	Mitigation Possible Y/N
Ecosystem modification/ Disruption in the downstream river	Modified biota (e.g. possible loss of some species of fish, invertebrates, algae, plants) and damage to the physical environment	High turbidity during construction	Moderate	Local	Short term	Negative	Probable	Medium	Y
Ecosystem modification/ disruption in the downstream river	Modified biota (e.g. possible loss of fish, invertebrates, algae, plants)	Oil pollution during construction	Low	Local	Short term	Negative	Improbable	Low	Y
Ecosystem modification/ disruption and loss of biodiversity	Loss of river environment and of associated biota	Inundation of riverine habitat beneath lakes	Very high	Dam basin	Long term	Negative	Definite	Medium	N
Ecosystem modification/ creation of new biodiversity	Creation of lake environments	Impoundment of rivers	High	Regional	Long term	Positive	Definite	High	Y
Modification/ Disruption of lake ecosystem and impairment of potable water supply	Excessive algae, toxins, offensive taste and odours, death of fish and zooplankton	Eutrophication of water during filling stages	High	Regional	Short term	Negative	Probable	Medium	N

Generic impact	Effect	Cause	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance	Mitigation Possible Y/N
Modification/ disruption of lake ecosystem and impairment of potable water supply	Excessive algae, toxins, offensive taste and odours, death of fish and zooplankton	Excessive nutrients entering the lakes	High	Regional	Long term	Negative	Improbable	Medium	Y
Modification/ disruption of lake ecosystem – reduced biodiversity and impaired ecosystem functioning	Suppression of riparian growth and consequent reduction in habitat for fish, invertebrates, algae and reduced purification of water	Fluctuations of water level in lake (drawdown)	High	Dam basin	Long term	Negative/ positive	Probable	Medium	Y
Ecosystem modification/ disruption – loss of natural biodiversity due to invasion by alien fish	Exotic fish species increase	Provision of lake habitat less suited to indigenous fish	Low	Dam basin and local	Long term	Negative	Probable	Low	N
Alteration of natural biodiversity	Increased productivity of a few indigenous fish	Increased habitat for indigenous fish	Moderate	Dam basin	Long term	Positive	Possible	Low	-
Loss of fish biodiversity	Loss of *Amphilius* sp. from dam basins	Inundation of desired river habitat	High	Regional	Long term	Negative	Definite	Medium	N
Loss of fish biodiversity	Eels unable to breed	Dams become barrier to eel migration	High	Regional	Long term	Negative	Improbable	Medium	Y

Generic impact	Effect	Cause	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance	Mitigation Possible Y/N
Possible loss/change in fish diversity	Genetic fragmentation of fish populations, especially by Mielietuin Dam	Dams become a barrier to fish migration	Moderate	Regional	Long term	Negative	Improbable	Medium	Y
Disruption of quality of experience for residents and tourists	Adult aquatic insects populations swarming around dam wall	Large habitat available for certain insects. Lights on top of walls attract insects	Low	Dam basin	Long term	Negative	Uncertain	Low	Y
Ecosystem modification/ disruption and impact on biodiversity	Water bird populations increase	Formation of lake habitat and loss of river habitat	Moderate	Regional	Long term	Positive	Probable	Low	-
Ecosystem modification/ disruption and impact on biodiversity	Invasion by indigenous weeds	Provision of lake habitat with excessive nutrients	Low	Dam basin	Long term	Negative	Improbable	Low	Y
Ecosystem modification/ disruption and loss of natural species to alien weeds	Invasion by alien weeds - modified biota (e.g. fish, invertebrates, algae, plants) and disruption of healthy ecosystem processes and the physical environment (particularly WQ)	Provision of lake habitat with excessive nutrients	High	Dam basin and conveyance servitude	Long term	Negative	Probable	Medium	Y

Generic impact	Effect	Cause	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance	Mitigation Possible Y/N
Improved in-dam water quality due to reduction in bacteria counts	Less faecal bacteria in lakes and downstream rivers	Removal of bacteria by lake processes	Moderate	Regional	Long term	Positive	Definite	High	-
Altered productivity of downstream rivers	Removal of nutrients from river (dam acting as a nutrient trap)	Purification processes take place in lakes	Moderate	Regional	Long term	Positive	Probable	Medium	-
Altered productivity and biodiversity of downstream rivers	Release of poor quality water from bottom water scours	Impoundment of water and development of anaerobic bottom water	High	Regional	Long term	Negative	Probable	Medium	Y
Improved biodiversity but human safety compromised	Increase in crocodile populations	Provision of large habitat with abundant food	Low	Dam basin	Long term	Neutral	Probable	Low	-
Human health compromised	Increased bilharzia populations but only if marginal vegetation develops	Provision of standing water with habitats suitable for snails	Moderate	Regional	Long term	Negative	Improbable	Medium	Y

8 SUGGESTED MITIGATORY ACTIONS

Below are some mitigations for the impacts suggested in the previous chapter. It must be appreciated that it is the responsibility of the full EIA investigation to provide mitigations that are more detailed.

8.1 Environmental reserve

A comprehensive determination of the reserve as required by the National Water Act (1998), and the setting of management classes for the different reaches and identifying the issues that need to be addressed to achieve those classes, would allow a proper evaluation of the significance of many of the impacts that have been noted. It is imperative that this assessment is done for the Thukela and Bushman's Rivers, preferably during the next phase of the planning process so that the outcomes can be incorporated into the plans.

8.2 Construction activities

Impacts resulting from construction activities were not specifically required by the Terms of Reference for this project, but clearly would need to be addressed. Proper control and minimisation of ingress of fines into the river during earth and rock moving will need to be done. Minimisation of oil spills from machinery can be controlled by proper site management. These controls will need to be developed during the full EIA phase of the project.

8.3 Loss of river

It will not be possible to mitigate this. Although it has been stated earlier in this document that these river reaches due to be lost are replicated elsewhere in the region, concern must be raised of the ongoing loss of "ordinary" river reaches. Clearly, in the long-term, as further developments take place, these "ordinary" river reaches will become rare, as will the organisms that inhabit them. Only wise management of these rivers will allow these developments to be sustainable in the long-term. The alteration of downstream river reaches is discussed in Dickens *et al.* (1999b).

8.4 Creation of a lacustrine (lake) environment

The creation of a lake environment has both positive and negative impacts, the negative needing some consideration for mitigation. Most of these will revolve around the way that the lakes are managed. Below are some of the issues that would have to be taken into consideration if the lakes are to be managed in a way so as to optimise the positive and reduce the negative aspects of their development. Some advance planning of this would be appropriate as it may have consequences for the overall project.

8.4.1 Drawdown

This is the inevitable consequence of the seasonal pattern of rainfall, set against the less variable demand for water for urban and industrial use. The principle is that drawdown should be minimised, and should take place as slowly as possible.

8.4.2 Physical and chemical conditions in the lakes

Theoretically, the physical and chemical condition of the lakes could be improved by artificial destratification of the water column. This very expensive process would have to be approached with caution. The anticipated mesotrophic/eutrophic status of the impoundments, and all of the negative affects which that has, could be improved by reducing the pollutant load to the impoundments. This would mean applying stringent effluent discharge standards to all wastewater discharge points in the upstream catchment (currently not in place - pers. com. Mr Kobus Rothman, DWAF). This would have major positive affects on the quality of water in both lakes, and will need to be modelled before a proper assessment of the water quality issues and the cost of mitigatory actions can be made.

Removal of vegetation from the inundation zone has been suggested in the past as a method to reduce the intensity of the nutrient flush into newly formed lakes. It is expensive and of unknown effectiveness and still does not solve the problem of nutrients leached from soil. Fire also rapidly releases nutrients from tree trunks that fall to the ground as ash, whereas they would otherwise have remained bound in the decomposing trees for several decades. Removal also removes a valuable habit for fish and other organisms. This approach should receive careful consideration before being undertaken.

Long-term benefits would be gained from proper catchment management practices. It is likely that this would be a function and mission of the Catchment Management Agency that will in the future be formed for the Thukela catchment. Particular benefits will be through reduced siltation of the lakes, and ingress of pollutants.

Note that the important water quality issues relating to impoundment water releases and their impacts on the downstream river, are discussed in Dickens *et al.* (1999b).

8.4.3 Water related diseases (bacterial, bilharzia and malaria)

By suppression of riparian vegetation, the drawdown of the lake would mitigate the likelihood of large bilharzia snail populations. Through natural process, pathogenic bacteria are not likely to survive in the lake. Malaria is currently not a problem in the area and so does not need special consideration. If it did become a problem, then drawdown and suppression of riparian vegetation may be one way of combating the disease. This practice of drawing down the level of the lake must be balanced against the negative consequences as described in Chapter 7.

8.4.4 Plankton

Plankton populations may become extreme during the first few years of the lakes' existence. Given that this would probably be limited to a few years, mitigation may not be appropriate. Provided that phytoplankton populations do not get "out of hand" in the longer term and form toxic scums due to the eutrophication of the lake, plankton presence is not a problem in need of control through mitigation. In fact, healthy plankton is a benefit to the functioning of the ecosystem. Maintenance of healthy plankton will result from effective nutrient control in the catchment. A healthy riparian zone around the lakes would also assist with maintaining a healthy plankton population. If the lakes were to degenerate, where scums of blue-green algae formed, mitigation would become exceedingly expensive and difficult as lakes are well-known to have a resilience to change, and even if water quality is improved substantially, may continue to support blooms of algae. Ideally a "budget" reflecting the incoming and outgoing nutrients from each lake should be maintained, so that management practices can be altered so as to prevent a steady build-up of nutrients in the system.

8.4.5 Fish

- The likely increases in fish and aquatic bird populations are seen as benefits of the lake. In order to provide cover for fish and perches for birds like fish eagles and cormorants, the terrestrial vegetation should not be cleared from the drawdown zone.
- Eelways should be constructed to enable the migrating elvers to negotiate the impoundment dam walls. There must also be some thought given to the downstream migrating adults which will go over the dam walls. The overflow area needs to be constructed to increase their chances of survival.
- A fishway for fish species should be considered but is unlikely to be necessary, especially for Lake Jana, for reasons given in Chapters 6 and 7. As mitigation of the barrier effect of Lake Mielietuin dam wall, occasional transport of fish from below the impoundment to the upstream river will ensure continued mixing of the genes.

- Illegal introductions of alien and translocated fish species should be prevented. Heavy fines, confiscation of vehicles, good law enforcement and awareness campaigns should be given attention.
- An artisanal fishery could be developed, providing both employment and food for local people. Conflicts of interest with anglers will be more likely in the smaller, more populated Mielietuin, than at the larger Jana impoundment.
- Both shore and boat anglers would benefit from the increased fish populations. The main species caught will be carp and *Clarias*, although *Oreochromis mossambicus* and scalies could also become significant. It is important that angling for indigenous species be promoted which will help control unwanted and illegal introductions of alien or translocated species.

8.4.6 Aquatic birds

The lakes will provide an increased habitat for many aquatic birds. If trees are allowed to remain standing when immersed in water, these will provide a valuable nesting habitat for species such as cormorants.

8.4.7 Crocodiles

Crocodiles are Red Data Book species. Nothing should be done to limit their population in the lakes unless they are an unmanageable threat to people. They would be a positive factor for tourism.

8.4.8 Aquatic weeds

- Immediate steps should be taken to eradicate the known water hyacinth populations in the catchment of Lake Jana. This is likely to require an intensive initial phase and an on-going low intensity control programme as water hyacinth seed is viable for many years. One objective of the control programme should be that plants are killed before they have a chance to flower. This matter should be treated as urgent, as for a relatively small cost before the impoundment is built, a great expense would be saved.
- Lakes and catchments should be routinely monitored for weeds (including all “foreign” boats entering the lakes - controlled access to allow for boats inspections).
- All new alien weed infestations should be either physically removed or chemically herbicided (“*prevention is better than cure*”).
- If resources are limited, and weed invasion occurs, then a full suite of suitable biocontrol agents should be introduced onto weeds at the earliest opportunity.

- A rigorously defined and comprehensive aquatic-weeds-control management plan should be in place *before* completion of the lakes.
- The responsibility for the implementation and adherence to this management plan should be formally and explicitly laid at the door of a single management agency.

9 BASELINE AND FUTURE MONITORING

Below are some suggestions for monitoring before and after construction of the dams. These suggestions have limited confidence, as they are part of a scoping report. One of the responsibilities of the full EIA process will be to suggest more detailed monitoring.

9.1 Pre-construction monitoring

It is suggested that some monitoring of water quality and the biota take place prior to construction of the dams. This would provide a baseline against which future impacts could be assessed, which would enable better management of the dams and help to minimise the impacts. Priorities below are marked with an asterisk *. It is suggested:

- * That monitoring of the Thukela, Klip and Bushman's Rivers be established as close as possible to the proposed impoundment inflow sites at weekly intervals in the summer months and at 2-weekly or monthly intervals in the winter period.
- Better monitoring at these sites would be the establishment of permanent weirs with kiosks to enable flow recording and the installation of automatic sampling equipment to sample flow on a flow-weighted volumetric basis. This method of sampling would provide the most representative and accurate water quality data for the rivers.
- * That monitoring at the DWAF stations used in this report be maintained to assess pollution levels, but that additional analyses of samples should be conducted for faecal bacteria (*E. coli*), turbidity, suspended solids, total phosphorus, iron, manganese, total organic carbon and occasional analysis for a range of other toxic metals.
- That monitoring of the Sundays, Mooi and Buffels Rivers at suitable sites close to their confluences with the Thukela River be set up to characterise water quality from these catchments so that future water quality in the Thukela River, when there is restricted flow from the lakes, can be estimated and any potential problems for water users identified. A water quality model using this type of data may be appropriate for this purpose.
- That a deterministic water quality model to predict the eutrophication status likely to develop in the Jana and Mielietuin Lakes be employed.
- * That all point source discharges upstream of the lakes be monitored for bacterial, organic and nutrient loads. This monitoring may already be in place, but its efficacy needs to be assessed and upgraded if necessary.
- The load of total phosphorus in milligrams per square metre, in order to predict the trophic status of the lake, will need to be established.

- There is a need to map the potential spawning sites above the future impounded water of Lake Mielietuin. At the same time there is a need to map and understand nursery areas for the larval fish in relation to potential spawning sites.
- There is a need to understand the spawning ecology and distribution of the KwaZulu-Natal endemics, *Labeo rubromaculatus* and *Barbus natalensis*. This understanding will indicate the value of the rivers upstream of Lake Mielietuin.
- Conduct a more intensive survey of the fish of the Bushman's River and immediate catchment area.
- * There is a need to assess the time of year when elvers are moving up the system at the dam wall sites. Also to assess the time of year when adult eels are migrating to the sea. This information would be necessary for the design and operation of eelways.
- * In order to assess if the dam walls will disrupt the populations of fish in the downstream rivers, there is a need to know the migration patterns of all species in the dam wall area, including distribution and spawning migrations, and to ascertain if alternative spawning sites will be available below the dam walls.
- There is a need to know if there are other alien or translocated species that may invade the impounded waters and do well to the detriment of the indigenous species.
- Since the habitat of *Amphilius natalensis* will be flooded, it is important to undertake a study to see if there are still viable populations above the impounded water level and elsewhere.
- There is a need for a thorough pre-impoundment survey and a "zero tolerance" attitude to aquatic weeds in the catchments.

9.2 Post-construction monitoring

It would only be possible to manage the impacts of the dam if decisions are informed by information gained by monitoring the lakes and rivers. Priorities below are marked with an asterisk *.

- In both lakes baseline monitoring should include the recording of the temperature and dissolved oxygen concentrations of the lake at regular intervals, from surface to bottom.
- A study should be conducted of the chemical nature of the water at the bottom of those lakes in which mixing to the bottom does not occur, if this is indeed the case.
- * Nutrient concentrations, in filtered and unfiltered samples, should be measured midway between the surface and the thermocline and midway between the top of the hypolimnion and the bottom.

- * Integrated water column samples measuring phytoplankton abundance (as Chlorophyll “a” concentration) and dominant species should be recorded at monthly intervals.
- There must be a dedicated, defined system to manage the baseline data (including quality assurance and quality control), to interpret the data and to implement the findings.
- Monitor the development of the fish population of the impoundment.
- Monitor the invasion of alien fish species from the impoundment to the downstream riverine environment.
- * Monitor the ability of eels to bypass the dam wall and their continued presence above the impoundment.
- * Regular aquatic weeds monitoring programme in place (part of comprehensive aquatic-weeds-control management plan) with an increased frequency of monitoring after high inflow/flood events as these carry weeds into the impoundments.
- Monitor potential nuisance insect species which may swarm around lights on the dam wall (e.g. Trichopterans and Ephemeroptera).
- Monitor *Bulinus* and *Biomphalaria* snails and the incidence of bilharzia in the surrounding communities and users of the lakes.
- Conduct epidemiological studies of malaria and other waterborne diseases in the area.

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Professor J. O'Keeffe for reviewing the draft report.

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Thirty-five years experience of fish distribution patterns and ecology in KwaZulu-Natal, particularly in the Thukela basin. Equally long experience of the development of fish populations in State lakes in KwaZulu-Natal and their utilisation by anglers.
Impact assessment of Lake Pongolapoort on Pongolo floodplain fish ecology.
Participation in DWAF fishway workshops and inspection of selected fishways in RSA, UK, Ireland and USA.

Mark Chutter, PhD

A river ecologist who has led a reconnaissance study of the Thukela/Mhlatuze transfer scheme and was study leader for the biophysical aspects of the Vaal Augmentation Planning Study (VAPS), Thukela option in its reconnaissance and pre-feasibility phases.
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APPENDICES

APPENDIX 1: WATER QUALITY INVESTIGATION

APPENDIX 2: AQUATIC WEEDS

APPENDIX 1

WATER QUALITY INVESTIGATION

Report No. WQP 8/99
Ref: 10.2.1 Tugela

REPORT ON

SPECIALIST STUDY ON THE IMPACTS RELATING TO THE CREATION OF IMPOUNDMENTS FOR THE THUKELA WATER PROJECT ON WATER QUALITY AND THE WATER QUALITY THAT WILL BE RELEASED

BY

Dean Simpson

WATER QUALITY
SCIENTIFIC SERVICES
UMGENI WATER

OCTOBER 1999

CONTENTS

SUMMARY AND CONCLUSIONS

Landuse in the catchments of the Jana and Mielietuin dams

Apart from the underlying geology and soils in a catchment, which usually determines the mineral content of drainage water, landuse activities generally determine the bacterial, organic and nutrient concentrations in rivers. Landuses with high pollution potentials are urban, industrial and agricultural uses. Consequently, the landuses in the Jana and Mielietuin dam catchments were determined to make this assessment. Comments are as follows:

- The major landuse in both catchments is unimproved grassland at 53% to 72% of the catchment areas, which has a low pollution potential provided that the soil cover is not stripped bare by overgrazing. Information from a 1994 study (WST Consortium) stated that the land in the Thukela and Bushmans rivers was overstocked with livestock, ranging from 60% to 100% over the carrying capacity which could be a threat to water quality through erosion and animal deposits from intensive activities such as cattle feedlots and piggeries.
- Agricultural land (all types) in the Jana dam catchment is quite high at 15.5% and thus the potential for erosion through poor farming practices and washoff of applied fertilizers is present, but as the distribution of agriculture is mostly in the middle to upper catchment, there will be some amelioration of pollutants washed off the land through in-stream processes before reaching the dam. The Mielietuin dam catchment has far less agricultural land, just 4.6%, and therefore less pollution potential than the Jana dam catchment.
- The Mielietuin dam catchment has more urban land at 3.0% compared to only 0.6% for the Jana dam catchment and therefore has the greater pollution potential. The WST Consortium study stated that urban informal settlements were growing rapidly in both catchments which should be seen as a threat to water quality as there would not be any services in these areas.
- The immediate surrounds of both dams is shrubland, thicket and bushland which is not seen as a threat to water quality and should be maintained as undeveloped areas.
- For the protection of water quality, developments in the dam catchments should be strictly controlled with sound planning principles in place, particularly for urban areas, controlled by a Catchment Management Authority. There should be good control of the discharge quality of effluents with a receiving water quality objective approach adopted. The apparent overstocking of the land with livestock should be investigated and a policy drawn up for the sustainable use of the land in the catchments.

Water quality in the catchments of the Jana and Mielietuin dams

The chemical data for 5 DWAF sampling sites in the catchments of the Jana and Mielietuin dams extending over a period ranging from 16 to 23 years were evaluated. The constituents analyzed were electrical conductivity, total dissolved salts, pH, sodium, magnesium, calcium, fluoride, chloride, the sum of nitrate and nitrite forms, sulphate, phosphate, alkalinity, silicon, potassium and ammonium species. The approach adopted was to perform percentile analyses on the data to determine its distribution, such as the medians and higher values; to plot the data as time series to show variation in concentrations; and perform trend analyses to show if water quality was deteriorating or improving with respect to the particular constituent. All data and graphs are given in an Appendix.

Comment on the water quality of the rivers are:

- The Thukela and Klip rivers that will feed the Jana dam show good water quality with respect to their inorganic constituent concentrations, which will not affect any user detrimentally.
- The phosphate-P concentrations of the Thukela and Klip rivers (medians of 0.022 and 0.018 mg/ℓ) are a cause for concern as the levels will stimulate algal growth, but without knowing the total phosphorus concentration the full impact cannot be assessed.
- The data for the Little Bushmans river that will feed the Mielietuin dam sampled above and below the town of Estcourt show the effects of pollution from the town as raised conductivity levels and associated ion concentrations, and the doubling of the phosphate-P concentration from 0.014 to 0.033 mg/ℓ at the 50^{th} percentile. The trend line for phosphate-P for the river below the town shows rising concentrations, as well as high sporadic phosphate-P concentrations indicating pollution incidents. These concentrations will stimulate algal growth appreciably.
- The Bushmans river below Wagondrift dam generally shows better water quality than that for the Little Bushmans river, but still the phosphate-P concentrations will support algal growth. Unfortunately, there are no data on algal counts or chlorophyll *a* concentrations for Wagondrift dam to support this statement.
- For all the rivers, both sulphate and pH values show statistically significant upward trends over the monitoring period, but current levels are not problematic to any user in either catchment. The trends could be due to river processes such as algal growth and atmospheric input, and will most probably level out as equilibrium establishes.
- Analyses for total phosphorus, turbidity, suspended solids and bacteria (E. *coli*) were not conducted on the samples, which is considered to be a serious omission in characterizing water quality in the catchments above the dams. Phosphorus which is usually the driving force in determining algal counts in dams is strongly adsorbed onto sediment particles and carried by rivers in this manner into dams as a nutrient to stimulate algal growth. Consequently, the fact that only analyses for soluble and not total phosphorus were available meant that estimates of likely total phosphorus concentrations entering the dams had to be made in order to suggest algal concentrations that would develop. The data were therefore severely limiting in this respect.

Water quality in the Thukela river downstream of the dams

The water quality for an Umgeni Water site on the Thukela at Middledrift some 150 river km downstream was used as a general indication of water quality in the basin for those constituents which were not included in the DWAF analyses. Comment on the data is as follows:

- The *E. coli* results show significant bacterial contamination with a 50^{th} percentile value of 300 cells/mℓ which is above the guidelines for full contact recreation (130 cells/100mℓ), livestock watering (200 cells/mℓ) and clearly also for direct domestic use. The high 95^{th} percentile value of 7 990 cells/mℓ shows severe bacterial pollution at times. It is possible that such concentrations may be found in the rivers at the dam sites.
- An algal count of 4 000 cells/mℓ at the 50^{th} percentile shows that sufficient nutrient concentrations are present to support significant algal growth in the river, while a maximum count of over 25 000 cells/mℓ found represents a bloom. These concentrations may have arisen as a result of entry of the downstream tributaries and may not be present at

the dam sites, but the phosphate-P concentrations reported above indicate that substantial algal growth can be sustained.

- The turbidity data indicate a very turbid system with a 50^{th} percentile value of 103 NTU and a 95^{th} of more than 4 000 NTU. Iron and manganese concentrations associated with turbidity are also high and could enter the dams and provide a store for release of the dissolved forms in the anoxic zones of the dams.
- The data distribution for total phosphorus show high values, 0.082 mg/ℓ at the 50^{th} percentile, which could support algal growth in the dams.
- From the analysis of 8 samples for toxic trace metals, 2 results each were above the detection limits for copper, zinc and mercury and 1 result each for arsenic and nickel. There were no positive results for cadmium, chromium, lead, silver and antimony. It can be concluded that the trace metals are not regularly present in the river and when found are at low concentrations which may exceed the aquatic life guidelines, but not those for other water uses.

Algal growth in the dams

To estimate the likely algal concentrations that will develop in the Jana and Mielietuin dams, an empirical model using mean total phosphorus inflow concentrations and dam residence times was employed. Only the soluble phosphorus concentrations (phosphate-P) were available and consequently the total phosphorus concentrations had to be estimated from a derived relationship for a dam system in KZN. The river phosphorus concentrations were weighted according to their respective catchment areas to arrive at the mean inflow concentrations. Outputs of the model were as follows:

- For the Jana dam, a mean chlorophyll *a* concentration of 6.08 μg/ℓ, a peak of 17.32 μg/ℓ and translated to algal counts (725 cells/mℓ per μg/ℓ chlorophyll *a*) a mean of 4 410 cells/mℓ and a peak of 12 560 cells/mℓ.
- For the Mielietuin dam, a mean chlorophyll *a* concentration of 6.70 μg/ℓ, a peak of 19.32 μg/ℓ and translated to algal counts a mean of 4 860 cells/mℓ and a peak of 14 000 cells/mℓ.
- The mean algal counts are relatively high and the peak counts could be considered blooms, which could create nuisance conditions at times with the development of blue-green algal species.
- The trophic classification of both dams would be between mesotrophic and eutrophic, but closer to mesotrophic.

Water quality in the dams and likely quality of downstream releases

To estimate the water quality likely to develop in the dams, use had to be made of data gathered for existing dams where good databases were available and the assumption was made that similar changes in the proposed dams would take place. Three types of water quality pertinent to this study were evaluated, namely the water quality for the inflow, the dam surface close to the dam wall which would represent the aerobic zone and lastly the bottom water which would be anoxic and represent bottom water release. Comments on water quality changes likely to take place and the consequences for downstream releases are as follows:

Turbidity

- The dam surface water turbidities will be far lower than normal river turbidities due to settlement. As an example the median inflow turbidity to Inanda dam was found to be 15 NTU, while that of the dam was just 3 NTU and consequently when surface water releases are being made the river will be clearer with less particulate matter than before.
- When bottom water is released on a monthly basis, the turbidities will rise in the rivers and compensate partially for the variability normally experienced, but still will not reach the naturally experienced pulses of very high values.
- No mitigatory steps can be suggested.

Iron and manganese

- The dam surface water iron and manganese concentrations will be lower than those naturally occurring in the rivers by a factor of about 2, and consequently when surface water is discharged the rivers will be deprived of these constituents.
- When bottom anoxic water is released, high concentrations of reduced dissolved iron and manganese will be introduced into the ecosystem with potentially harmful effects as aquatic guideline criteria will be exceeded. The data evaluated suggest that dissolved iron concentrations, which should not vary by more than 10% of the background value (DWAF Guidelines, 1996), will be orders of magnitude higher. For dissolved manganese the data suggest that the target guideline concentration will be exceeded by the 30^{th} percentile (70% of the time), the chronic effect value at the 50^{th} percentile (50% of the time) and the acute effect value at the 95^{th} percentile (5% of the time). The discharge of bottom water will result in drastic changes in the concentrations of iron and manganese in the rivers.
- The only mitigatory step that can be taken would be to ensure that dilution of the bottom water takes place in the tailponds of the dams before overflow to the rivers. Unlike iron, which is relatively easily oxidized, there will not be rapid oxidation and precipitation of manganese as the process is extremely slow and will persist down river.

E. coli

- The data evaluated suggest that there will be a great improvement in the bacterial water quality in the dams by orders of magnitude and consequently this is a positive effect of impoundment for the improvement in water quality for most users. Data for Inanda dam showed that at the 90^{th} percentile, dam surface counts of *E. coli* were just over 10 cells/100 mℓ while river inflow was over 1 000 cells/100 mℓ. The data also show that when bottom water releases are made there will be little change in concentrations.

pH

- The pH values of surface dam water are unlikely to be very different to those of the natural regime for the rivers and therefore normal release of water from the dams will not change the natural regime.
- Bottom water which will be anoxic is likely to have lower pH values than the natural by between 0.5 and 1 pH units due to anaerobic processes taking place. Release of bottom water is potentially harmful to the ecosystem as the aquatic guideline limit of a maximum change of 0.5 pH units will be exceeded.
- The only mitigatory step to raise the pH is blending with the tailpond water, but it would take more high pH water than low pH water to effectively raise pH as it is a logarithmic value. As an example it would take 3 times as much pH 8 water mixed with one volume of pH 7 water to raise the pH to 7.5.

Ammonia

Free ammonia is the toxic form of ammonium species in water to aquatic life. The percent of free ammonia of the total concentration present is dependent on an equilibrium controlled by pH and temperature. High ammonium concentrations are usually produced in the anoxic zones in dams and therefore release of bottom water is potentially toxic to aquatic life. The data examined for the KZN dams showed:

- That there were very much higher total ammonia concentrations in the bottom water than in the inflow or surface water.
- That when the total ammonium species concentrations were used to calculate free ammonia concentrations at an assumed pH of 8.0 and temperature of 25^{o}C, the bottom water exceeded the target aquatic guideline concentration at the 55th percentile and the chronic effect value at about the 75th percentile. This means that 45% of releases could potentially be harmful and 25% very harmful to the ecosystem.
- The only mitigatory step that could be taken would be to ensure the release of as much surface water as possible together with the monthly bottom water releases.

Temperature and dissolved oxygen profiles likely to develop in the dams and impacts of releases

Temperature

The change in temperature of the rivers below the dams with respect to the natural regime will depend upon where the dam releases come from (different levels or scour) and the time of the year. As a generality for summer, low level and bottom releases will be colder and surface releases warmer than inflow temperatures. To quantify the changes, data for the KZN dams showed the following:

- That, when stratified, the deeper dam (42 m) had more stable and lower temperatures than the shallower dam (16 m). The inference is that the very much deeper Jana (160-190 m) and Mielietuin (75-95 m) dams will have stable low bottom temperatures that will be discharged.
- While dam mixing and turnover does occur for both dam studied, isothermal conditions in the deeper dam only occurred for about 2 months of the year, while for the shallower dam for 4 months. The indication is that the depth of the Jana and Mielietuin dams may result in them being permanently stratified with discharge of cold water all year round.
- That the maximum temperatures differences between surface and bottom water occurred in January/February and were about 10^{o}C. If prevailing in the Jana and Mielietuin dams, there will be a considerable shock to the ecosystem when the monthly bottom water releases take place. The guidelines for aquatic life state that temperature changes should not exceed 2^{o}C.
- Comparing dam inflow temperatures to those at different levels in the dam showed that in summer, surface and 6 m depth temperatures could be warmer by up to 5^{o}C, while bottom temperatures could be up to 13^{o}C colder. Consequently, the natural temperature regimes for the rivers will be greatly disturbed by dam discharges. In mitigation, the level for discharge from the dams could be selected to most closely match the natural temperature of the river.

Dissolved oxygen

- Data from the KZN dams indicated that dissolved oxygen concentrations in the Jana and Mielietuin dams would be depleted below 4mg/ℓ, which is recognized as the lower limit for aquatic life, at about the 8 to 10 m water depths. These patterns were also seen for dams in Gauteng. Below this depth dissolved oxygen concentrations gradually declined to zero. There is little doubt that the bottom releases for the Jana and Mielietuin dams will be completely anoxic and potentially detrimental to the ecosystem.
- The great depth of the Jana and Mielietuin dams may prevent mixing and turnover in the dams thus ensuring that discharges will be anoxic all year round.
- For mitigation of monthly releases of anoxic bottom waters, the release mechanism should be such that the water is rapidly re-oxygenated which can be brought about by spraying the water into the tailponds below the dams. This mechanism is used at the Albert Falls dam in KZN and measurement has shown that near dissolved oxygen saturation concentrations are reached quickly in the receiving pond.

Table of impacts of poor water quality in the Jana and Mielietuin dams and release water to the downstream rivers

Impact	Magnitude & Intensity	Extent & Spatial Scale	Duration	Status	Confidence	Significance	Probability
High algae. in the dams	moderate	dam basin	indefinite	negative	possible	moderate	probable
High algae in surface water releases	moderate	local	indefinite	negative	possible	moderate	probable
Lower turbidity of surface water releases	low	local	indefinite	positive	definite	low	probable
High dissolved iron & manganese in bottom water releases	high	local	indefinite	negative	definite	high	definite
E. coli in all releases	high	local	indefinite	positive	definite	high	definite
Low pH of bottom water releases	high	local	indefinite	negative	definite	moderate	definite
High free ammonia of bottom water releases	high	local	indefinite	negative	definite	high	definite
Low temperature of bottom water releases	high	local	indefinite	negative	definite	high	definite
Low dissolved oxygen of bottom water releases	high	local	indefinite	negative	definite	high	definite

Baseline and future monitoring

It is suggested that the following monitoring and water quality modelling be set up to better assess the water quality that will develop in the Jana and Mielietuin dams and possible downstream impacts:

- That monitoring of the Thukela and Bushmans rivers be established as close as possible to the dam sites at weekly intervals in the summer months and at 2-weekly or monthly intervals in the winter period. Better monitoring at these sites would be the establishment of permanent weirs with kiosks to enable flow recording and the installation of automatic sampling equipment to sample flow on a flow-weighted volumetric basis. This method of sampling would provide the most representative and accurate water quality data for the rivers.
- That monitoring at the DWAF stations used in this report be maintained to assess pollution levels, but that additional analyses of samples should be conducted for faecal bacteria (*E. coli*), turbidity, suspended solids, total phosphorus, iron, manganese, total organic carbon and occasional analysis for a range of other toxic metals.
- That monitoring of the Sundays, Mooi and Buffels rivers at suitable sites close to their confluences with the Thukela river be set up to characterize water quality from these catchments, so that future water quality in the Thukela river when there is restricted flow from the dams can be estimated, and any potential problems for water users identified. A water quality model using this type of data may be appropriate for this purpose.
- That a deterministic water quality model to predict the eutrophication status likely to develop in the Jana and Mielietuin dams be employed.
- That all point source discharges upstream of the dams be monitored for bacterial, organic and nutrient loads. This monitoring may already be in place, but its efficacy needs to be assessed and upgraded if necessary.

SPECIALIST STUDY ON THE IMPACTS RELATING TO THE CREATION OF IMPOUNDMENTS FOR THE THUKELA WATER PROJECT ON WATER QUALITY AND THE WATER QUALITY THAT WILL BE RELEASED

INTRODUCTION

The Department of Water Affairs and Forestry (DWAF) has initiated the Thukela Water Project which proposes to build two large dams in the Thukela river catchment in order to augment water supply in the Vaal River System. Water will be abstracted from these dams at a combined rate of approximately 15 m^3/s *via* pipelines and canals to the existing Kilburn dam from which water will be transferred *via* the Drakensburg Pumped Storage Scheme. The construction and operation of these dams will have significant impacts of the ecosytem and consequently DWAF has commissioned specialist studies to estimate the impacts and suggest mitigatory steps that can be taken to minimize adverse effects.

The purpose of this report is to estimate the water quality that will develop in the dams, to what degree eutrophication will take place and what quality of water will be released to the river below, either from a selected level or a bottom release. Different water quality will prevail at different depths in the dams which will affect the downstream ecosystems and therefore operational rules for releases to optimize water quality are important.

METHODOLOGY

The approach adopted to meet the objectives has been as follows:

- To determine landuse in the catchments of the proposed dams which gives an indication of likely runoff water quality, as certain categories of landuse have greater potential to pollute water than other ones.
- To gather and evaluate existing water quality data for the rivers above and below the proposed dams from available sources (no new monitoring was carried out).
- To examine the data for historical trends to determine if constituent concentrations (levels of pollution) were changing or not.
- To use estimated phosphorus concentrations in the inflows to the dams, together with physical data for them, to run an empirical model to suggest the algal concentrations likely to develop.
- To use existing data (Umgeni Water data) collected for dams to estimate changes in water quality likely to take place through impoundment, and the quality likely to be released from different levels in the dams.

SOURCES OF INFORMATION, ASSUMPTIONS AND CONSTRAINTS

To estimate the water quality likely to enter the proposed dams, the available chemical analysis data for five DWAF monitoring stations above the proposed dam sites were extracted. Two are above the Jana dam, one on the Thukela river at Thukela drift/Colenso and the other on the Klip river at Ladysmith. For the Mielietuin dam, two sites are on the Little Bushmans river, one above and one at Estcourt, while the other is on the Bushmans river below Wagondrift dam. Analyses were available for electrical conductivity (EC), total dissolved salts (TDS), pH, sodium, magnesium, calcium, fluoride, chloride, the sum of nitrate and nitrite forms, sulphate, phosphate, alkalinity, silicon, potassium and ammonium species.

The location of the stations is shown in the map in Figure 1 (Appendix 1), while details of the analysis records are given in Table 1.

Table 1: DWAF stations records

Station	Description	Period	Analysis frequency
V1H001	Thukela river at Thukela drift/Colenso	1976 to 1999	For EC 3/month For others 1.1/month
V1H038	Klip river at Ladysmith	1977 to 1999	For EC 1.8/month For others 1.1/month
V7H018	Little Bushmans river at Sloy/Craig	1976 to 1999	For EC 1.7/month For others 1.1/month
V7H012	Little Bushmans river at Estcourt	1982 to 1999	For EC 2/month For others 0.9/month
V7H020	Bushmans river below Wagondrift dam	1983 to 1999	For all 2.4/month

As may be seen from Table 1, the maximum frequency of analysis was for EC at an average of 3 samples per month, while for the other constituents the frequencies ranged from 0.9 to 2.4 per month, effectively being as little as monthly analyses. The frequencies of analyses, particularly for phosphate, nitrate and ammonia concentrations (the plant nutrients) are considered to be too low to adequately characterize water quality and evaluate pollutant loads. A weekly sampling frequency, particularly during the summer months, would be considered essential for this purpose. The paucity of the data is considered to be a severe limitation in suggesting the likely water quality that will develop in the dams.

Analyses for total phosphorus, turbidity, suspended solids and bacteria (E. *coli*) were not conducted on the samples, which is considered to be a serious omission in characterizing water quality in the catchments above the dams. Phosphorus which is usually the driving force in determining algal counts and speciation in dams is strongly adsorbed onto sediment particles and carried by rivers in this manner into dams as a nutrient to stimulate algal growth. Consequently, the fact that only analyses for soluble and not total phosphorus were performed means that estimates of likely total phosphorus concentrations entering the dams had to be made in order to suggest algal concentrations that would develop. Data on the relationship between soluble and total phosphorus concentrations for the inflow to an impoundment in KZN was used for this purpose, but clearly, this method would be subjective and could lead to a large error. The lack of analyses for turbidity/suspended solids concentrations and bacteriological analyses, such as for E. *coli* means that estimating the extent of diffuse pollution to rivers from informal settlements without sanitation is very limited.

Other analytical data sourced to characterize water quality in the Thukela catchment was for an Umgeni Water sample site 150 on the Thukela river at Middledrift. The location of the site may be seen in the map in Figure 1 (Appendix 1). Although the site is well below the proposed dams and includes inflows from major tributaries such as the Sundays, Buffels and Mooi rivers, the data is considered potentially useful in characterizing the overall water quality of the Thukela river as the data-set contains analyses not included in the DWAF analyses such as for E. *coli*, algae, turbidity, suspended solids, total phosphorus and a number of toxic heavy metals. However, the usefulness of the data is limited as the period of analysis is short, just 1997 to 1999, and only up to a maximum of 15 results per determinand are available. Therefore, only broad and not specific consequences can be suggested.

To estimate how water quality will change from the river inflows to that in the dams and therefore the quality that will be released downstream, use has been made of existing data for dams operated by Umgeni Water. Data for temperature and dissolved oxygen profiles for the Midmar and Inanda dams and inflow and surface dam water quality has been evaluated and the results assumed to be broadly representative of what will occur in the Jana and Mielietuin dams. Constraining factors to this approach are the facts that the Midmar and Inanda dams are far shallower than those proposed and are different geographically with respect to altitude and therefore diurnal temperature effects. Consequently, the extrapolated temperature profile data will be more representative of relative differences rather than absolute temperatures.

RESULTS

Landuse in the proposed Jana and Mielietuin dam catchments and impact on water quality

Apart from the underlying geology in a catchment which affects drainage water quality mainly with respect to the mineral content, landuse can have a profound effect on runoff water quality, particularly high pollution potential landuses such as urban, industrial and agriculture. The landuses in the catchments of the proposed dams were determined from 1996 Landsat data and are presented in Tables 2 and 3.

Table 2: Landuse in the Jana dam catchment

Landuse Description	Area (km2)	% Area
Barren rock	4.5	0.1
Cultivated: temporary - commercial dryland	198.6	3.0
Cultivated: temporary - commercial irrigated	426.1	6.5
Cultivated: temporary - semi-commercial/subsistence dryland	391.1	6.0
Degraded: thicket & bushland (etc)	91.1	1.4
Degraded: unimproved grassland	283.0	4.3
Dongas & sheet erosion scars	53.0	0.8
Forest	36.7	0.6
Forest and Woodland	27.9	0.4
Forest plantations	89.5	1.4
Improved grassland	0.3	0.0
Mines & quarries	3.4	0.1
Shrubland and low Fynbos	14.4	0.2
Thicket & bushland (etc)	1387.2	21.1
Unimproved grassland	3461.8	52.7
Urban / built-up land: commercial	2.3	0.0
Urban / built-up land: industrial / transport	4.1	0.1
Urban / built-up land: residential	35.4	0.5
Urban / built-up land: residential (small holdings: shrubland)	0.3	0.0
Waterbodies	58.5	0.9
Wetlands	4.4	0.1
TOTALS	**6,573**	**100**

Table 3: Landuse in the Mielietuin dam catchment

Landuse Description	Area (km2)	% Area
Cultivated: temporary - commercial dryland	17.1	1.3
Cultivated: temporary - commercial irrigated	17.5	1.3
Cultivated: temporary - semi-commercial/subsistence dryland	27.2	2.0
Degraded: unimproved grassland	46.4	3.5
Dongas & sheet erosion scars	0.7	0.1
Forest	2.4	0.2
Forest plantations	51.0	3.8
Improved grassland	4.0	0.3
Shrubland and low Fynbos	0.3	0.0
Thicket & bushland (etc)	154.6	11.6
Unimproved grassland	965.2	72.3
Urban / built-up land: commercial	0.6	0.0
Urban / built-up land: industrial / transport	1.7	0.1
Urban / built-up land: residential	37.8	2.8
Waterbodies	6.4	0.5
Wetlands	2.7	0.2
TOTALS	**1336**	**100**

The major landuse in both catchments is unimproved grassland at 52.6% and 72.3% for the Jana and Mielietuin catchments respectively followed by thicket and bushland as the next highest categories. Neither of these landuses has a high potential for water pollution. The Jana dam catchment has the greater collective percentage of all types of agriculture, 15.5%, compared to the Mielietuin dam, 4.6%, and therefore, if the ground is tilled and fertilizer applied for agriculture, then the Jana dam catchment will have the greater potential for pollution of runoff water through erosion and fertilizer washoff. Conversely, the Mielietuin catchment has the greater percentage of industrial and residential landuse, being collectively 3.0% of the catchment area for all urban landuse compared to only 0.6% for the Jana catchment. In the Mielietuin catchment the urban areas consist of the towns of Estcourt, Wembesi and Weenen with their associated infrastructure, while the Jana dam catchment includes the towns of Bergville, Ladysmith, Ezakheni and Winterton. Both dams can receive polluted runoff from the urban areas as well sewage effluents, but since the Mielietuin dam has the higher percentage of urban land in its catchment, runoff to the dam is likely to be poorer water quality. Should there be growth of urban centres, settlements of agriculture in either catchment, then runoff water quality could be expected to deteriorate. Mitigatory steps to take would be to ensure that good town planning to avoid uncontrolled development is practiced and there is strict control of discharges of sewage and industrial effluents (appropriate standards) in order to minimise pollution and the deterioration of environmental water quality.

To show the spatial distribution of landuse in the catchments of the dams, maps are shown in Figures 2 and 3 (Appendix 1). For these maps certain categories of landuse, such as the different types of agriculture (dryland, irrigated, subsistence) and urban landuse (commercial, industrial, residential) were grouped together simply as agriculture and urban, in order to make viewing easier, otherwise the maps would have had too many categories for clear distinction between them. The groupings of landuses used for the maps with areas and percentages are shown in Table 4.

Table 4: Grouped landuses in the Jana and Mielietuin dam catchments

	Jana dam		Mielietuin dam	
Landuse Description	**Area (km2)**	**% Area**	**Area (km2)**	**% Area**
Cultivated, all types	1015.7	15.5	61.8	4.6
Degraded unimproved grassland	336.0	5.1	47.1	3.5
Grassland	3462.1	52.7	969.3	72.6
Forestry	154.1	2.3	53.3	4.0
Shrubland, thicket and bushland	1492.7	22.7	154.9	11.6
Urban	42.0	0.6	40.1	3.0
Waterbodies and wetlands	62.9	1.0	9.1	0.7
Other, mines, quarries and rock	7.9	0.1	0	0
Totals	**6573.4**	**100**	**1335.6**	**100**

Figure 2 (Appendix 1) of the Jana dam catchment map shows that:

- Cultivated land is distributed mostly in the middle to upper catchment and therefore there will be some amelioration of pollutants washed off these areas by in-stream processes such as sedimentation and absorption and uptake of nutrients before entering the dam.
- The immediate surround of the dam consists of shrubland, thicket and bushland which should not have a high water pollution potential unless there has been over-grazing by livestock.
- The major urban center of Ladysmith on the Klip river is not far up the catchment and is fairly close to the dam, and therefore there would not be much amelioration of pollution from this source.

Figure 3 (Appendix 1) of the Mielietuin dam catchment map shows that:

- The limited agriculture is widely distributed and not seen as a major threat to water quality entering the dam.
- As for the Jana dam, the immediate surround is shrubland, thicket and bushland and the same comments apply.
- The urban areas are up to half-way up the catchment, but the major town, Estcourt, is closer to the dam which means that improvement of polluted runoff through river processes from this source will be limited.

Information given in the Vaal Augmentation Planning Study on water quality (WST Consortium) stated that the Upper and Little Thukela, Klip and Bushmans river catchments had rural populations in certain areas greater than their economic sustainability (48 persons/km^2), which was seen as a threat to water quality and to dams in their catchments. Also stated, was that urban informal settlements were growing rapidly and the land was overstocked with livestock (assuming a carrying capacity of 5 ha/livestock unit) ranging from 60% to 100% over the carrying capacity. Clearly, such situations could lead to increased pollution, accelerated erosion and a general deterioration in water quality entering the dams. For mitigation, consideration needs to be given to putting in place some control of the numbers of livestock allowed on the land, otherwise water quality will most likely deteriorate.

Water quality in the Jana and Mielietuin dam catchments

The location of the five DWAF and one Umgeni Water station selected for water quality data may be seen in the map in Figure 1. The DWAF stations are all well above the sites of the proposed dams which is not ideal for characterizing the water quality that will enter the dams. Station V1H038 on the Klip river is above the town of Ladysmith and at least 40 km above the Jana dam, while station V1H001 on the Thukela river is probably only slightly closer. The stations above the Mielietuin dam on the Little Bushmans river are V7H018 above and V7H012 below Estcourt and V7H020 on the Bushmans river below Wagondrift dam. All are also appreciable distances upstream of the Mielietuin dam, whereas closer stations would have been preferable for assessing water quality likely to enter the dams.

Notwithstanding these imperfections of the positions of the stations, the data have been evaluated for their concentration distributions and long term trends. No account has been taken of hydrological data as it would not be relevant to monthly samples. Tables of percentile values for all constituents analyzed have been drawn up showing medians (50^{th} percentile) which gives an idea of typical concentrations to be expected, while the higher percentiles show the extreme values recorded and their frequency of occurrence. The time series graphs of constituent concentrations drawn up show the high variability and trend lines (statistical best fit lines) have been superimposed on the graphs to show rising, falling or unchanging concentrations with time. The equations for the trend lines are also shown together with the R^2 values which indicate the strength of the relationships of the data to the trend lines. Some of the data extends back 23 years and therefore this analysis is of value to discern long term trends. All these tables and graphs are given in Appendix 2. Comments on water quality at the stations that will feed the dams are as follows.

Jana dam

V1H001 - Thukela river at Thukela Drift/Colenso

- The conductivity is moderate at 10 mS/m for KwaZulu-Natal rivers and does not indicate any significant mineralisation of the water. No trend is visible, showing stable water quality from a dissolved salts point of view.
- The TDS concentrations show a slight rising trend over time, but the significance of the trend is low and may be due to increasing dissolved organic matter rather than to increasing salt content.
- The sodium, magnesium, calcium, fluoride, chloride, silicon and potassium concentrations show either stable or slightly rising trends which are not significant.
- Sulphate, on the other hand, shows a distinctly rising trend from about 2.5 mg/ℓ to 8 mg/ℓ over the period 1976 to 1999. The graph shows a general increase to higher values from about 1992. No reason can be advanced for this sudden rise, but the concentrations present are not a problem to any user.
- pH shows a distinctive rise from a level of pH 7 to about pH 8 and the R^2 value, 0.49, indicates that the trend is statistically significant. The alkalinity graph trend does not support this upward pH trend. A reason could perhaps be due to increased algal growth in the river and removal of dissolved carbon dioxide, but this cannot be confirmed as no analyses for algae have been conducted.
- The nitrate concentrations also show an upward trend although the significance is not high (R^2 = 0.11). This upward trend could be expected as there is a significant amount of

agriculture in the Jana dam catchment. However, the 50th percentile concentration of only 0.18 mg/ℓ and the 95th percentile of 0.40 mg/ℓ are not high values to be concerned about.

- Neither the phosphate and the ammonia concentrations show any trends and display highly variable data. The 50th and 95th percentile concentrations for phosphate (expressed as phosphorus) of 0.022 and 0.073 mg/ℓ respectively are sufficiently high to stimulate algal growth, but the ammonia concentrations are low and no cause for concern.

V1H038 - Klip river at Ladysmith

- The conductivity level of this tributary is higher than that for the Thukela river being almost double at 20 mS/m. This will result in a conductivity level between 10 and 20 mS/m entering the Jana dam which is satisfactory for all user groups. The data show a slightly falling trend but the significance is low, as is the case also for TDS.
- Similar slightly falling or unchanging trends are shown for sodium, magnesium, calcium, fluoride, chloride, silicon and potassium.
- As was the case for the Thukela river, the sulphate concentrations indicate a rising trend from 5 to just over 10 mg/ℓ over the 22 year period, but the levels are not a problem. It is tentatively suggested that the rise in sulphate concentrations may be due an activity such as emissions and fallout from power stations.
- pH also shows a significant rise to just over pH 8 and a similar reason to that given above (algal growth) may be the major cause. The 50th percentile is pH 7.7 and only at the 95th percentile is the Target Water Quality Guideline for the irrigation of crops pH maximum of pH 8.4 reached (DWAF, SA Water Quality Guidelines). This is not considered to be a problem, unless the levels keep rising when other water quality users may be affected.
- None of the plant nutrients, phosphate, nitrate and ammonia show any significant trends, either rising or falling concentrations and consequently the importance attached to them is their current levels. The 50th percentile phosphate concentration of 0.018 mg/ℓ is similar to that of the Thukela river (0.022 mg/ℓ) and can certainly support algal growth. However, more seriously, the graph shows occasional concentrations up to almost 0.5 mg/ℓ, which probably could be attributed to diffuse rather than point source pollution since the flow on two of the three sampling occasions was higher than the background.

A blend of water qualities from the above two stations will constitute the inflow water quality to the Jana dam. No problems are seen in meeting the requirements for all users, although the earlier stated limitation of the data with respect to the constituents analyzed should be borne in mind. The phosphate-P concentrations are a cause for concern as the levels will stimulate algal growth, but without knowing the total phosphorus concentration the full impact cannot be assessed. The data indicate sporadic pollution incidents which may well be due to urban developments such as Ladysmith and the settlements shown in the landuse map, but without any results for the organic content of the waters, there is little more that can be said in this regard.

Mielietuin dam

V7M018 Little Bushmans river at Loch Sloy/Craig

- This station is above the town of Estcourt and is included mainly to assess the base water quality before possible entry of pollution from Estcourt.

- The conductivity level is moderate below 10 mS/m for KwaZulu-Natal rivers and shows a slow trend line rise in values which is supported by the upward trends in TDS, sodium, magnesium, calcium, fluoride, chloride and sulphate. The rising trend line for sulphate is far more pronounced with a trendline change from about 3 to 8 mg/ℓ over a period of 22 years and has a significant R^2 value of 0.205. Again, the reason for the change in sulphate levels would be speculative.
- As for the previous two stations, the pH values show a strong rise in the trend line from a value just above pH 6 to almost pH 8 which is more than an order of magnitude change. The R^2 value for the relationship is significant at 0.50. The graph shows a sharp jump in pH values in 1988/89, so there must have been some significant occurrence to cause this change. However, the 95th percentile pH is only 8.0 and not excessively high for river water.
- The trend lines for nitrate and ammonia show rising and falling trends respectively, but neither are significant statistically and the concentrations are low. For nitrate the 50th percentile is 0.25 mg/ℓ and for ammonia 0.02 mg/ℓ which do not reflect any pollution.
- The graph for phosphate-P does not show any trend and the concentrations are variable about a 50th percentile of 0.014 mg/ℓ, which would support algal growth although this is not a cause for concern. The odd concentration is up to 0.15 mg/ℓ with one extreme value of 0.84 mg/ℓ.

V7H012 - Little Bushmans river at Estcourt

This station is below Estcourt and therefore water pollution from this source can be assessed by comparing the results with those from V7H018 above the town. Comments are:

- The conductivity level is appreciably higher than that of station V7H018 as shown by 50th percentiles of 14.6 and 7.1 mS/m which is a doubling. This general rise in conductivity from above to below Estcourt is also shown by comparative rises in the concentrations (generally double or more) for all the ions analyzed (sodium, magnesium, calcium, fluoride, chloride, sulphate, potassium) and TDS that collectively contribute to conductivity.
- Again, as for the other stations, pH and sulphate show statistically significant rises in their trend lines over the monitoring period of 17 years. However, the levels of pH and sulphate are no cause for concern with respect to any water users.
- The nutrient concentrations at this station are distinctly higher than those shown for above the town, V7M018, and indicate some degree of pollution. For nitrate the difference between the sites is not great, a rise of just 0.25 to 0.30 mg/ℓ at the 50th percentiles, but for phosphate-P the rise is more than double from 0.014 to 0.033 mg/ℓ, which certainly indicates significant enrichment from the town. The phosphate-P graph shows a number of high concentrations ranging about 0.20 to 0.25 mg/ℓ with a maximum of 0.42 mg/ℓ , which clearly reflects pollution. These concentrations will stimulate algal growth appreciably. The trend line for phosphate-P indicates that concentrations have risen over the monitoring period (17 years), which may be due to general growth of the urban areas of Estcourt. For ammonia concentrations, the 50th percentile is not particularly high at 0.06 mg/ℓ and is no cause for concern, but, as for phosphate-P, there are some very high concentrations shown which are up to 3 mg/ℓ, certainly indicating severe pollution at times.

V7H020 - Bushmans river below Wagondrift dam

- As shown in Figure 1, this station is immediately below the Wagondrift dam and is the other main feeder river to the Mielietuin dam. Conductivity is low at below 10 mS/m and the trend line for the graph is level indicating no real change since 1983. TDS concentrations on the other hand show a weak rising trend line, while those for sodium, magnesium, calcium, chloride, sulphate and potassium show either weakly rising trends or none at all. The exception is for fluoride which shows a strong rising trend from about 0.1 to more than 0.2 mg/ℓ with a significant R^2 value of 0.19. However, these fluoride concentrations are not detrimental to any user including the environmental. The overall conclusion is that the mineral content of the river at this point has not changed materially over the monitoring period.
- As was found for the other stations, pH displays a strong rising trend line from about pH 6.5 to just over 8. A major change appears to have taken place about 1989/90 when there was a strong upward shift in pH and thereafter fairly stable values were recorded. The fact that this station is below a dam where water quality can be changed by detention in the dam may be a contributing factor to the trend in that algae may be depleting the water of carbon dioxide.
- The nutrient concentrations for nitrate and ammonia do not show any change, and in fact the ammonia concentrations appear to have fallen over the period. Both levels of these nutrients are low and no cause for concern. The phosphate-P concentrations show a rising trend line which may be considered as significant as the R^2 value is 0.10. The 50^{th} and 95^{th} percentile concentrations are 0.016 and 0.039 mg/ℓ respectively, which could promote algal growth in an impoundment. Since these results are for the outflow of a dam, they are surprisingly high as dams usually through algal growth deplete the water of soluble phosphate-P. Unfortunately, there are no algal results available for the dam.

A combination of the Little Bushmans and the Bushmans rivers will constitute the inflow to the Mielietuin dam. Water quality is shown to be poorer from the Little Bushmans river which has the town of Estcourt and associated infrastructure in the catchment. The level of pollution may well increase with further development or if there is no control of developments practiced. The same mitigatory steps advocated for the Jana dam would apply. Dams tend to act as sinks for sediments and nutrients received and since part of the inflow to the Mielietuin dam will come from the Wagondrift dam means that this better water quality will provide dilution and amelioration of the more polluted water from the Little Bushmans river.

Water quality of the Thukela river downstream of the dams

As part of Umgeni Water’s strategy to supply potable water to rural populations, monitoring of the Thukela river at Miffledrift, some 185 river km downstream of the proposed dams, was undertaken in 1997. The location of the site may be seen in the map in Figure 1 as site 150. Although this sampling site includes inflows from the Sundays, Buffels and Mooi rivers, which will influence water quality downstream of the dam sites, the value of the data for the site is that it includes analyses for constituents such as *E. coli*, algae, turbidity, suspended solids and a number of metals not included in the DWAF datasets. These constituents are of value in giving some idea of current water quality in the Thukela river and making some assumptions of the upstream water quality that will enter the dams. The limitation of presenting and using this data is realized, but there is no choice as no other data is available. The results are given in Table 5 for certain constituents as percentile values to show the distribution of the data and in Table 6 for the trace metals as individual results as many of them are below the detection limits which precludes statistical analyses.

Table 5: Analytical data as percentiles for the Thukela river at Middledrift, Umgeni Water site 150, from June 1997 - July 1999

Percentiles	**Units**	**0%**	**25%**	**50%**	**75%**	**90%**	**95%**	**100%**	**n**
E. coli	/100 mℓ	106	245	300	755	2708	7990	18000	15
Algae	/mℓ	455	3018	4006	8338	13796	18114	25558	14
pH		7.1	7.9	8.1	8.2	8.2	8.3	8.5	14
Turbidity	NTU	4	28	103	145	2472	4070	4350	15
Conduct.	mS/m	10.8	18.7	22.1	27.6	32.1	33.6	35.1	14
Iron	mg/ℓ	0.09	0.58	0.96	1.44	7.03	10.68	14.10	13
Manganese	mg/ℓ	0.02	0.06	0.10	0.21	1.19	2.19	3.33	13
Nitrate	mg/ℓ	0.03	0.11	0.23	0.40	0.51	0.53	0.56	14
Ammonia	mg/ℓ	0	0.02	0.04	0.04	0.07	0.12	0.21	14
TP	mg/ℓ	0.008	0.065	0.082	0.109	0.267	0.551	0.943	13
SRP	mg/ℓ	0.002	0.002	0.012	0.019	0.042	0.063	0.091	13
SS	mg/ℓ	4	51	123	146	2334	3835	4147	15

Table 6: Analytical data for metals for the Thukela at Middledrift, Umgeni Water site 150, from June 1997 - July 1999

Metal	Cu	Zn	Cd	Pb	Cr	Hg	As	Se	Ni	Ag	Sb
Unit	mg/ℓ	mg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ
14/7/97	<0.05	<0.02	<1	<4	<3	<0.5	<2	<0.5	<3	<3	<2
13/10/97	<0.05	0.03	<1	<4	<3	2.3	<2	<0.5	<3	<3	<2
13/1/98	<0.05	<0.02	<1	<4	<3	<0.5	<2	<0.5	6.2	<3	<2
23/4/98	<0.05	<0.02	<1	<4	<3	<0.5	<2	<0.5	<3	<3	<2
9/7/98	<0.05	<0.02	<1	<4	<3	<0.5	<2	<0.5	<3	<3	<2
12/10/98	0.06	0.06	<1	<4	<3	0.5	26	0.5	<3	<3	<2
21/4/99	<0.05	<0.02	<1	<4	<3	<0.5	<2	0.5	<3	<3	<2
13/7/99	0.05	<0.02	<1	<4	<3	0.5	<2	0.5	<3	<3	<2

Comments on Table 5 and the implications for water quality above and below the dams are:

- The *E. coli* results show significant bacterial contamination with a 50^{th} percentile value of 300 cells/100 mℓ which is above the guidelines for full contact recreation (130 cells/100 mℓ), livestock watering (200 cells/100 mℓ) and clearly for direct domestic use. The high 95^{th} and 100^{th} percentile values, 7 990 and 18 000 cells/100 mℓ, show severe bacterial pollution at times. It is possible that such concentrations may be found at the dam sites.
- An algal count of 4 000 cells/mℓ at the 50^{th} percentile shows that sufficient nutrient concentrations are present to support significant algal growth in the river, while a maximum count of over 25 000 cells/mℓ represents a bloom. Of course these concentrations may be arising from the downstream tributaries and may not be present at the dam sites, but the phosphate-P concentrations reported earlier for the sampling stations above the dams indicate that substantial algal growth can be sustained.
- pH levels are normal for river water and similar to those already reported.

- The turbidity data indicate a very turbid system with a 50th percentile value of 103 NTU and a 95th of more than 4 000 NTU. The suspended solids concentrations support the turbidity data close to a 1:1 ratio of values. The iron and manganese concentrations are high and their distributions rise in a manner similar to turbidity, indicating that they are mostly adsorbed onto the particles rather than being in their soluble forms. Iron and manganese can, however, be released as their soluble forms in the anoxic zones in dams. These data indicate that the rivers and proposed dams could receive very turbid inflow at times.
- The nutrient concentrations as shown by the nitrate and ammonia data are low and similar to those found for the DWAF stations, while that for soluble reactive phosphorus (SRP) is moderate at 0.012 mg/ℓ. The reason for the low inorganic nutrient concentrations may be due to them having being stripped out of the water by the high algal growth taking place in the river and mentioned above. In fact the SRP concentrations are lower than those shown for the DWAF stations, which is surprising as increasing concentrations would be expected in a down river direction. The data distribution for total phosphorus (TP) concentrations show high values, which may be expected as phosphorus is strongly adsorbed onto particles and turbidities are high.

It would be very speculative to assume that the water quality in the rivers and about the dams would be the same for the constituent concentrations given above, but it is likely that there will be similarities, and if so, the indication is that water quality would be poor at times with respect to turbidity and associated constituents. Only with a new monitoring and analysis programmes can the water quality in the vicinity of the dams be characterized for the above constituents.

Comment on the results for the trace metals given in Table 6 are as follows:

- Over the past two years 8 samples have been analyzed for 11 toxic trace metals and some confidence can be placed in the results as the samples were taken at times of low and high turbidity thus covering both low and high flow conditions.
- For cadmium, chromium, lead, silver and antimony all results were below the detection limits for the methods and therefore would be considered non-problematic for the river system.
- For copper and zinc, 2 results each were above the detection limits and also above the aquatic life guidelines, but not for any other users. It is probable that the metals were associated with particulate matter rather than in the soluble form and therefore not a danger to aquatic life.
- For mercury, 2 results were positive at 2.3 and 0.5 µg/ℓ. These concentrations exceed the guideline criteria for domestic, aquatic life and livestock uses. Again, the metals may not have been in their soluble forms and therefore not problematic as sedimentation could occur. The source may be from natural weathering processes or anthropogenic activities.
- For arsenic, 1 result was above the detection limit at 26 µg/ℓ and only the aquatic life guideline was exceeded.
- Nickel had 1 positive result but no guideline concentrations for water users could be found.

From the foregoing, it can be stated that the trace metals are not regularly present in the river and when found are at low concentrations which mainly exceed the aquatic life guidelines but not those for other water users. The source of the metals is most likely due to urban activities, but the location cannot be stated. The conclusion is that these metal concentrations are unlikely to be exceeded in the rivers at and about the vicinity of the proposed dams, in which case toxic metal contamination in the dams would not be expected.

Likely physical and water quality characteristics of the Jana and Mielietuin dams

Algal growth

The water quality likely to enter the dams has been described above and will now be used to suggest the algal concentrations that will develop in the dams and their trophic status. For this purpose it is assumed that phosphorus will be the limiting nutrient in the dams, as it usually is in KZN dams, and will determine algal growth. A simple empirical model (OECD) which uses the mean total phosphorus (TP) concentration entering a dam together with the retention time has been used to suggest chlorophyll *a* concentrations that will result. Then a calculated ratio of chlorophyll *a* to algal counts has then been used to estimate algal concentrations. The models for calculation of mean and peak chlorophyll *a* concentrations are as follows:

Mean chlorophyll *a*, $\mu g/\ell = 0.37 \times (TP_{inflow} / (1 + (T_w)^{0.5}))^{0.79}$

Peak chlorophyll *a* $\mu g/\ell = 0.74 \times (TP_{inflow} / (1 + (T_w)^{0.5}))^{0.89}$, where T_w = Retention time, years

For calculation of algal counts from chlorophyll *a* concentrations, a relationship using 10 years of data for Midmar dam was developed, ie: 1 μg/ℓ Chlorophyll *a* = 725 cells/mℓ algae.

To estimate the TP concentrations entering the dams, account had to be taken of the fact that the available data in each case was for 2 rivers considerable distances upstream of the dams and it thus had to be assumed that there would be little change in quality during the intervening river passages to each dam. For the Jana dam, the stations are V1H001 and V1H038 and for the Mielietuin dam V7H012 and V7H020. From the time series phosphate-P graphs for these stations, concentrations predicted by the trend line equations were calculated for October 1999 and assumed to exist as mean concentrations in the rivers at this time. The two river concentrations for each dam were then weighted according to the catchment areas (DWAF green book) behind them and weighted means calculated for each dam. However, these results were for phosphate-P (soluble phosphorus) concentrations when TP concentrations are required for the models, and therefore a conversion had to be made. For this purpose the mean TP to phosphate-P ratio for the Inanda dam inflow as a surrogate was calculated and found to be 2.5. Then, assuming that the weighted mean phosphate-P concentrations would be entering the dams they were then converted to TP concentrations using this factor. Details of the calculations using the models are given below:

Table 7: Dam characteristics, calculated phosphate-P and TP concentrations, modelled chlorophyll *a* and algal concentrations

	Jana dam	Mielietuin dam
MAR, x 10^6 m^3	1 446	288
Capacity, x 10^6 m^3	1 468 - 2 483	284 - 426
Retention time, years	mean = 1.72	mean = 1.235
V1H001 phosphate_P conc. from trend line, µg/ℓ	31	-
V1H038 phosphate_P conc. from trend line, µg/ℓ	28	-
V7H012 phosphate_P conc. from trend line, µg/ℓ	-	61
V7H020 phosphate_P conc. from trend line, µg/ℓ	-	26
V1H001 catchment area, km^2	4 176	-
V1H038 catchment area, km^2	1 644	-
V7H012 catchment area, km^2	-	196
V7H020 catchment area, km^2	-	744
Weighted mean phosphate-P, µg/ℓ	30	33
Phosphate-P x 2.5 = TP	75	82.5
Mean chlorophyll a, µg/ℓ	6.08	6.70
Peak chlorophyll a, µg/ℓ	17.32	19.32
Mean algal count, cells/mℓ	4 410	4 860
Peak algal count, cells/mℓ	12 560	14 000

It may be noted that the phosphate-P concentrations for the two rivers feeding the Jana dam are similar, whereas those for the Mielietuin dam are quite different at 61 µg/ℓ for V7H012, the Little Bushmans river below Estcourt and 26 µg/ℓ for V7H020 on the Bushmans river below Wagondrift dam. The difference in concentrations is due to pollution from Estcourt in the case of V7H012 giving the high value, and the ameliorating effect of Wagondrift dam in giving a low concentration. The weighted mean was drawn down to just 33 µg/ℓ due to the fact that the catchment area of Wagondrift dam is far larger than that of the Little Bushmans at Estcourt.

The estimates of algal counts in the dams indicates that both dams will have relatively high mean counts at over 4 000 cells/mℓ and significant peak algal counts with up to 14 000 cells/mℓ which could be described as a bordering on a bloom. The data suggest that the Mielietuin dam will have the higher algal counts, although there are not large differences. According to the OECD trophic classification, both dams would be classified as being between mesotrophic and eutrophic, but closer to mesotrophic. There is the likelihood that when blooms develop blue-green algae such as *Microcystis* and *Anabaena* will dominate, which could lead to obnoxious byproducts such as taste and odour in the water and the production of algal toxins, apart from presenting unpleasant aesthetic conditions. Mitigatory steps to take to protect water quality in the dams would be to ensure that phosphorus concentrations in the rivers flowing into the dams do not increase. To do this there would need to be strict control on the quality of effluent discharges to the rivers, perhaps even introduction of the Special Standard for phosphorus, and developments in the catchments would need careful planning to avoid deterioration of runoff water quality.

It must be borne in mind that these estimates have been made by making a number of far-reaching assumptions and that in the light of more accurate data on water quality entering the dams, they may well change. It is recommended that monitoring of the rivers at the actual dam sites, or as close to them as is practical, be set up and that more comprehensive analysis of the samples be undertaken to obtain more accurate data on phosphorus concentrations as well as other constituents such as suspended solids and turbidity. Perhaps even the construction of weirs immediately before the dams should be considered to enable simultaneous flow recording and automatic sampling to improve the collection of water quality data. Only then will more accurate estimates of water quality likely to develop in the dams be possible.

Water quality in the dams and likely quality of downstream releases

In order to estimate the water quality, apart from algal counts discussed above, likely to develop in the dams, use has had to be made of data gathered for existing dams where there are good databases available and the assumption made that similar changes will take place. This is not an unreasonable assumption to make as there are common processes that take place in all dams, such as sedimentation, stratification and die-off of bacteria. To describe the changes likely to take place in the proposed dams, data for Inanda dam for a 3 year period (1996 - 1999) has been examined. Three types of water quality pertinent to this study have been evaluated, namely the water quality for the inflow, the dam surface close to the dam wall which would represent the aerobic zone and lastly the bottom water, which would be anoxic when the dam was stratified and represent scour water release. In operation of this scheme, water will be continually released from a level drawoff in the dam (release valves are planned at 6 m intervals) and once a month from the scour valve. In the evaluation, the quality of surface/level release water and bottom/scour water will be compared to that of the inflow quality, as this is the basic change that will take place in the river when replaced by a dam with consequences for the ecosystem. The constituents being considered here are turbidity, iron, manganese, *E, coli*, pH and ammonia. The nutrients, nitrate and phosphorus are not considered as they will be depleted to a large extent by algal growth in the dams and should not be problematic. The inorganic ion concentrations such as sodium, potassium and chloride etc. that contribute to conductivity will not change much in passage through the dams as they can be regarded as conservative constituents and therefore do not warrant further discussion.

Turbidity

The turbidity data for the inflow, surface and bottom water for Inanda dam for 3 years are shown in Figure 4 as time series graphs and in Figure 5 as the percentile graphs showing the distribution of the data. As expected, there is high variation in the turbidity graphs in Figure 4, but certain trends are clearly visible. The inflow turbidities show the highest values and have the most variability, while those for the bottom water generally fluctuate between 10 and 100 NTU with less variability. The surface water has by far the lowest turbidities and seldom exceeds 10 NTU. Clearly, there are large differences in turbidity between the different zones in the dam, which has implications for significant changes in river turbidly. When level water is discharged from the dams or there is overflow, the turbidities will generally be far lower than those naturally occurring in the rivers and there will not be any pulses of high turbidity that the rivers normally receive when there is rainfall. When bottom water is released on a monthly basis, the turbidities will rise in the rivers and compensate partially for the variability normally experienced, but still will not reach very high values. The percentile graphs in Figure 5 attempt to quantify the changes likely to occur and can be interpreted as follows:

- At the 50th percentile, taken as representing the usual condition, the inflow turbidity is about 15 NTU while the dam surface turbidity is just over 3 NTU so therefore under these conditions the river will receive about 5 times less turbidity and matter associated with particles than before. This pattern is carried through to the higher percentiles.
- Conversely, when bottom water is released the turbidity is higher at the 50th percentile than that of the inflow, but not greatly. The real change is for the extreme river events when the turbidity could rise to more than 1 000 NTU, but the maximum for bottom water is only about 150 NTU and therefore does not replace the high turbidity pulses that the river would normally receive.

No mitigatory measures can be suggested to normalize the change in turbidity that will take place in the rivers.

Figure 4: Inflow, dam and bottom water turbidities for Inanda dam, 1996-1999.

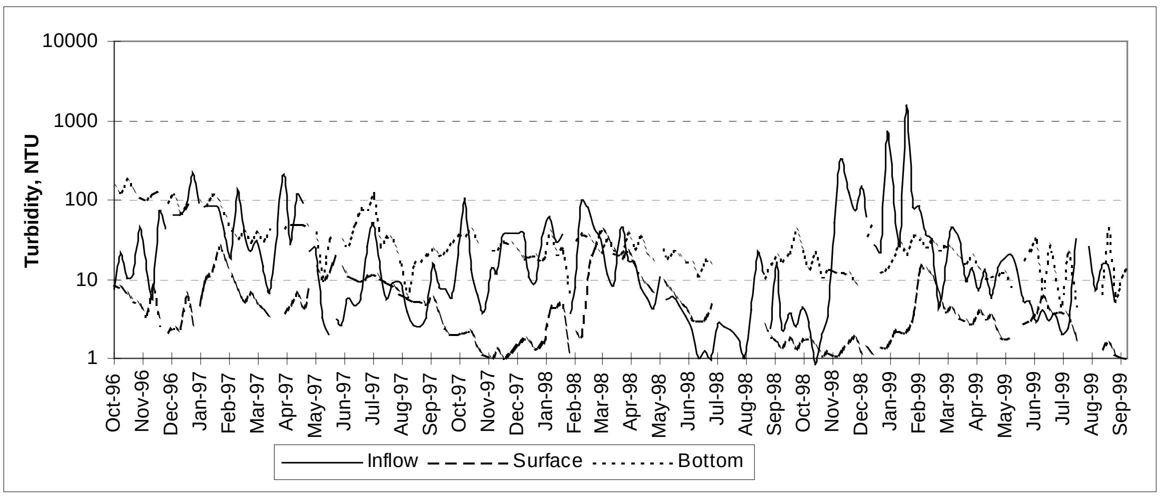
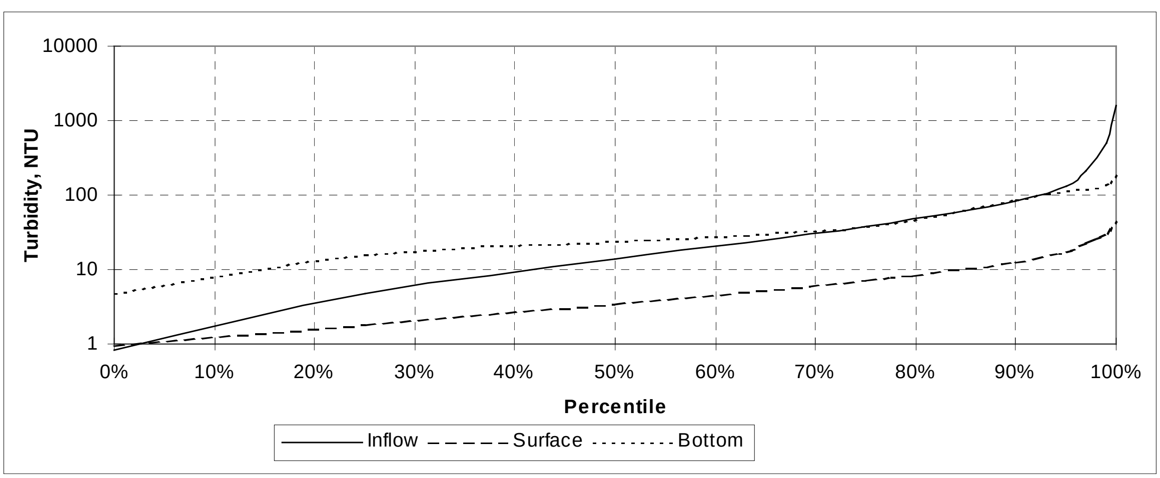


Figure 5: Percentiles for inflow, dam and bottom water turbidities for Inanda dam



Iron

Iron is closely associated with turbidity and in oxygenated water it usually exists in the insoluble ferric state as particulate and colloidal forms. Consequently, these forms will predominate over the soluble reduced forms of iron in rivers. To show how iron concentrations will change in the rivers when the dams are constructed, the data have been treated in a similar manner to that for turbidity and the graphs are shown in Figures 6 and 7.

Figure 6: Inflow, dam and bottom water iron concentrations for Inanda dam, 1996-1999

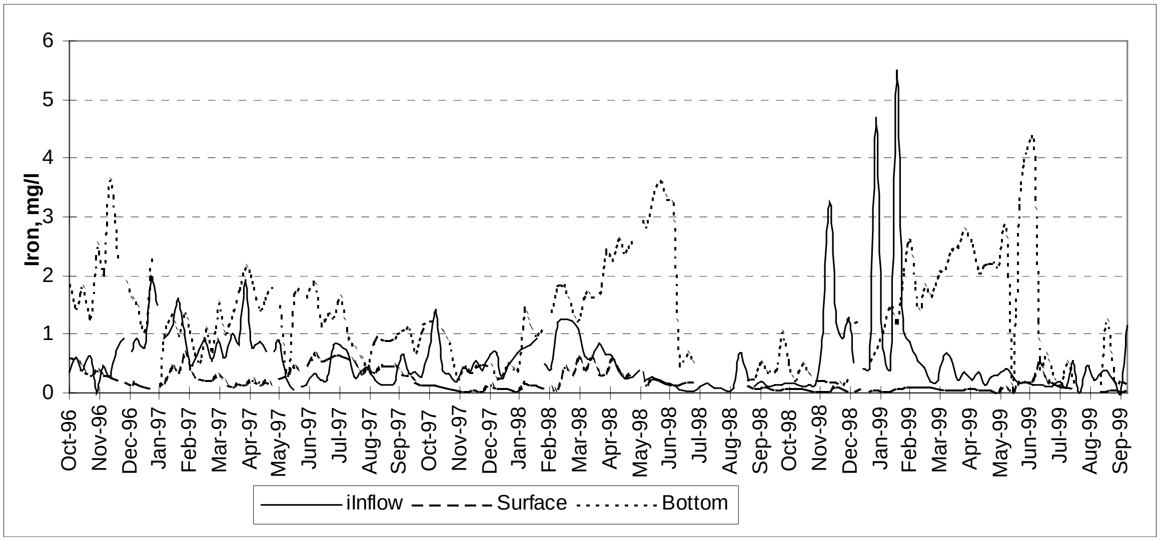
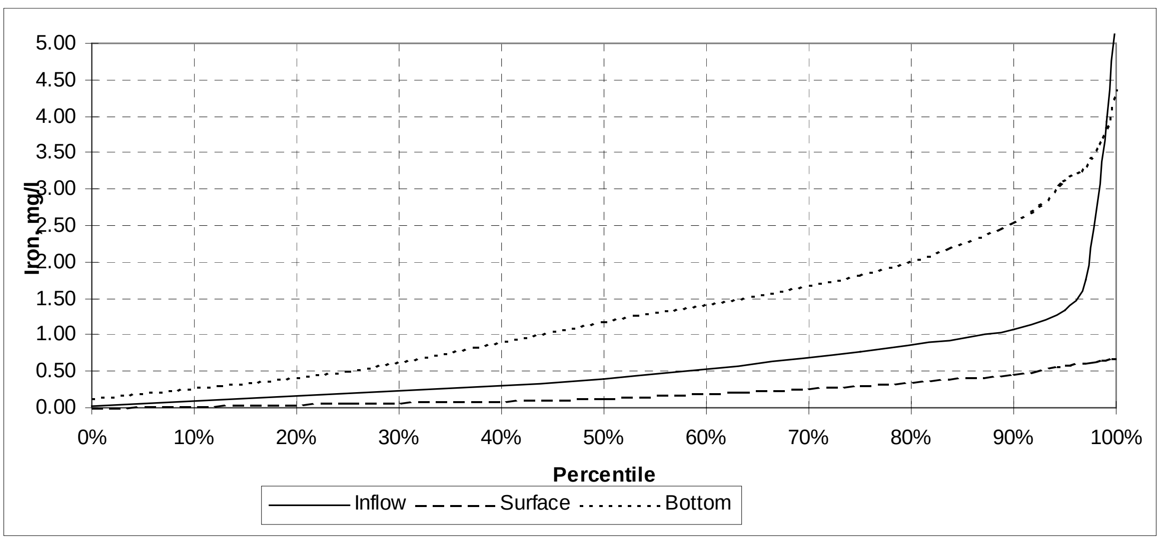


Figure 7: Percentiles for inflow, dam and bottom water iron concs. for Inanda dam



As before, taking the inflow as representing the river iron concentration regime, very high peak concentrations are shown at times and generally the concentrations are very much higher than those in the dam surface water representing normal discharge (Figure 6). This fact can be seen quantitatively in Figure 7 for the 50th to 90th percentile concentrations where differences are about twofold, while at higher percentiles the differences rise sharply. However, for both cases the iron will mostly be in the particulate form and should not affect the rivers below the dams except for a lesser concentration of particulate iron. The great change will come when bottom water is discharged, as under anoxic conditions insoluble iron is reduced to the soluble ferrous state and these concentrations which could affect biological life are depicted in the graphs. Figure 6 shows that bottom water generally has the highest iron concentrations and this is quantified in Figure 7 by the percentile data. At all percentiles, the iron concentrations for the bottom water are well over double that of the inflow water, but it is the fact that in this case much of the iron will be in the soluble form which is important for the ecosystem. The tentative aquatic guidelines (DWAF) state that the dissolved iron concentration should not be allowed to change by more than 10% of the background value. Although this guideline is only tentative, it will be hugely violated when bottom water is released on a monthly basis, probably by concentrations orders of magnitude higher. No toxic concentration level is given in the aquatic guidelines and therefore the effect of dissolved soluble iron concentrations of up to 4 mg/ℓ on the ecosystem cannot be assessed.

Mitigatory steps to take would be to ensure that the tailponds of the dams are full at the time of the bottom discharges so that mixing with better quality water and dilution can take place and facilitate some oxidation and immobilization of the iron through precipitation before entering the river system.

Manganese

The occurrence of manganese in rivers is closely associated with iron and behaves in a similar manner to that described above, except that soluble manganese produced under anoxic conditions in dams is far slower and more difficult to oxidize when exposed to aerobic conditions than iron. It has been reported that reduced manganese in distilled water hardly changes its form over a period of 2 years, but that in natural waters the rate of oxidation is faster and requires bacterial mediation (Chiswell and Mokhtar, 1986). Consequently, dissolved manganese in releases is likely to persist downriver for some distance. A similar treatment to iron has been given in the evaluation of the changes likely to take place for manganese through impoundment. The time series and percentile graphs are shown in Figures 8 and 9 respectively.

Figure 8: Inflow, dam and bottom water manganese concentrations for Inanda dam, 1996-1999

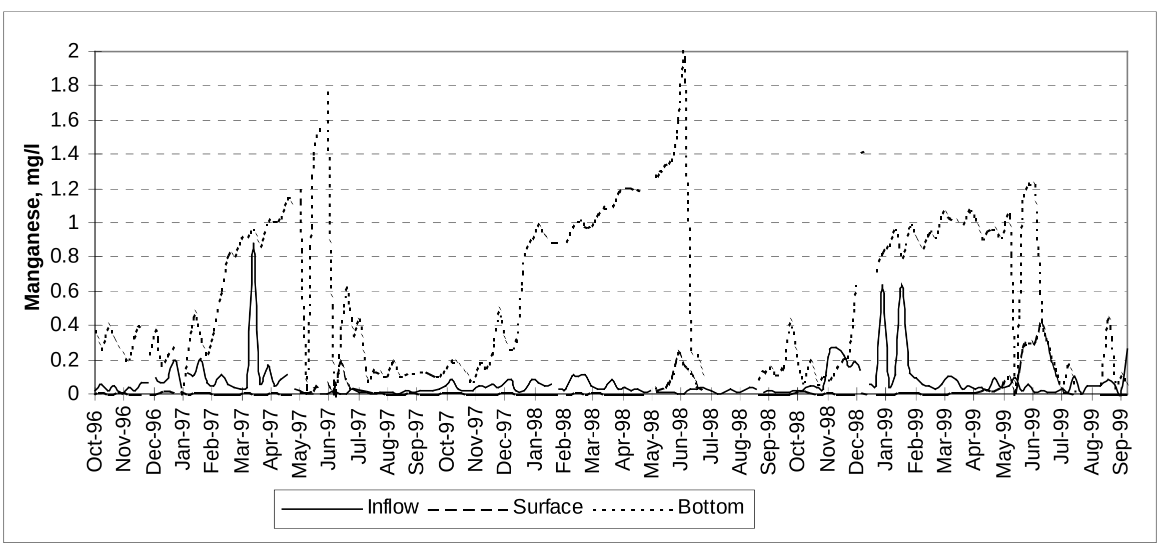
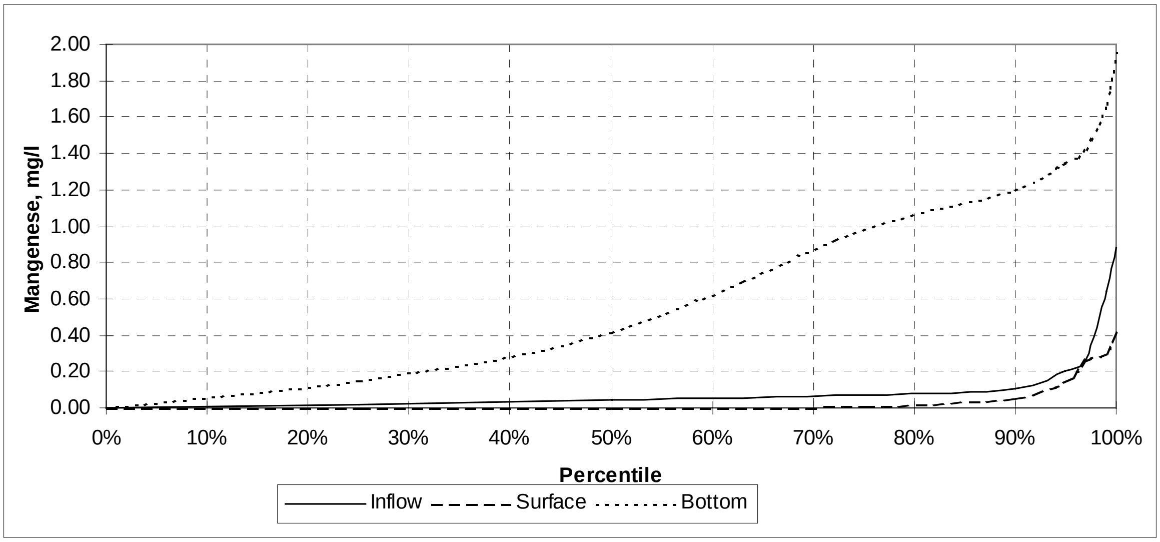


Figure 9: Percentiles for inflow, dam and bottom water manganese concentrations for Inanda dam



Unlike the graphs for iron, those for manganese concentrations show much higher differences between bottom water and those for inflow and dam surface water. The inflow and dam water results are quite close as shown in Figure 8, except for the occasional high concentration pulse for the inflow, but their data distributions are very similar as shown in Figure 9. As stated, the bottom water concentrations are very much higher than those for the inflow and dam surface water being about 20 times at the 50th percentile and 12 times at the 90th percentile. As was the case for iron, much of the manganese will be in the soluble form which can impact on the river ecosystem when bottom water releases are carried out. The aquatic life guidelines (DWAF) for manganese in its dissolved form recommend 0.18 mg/ℓ as the target concentration not to be exceeded with the chronic effect value (CEV) at 0.37 mg/ℓ and the acute effect value (AEV) at 1.3 mg/ℓ. Figure 8 for the bottom water shows that the target guideline is exceeded by the 30th percentile, the CEV by the 50th percentile while the AEV is reached at about the 95th percentile. Clearly, released bottom water with this quality could be detrimental to life in the river below the dam. Although the inflow water quality entering the dams will have different manganese concentrations to those assumed here, the data given for the Umgeni Water sample site, 150, much lower down the catchment shows just as high, or even higher concentrations of iron and manganese indicating that these metals are abundant in the Thukela river system and that there should be ample supply to the dams.

As for iron, the only mitigatory step that can be taken would be to ensure that dilution of the bottom water takes place in the tailponds of the dam before overflow to the rivers. Unlike iron, however, there will not be rapid oxidation and precipitation of manganese as the process is very much slower that that for iron.

E. coli

Although there are no *E. coli* results available from the DWAF data, it can be assumed that bacterial contamination of the rivers entering the dams will take place from point (effluents) and diffuse sources (settlements, livestock). The data for the Umgeni Water site, 150, below the proposed dams indicates significant *E. coli* concentrations at times, see Table 5. It is therefore not unreasonable to assume that the *E. coli* concentrations flowing into and out of the dams could be similar to those for Inanda dam. The inflow, dam surface and bottom water *E. coli* concentrations are shown in Figures 10 and 11.

Figure 10: Inflow, dam and bottom water *E. coli* concentrations for Inanda dam, 1996-1999

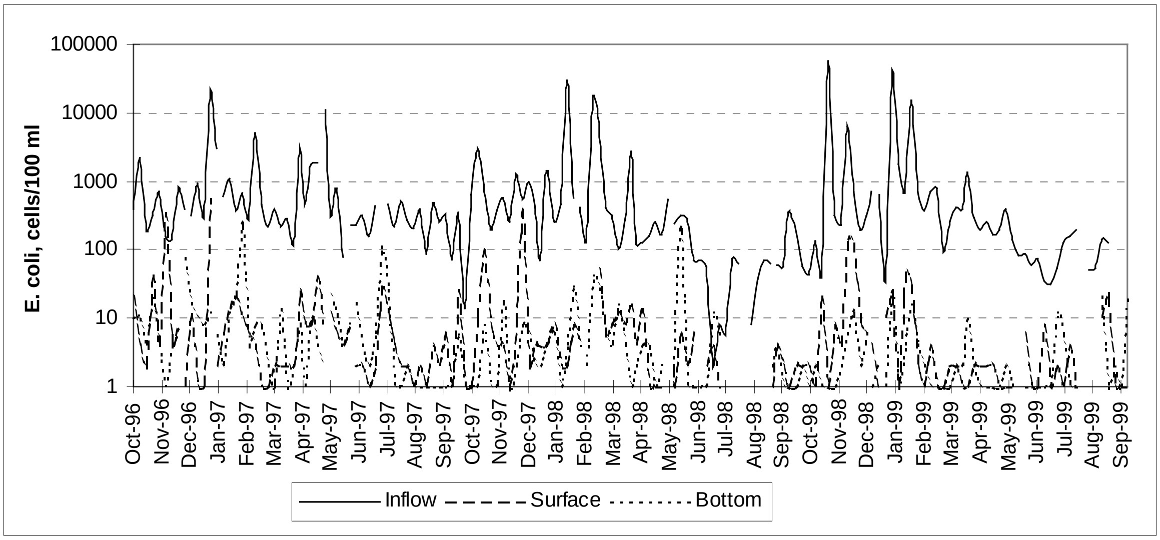
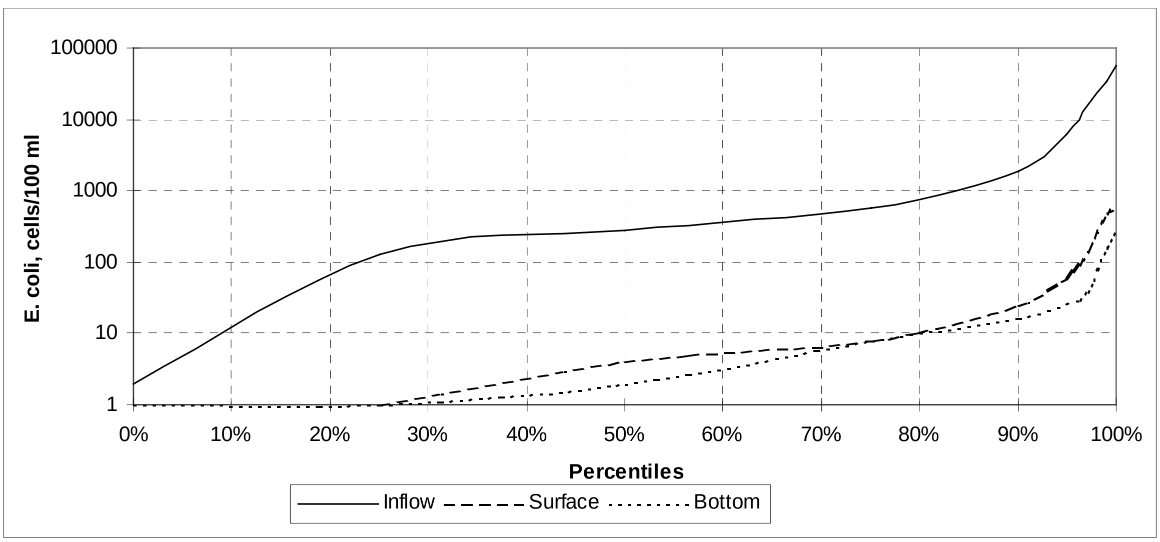


Figure 11: Percentiles for inflow, dam and bottom water *E. coli* concentrations for Inanda dam



The inflow *E. coli* concentrations shown in Figure 9 are generally orders of magnitude higher than those for the dam surface and bottom waters. Bacterial die-off is a normal process that occurs in impounded waters due to irradiation by ultraviolet light and the long retention times in dams. This process therefore greatly improves the bacterial quality of polluted river water. The graphs show that there is little difference in *E. coli* concentrations between the surface and bottom water which have similar data distributions. Consequently, there will be little or no change in bacterial water quality when monthly bottom releases take place. The overall effect of the dams will be a great improvement in water quality from this point of view and therefore no mitigatory steps are required.

pH

The water quality guidelines (DWAF) state that for aquatic ecosystems the pH values should not be allowed to vary from the range of background pH values by more than 0.5 pH units or by greater than 5%, whichever criteria is the more conservative. To evaluate the effects of impoundment on pH, data for Inanda dam was again used and is shown in Figures 12 and 13.

Figure 12: Inflow, dam and bottom water pH values for Inanda dam, 1996-1999

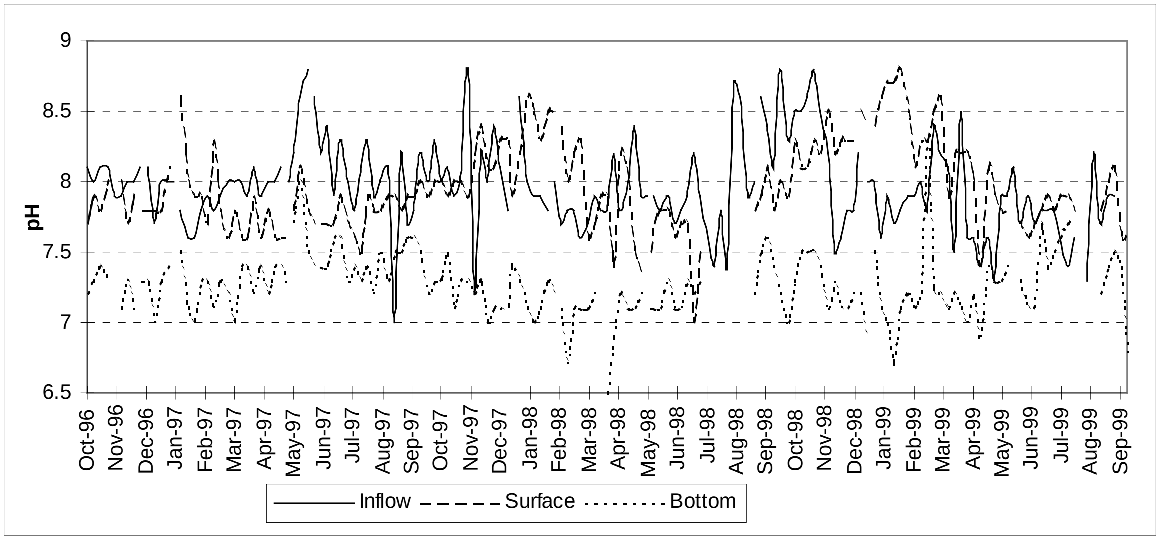


Figure 13: Percentiles for inflow, dam and bottom water pH values for Inanda dam

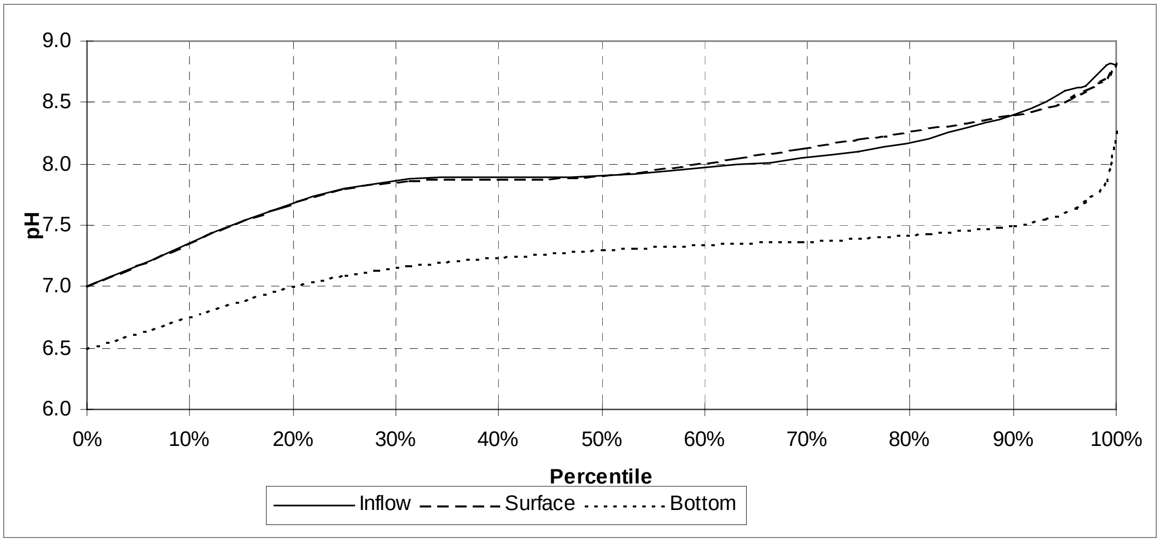


Figure 12 shows that the inflow and dam surface pH values are similar with one or the other being slightly higher or lower at times, while the data distribution graphs in Figure 13 are almost identical. It can therefore be assumed that impoundment will not materially change the natural pH values of the rivers below the dams as long as release is from the aerobic zones of the dams. In Figure 12, the bottom water shows pH values consistently lower than those for the inflow and surface waters with the differences being greater in the summer months when stratification is strong than in the winter months when dam turnover and mixing takes place. The reason for the lower pH values is due to the bottom water being anoxic and anaerobic processes taking place. The data distribution graphs given in Figure 13 show the bottom water to be between 0.5 and 1 pH units lower throughout the percentiles given. Consequently, when monthly bottom water releases from the dams take place, detrimental changes in pH in the receiving rivers could occur as the guidelines given above will be exceeded.

The degree of lowering of pH in the rivers below the dams will depend on the relative volumes of bottom to surface water being released at the time. It should, however, be borne in mind that pH values are the negative logarithms of the hydrogen ion concentrations in water and they cannot simply be averaged to determine the final pH value for a blend of water. For example, should the blend be 50% bottom water with a pH value of 7 and 50% of surface water with a pH value of 8, the resulting pH will not be 7.5, but rather 7.26. To reach a pH value of 7.5 in this example, it can be calculated that there would need to be a blend of 76% of the high pH water with 24% of the low pH water. In practice, the pH of the bottom water released to the river will probably dominate and change that of the river. As a result, there are no mitigatory steps to prevent pH changes in the river taking place that can be suggested.

Ammonia

The ammonia concentrations of the inflow, surface and bottom water for Inanda dam were examined as a common process that occurs in the anoxic zones of dams is the decomposition of organic nitrogen to the inorganic reduced form ammonia, which leads to higher concentrations in this zone. Consequently, when bottom water is released the ammonia concentrations in the rivers below the dams could increase significantly. The increase in concentration will not have any toxic effect to the ecosystem provided that the form of the ammonia is the ammonium ion and not free ammonia which is toxic. Ammonium ions and free ammonia exist in an equilibrium, which is driven by the pH and temperature of the water. As pH and temperature increase, the equilibrium is shifted towards the free unionized ammonia form. The aquatic guidelines (DWAF) give the target concentration of free ammonia not to be exceeded as 0.007 mg/ℓ, the CEV as 0.015 mg/ℓ and the AEV as 0.1 mg/ℓ. Bearing these facts in mind the data for Inanda dam are presented in Figures 14, 15 and 16. Figures 14 and 15 show time series variability and data distribution. Figure 16 is a graph of the data distribution converted to free ammonia concentrations assuming, as a worst case scenario, a pH value of 8.0 and a temperature of 25°C, which could develop lower down the river.

Figure 14 shows the very much higher total ammonia concentrations that develop in the bottom water of Inanda dam compared to the inflow and dam surface water concentrations. The data distribution percentile graphs in Figure 15 adequately show the similarity between inflow and surface water concentrations and the higher percentiles for bottom water, being about double at the 50th percentile and 5 times higher at the 90th percentile. However, Figure 16 is the interesting graph as it shows that the bottom water exceeds the target aquatic guideline concentration at the 55th percentile and the CEV at about the 75th percentile. Should a similar regime exist with the proposed dams, then statistically 45% of bottom water releases would be harmful to the ecosystem and 25% of releases more harmful as exceeding the CEV. Of course, blending of the bottom water with aerobic surface release water will reduce the ammonia concentrations and therefore the toxicity as well. The only mitigatory step that could be taken would be to ensure the release of as much surface water as possible together with the monthly bottom water releases.

Figure 14: Inflow, dam and bottom water ammonia concentrations for Inanda dam, 1996-1999

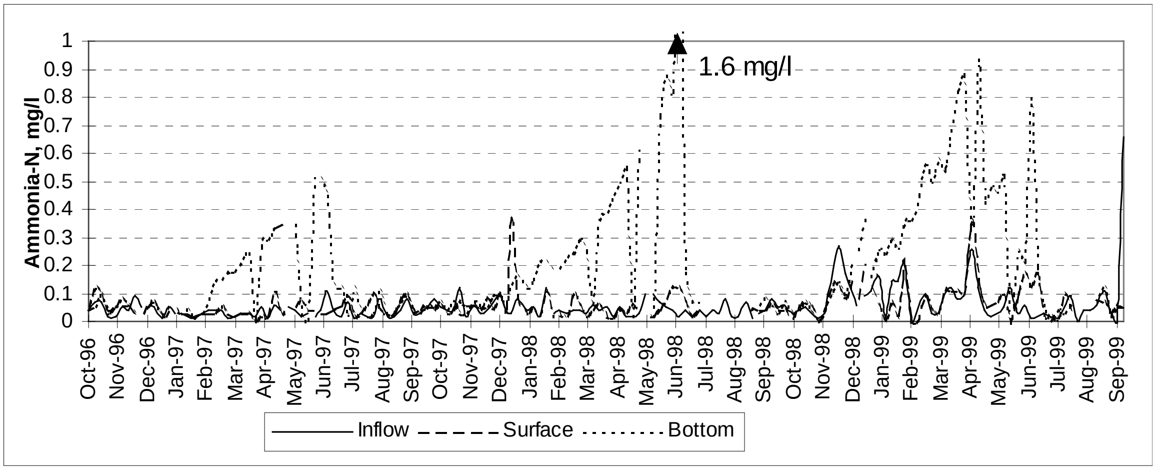


Figure 15: Percentiles for inflow, dam and bottom water ammonia concentrations for Inanda dam

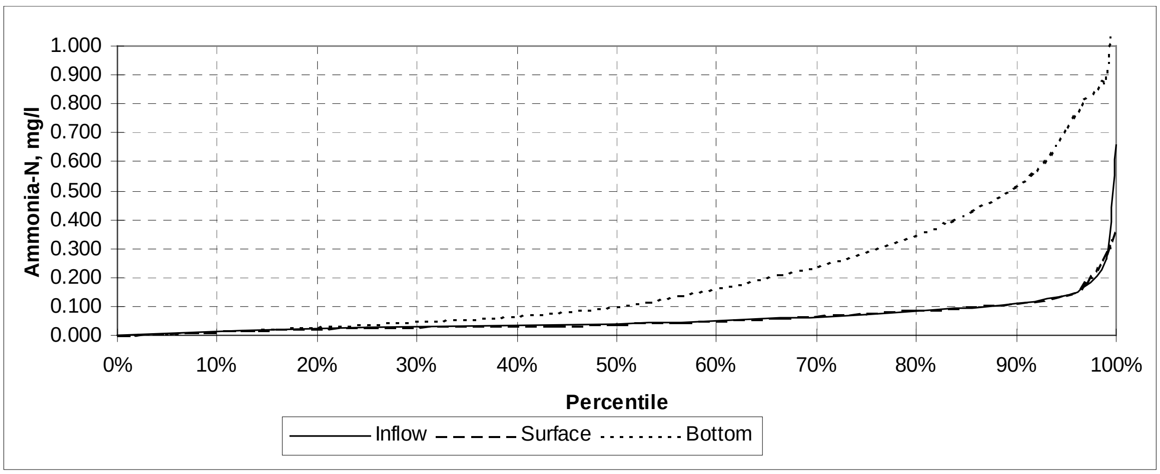
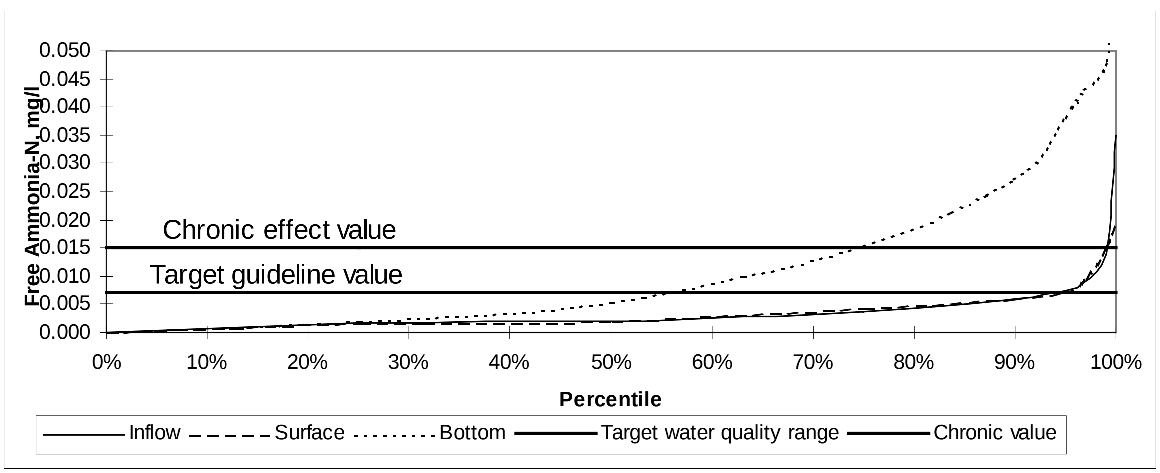


Figure 16: Percentiles for inflow, dam and bottom water free ammonia concentrations for Inanda dam



Temperature and dissolved oxygen profiles likely to develop in the dams and impacts of releases

Temperature

The change in temperature of the rivers below the dams with respect to the natural regime will depend upon where the dam releases come from (different levels or scour) and the time of the year. As a generality for summer, low level and bottom releases will be colder and surface releases warmer than inflow temperatures, while in winter, provided that the dam has turned and mixed, releases from all levels will be warmer. These patterns have been found for the Midmar and Inanda dams in KZN, and it is assumed that similar patterns will develop for the proposed Jana and Mielietuin dams. With this in mind and to quantify the changes from the natural regime that can come about, the data for Midmar and Inanda dams have been evaluated. A limitation of making this assumption is that the Jana and Mielietuin dams will be far deeper and larger than both Midmar and Inanda dams, as well as having quite different geographic locations and elevations. The wall heights of the Jana and Mielietuin dams could be up to 190 m and 95 m respectively, while the maximum depths for the Midmar and Inanda dams are about 22 m and 44 m respectively. Consequently, stratification in the proposed dams could be stronger and it is suggested that their great depths may prevent complete dam mixing and turnover in winter, thus having year-round stratification of temperature and possibly dissolved oxygen as well. Nevertheless, the Midmar and Inanda data are shown to make estimates of temperature changes likely to occur and it should be borne in mind that it is the relative temperature differences between inflow and dam levels and not the actual temperatures that will be discussed.

Typical stratification patterns for Midmar and Inanda dams are given at 2 m depth intervals for the 1997/98 cycles in Figures 17 and 18 respectively. The following points may be noted from the Figures:

- For both dams, the maximum temperatures differences between surface and bottom water occurs in January/February and is about 10^{o}C.
- Bottom temperatures for Midmar dam increase from October to May by about 5^{o}C, while for Inanda dam the increase over the same period is only about 1^{o}C. The difference between these patterns is considered to be due to the greater depth in Inanda dam and therefore stability. The inference is that deeper dams such as the Jana and Mielietuin will have stable bottom temperatures.
- For Inanda dam, the differences in temperatures between 2 m depths greater than about 32 m decreases rapidly indicating that a finite lower temperature is being reached. The inference is that in the deeper Jana and Mielietuin dams, a lower temperature limit with depth will aslo be reached.
- Dam turnover and isothermal conditions for Midmar dam were reached in May, but for the deeper Inanda dam, dam turnover only occurred in mid-June. The result is that isothermal conditions in Midmar dam prevailed for about 4 months but for Inanda dam only about 2 months. The inference is that the period of temperature stratification for dams is a function of depth and that for the very deep Jana and Mielietuin dams, stratification may be permanent features.

If the above patterns and suggestions are assumed for the Jana and Mielietuin dams, then temperature differences of about 10^{o}C between surface and bottom waters will exist and consequently when monthly bottom releases take place there will be a considerable shock to the ecosystem. The guidelines for aquatic life (DWAF) state that temperature changes should not exceed 2^{o}C from the natural regime. A further negative impact could be that because of the size and depth of the dams, this imbalance could exist all year round.

Figure 17: Midmar dam temperature profiles for 1997/98

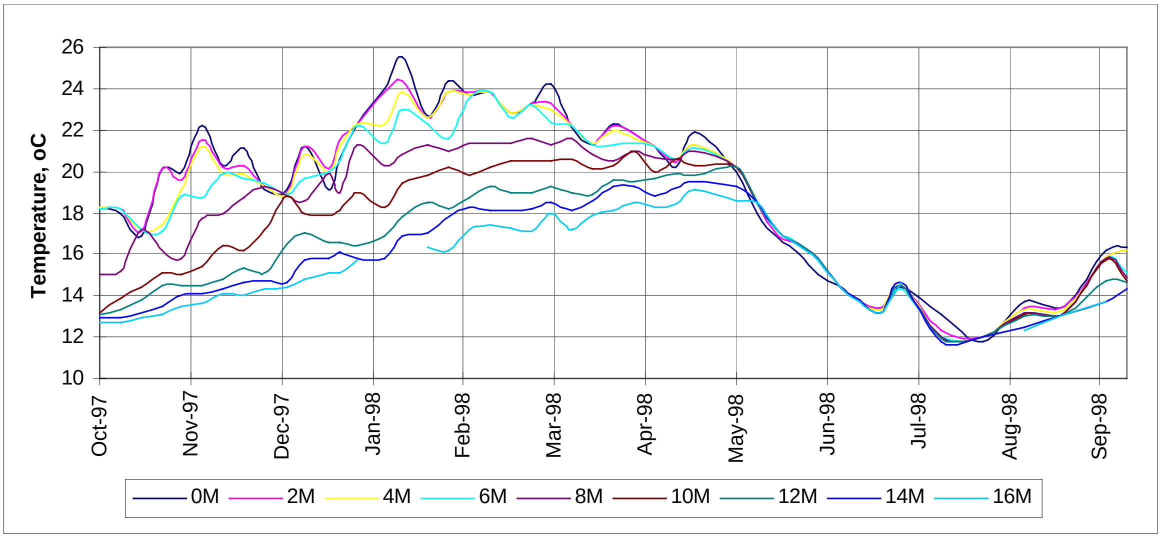
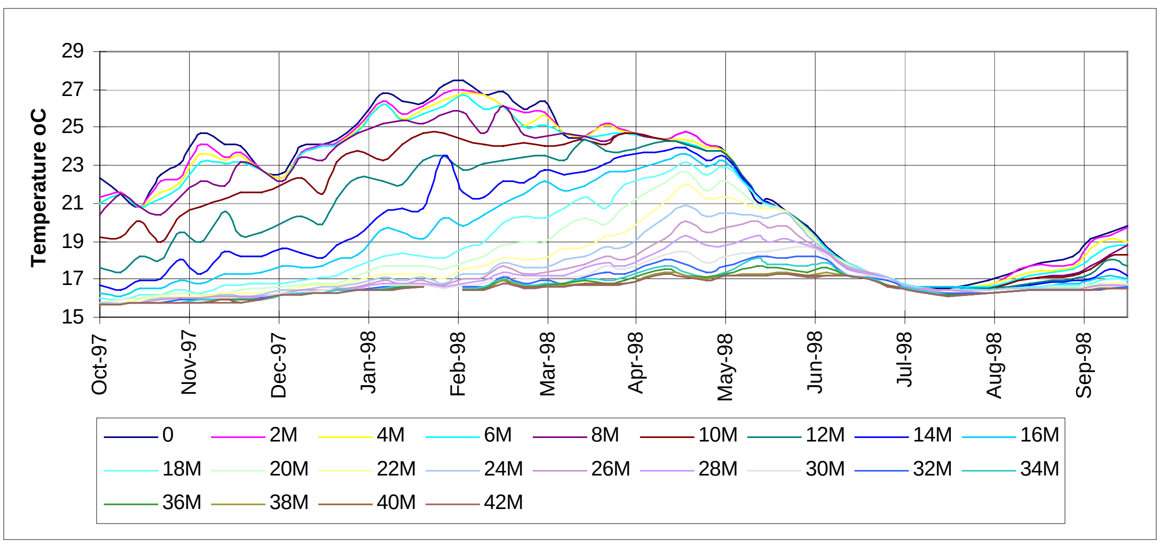


Figure 18: Inanda dam temperature profiles for 1997/98



To give an idea of how different temperatures in discharges from the dams will be to the natural temperatures of the rivers that they displace, the differences between level temperatures for the Midmar and Inanda dams and their inflow temperatures have been graphed in Figures 19 and 20. A limitation of using this data for this purpose, apart from the limitations mentioned above, is that the dam inflow temperatures are spot readings usually taken in the mornings and therefore do not take account of diurnal variations. These facts should be borne in mind in assessing the data presented.

Points to note about Figures 19 and 20 are that the differences for both graphs are both warmer and colder than the inflow temperatures depending on the levels in the dams. For Midmar dam, the surface and 6 m depth temperatures are generally warmer by up to 5^{o}C between October and May, while for the same period the 16 m depth temperature is as much as 7 to 8°C colder than the inflow. After turnover during May to July, all levels are generally warmer than the inflow. The data for Inanda dam generally support these trends with the exception that the lowest depth, 42 m, shows a temperature as much as 13°C colder than the inflow, no doubt being due to the greater depth in the dam. The implication for the Jana and Mielietuin dams is that that the natural temperature regime of the rivers will be disturbed, the severity of which will depend on the dam discharge level being used. In mitigation, the level for discharge from the dams could be selected to most closely match the natural temperature of the river. However, this will not be possible when monthly bottom discharges are made and far colder water is discharged. Mixing with water in the tailponds may ameliorate these changes to some degree.

Figure 19: Differences in temperature between levels and inflow to Midmar dam

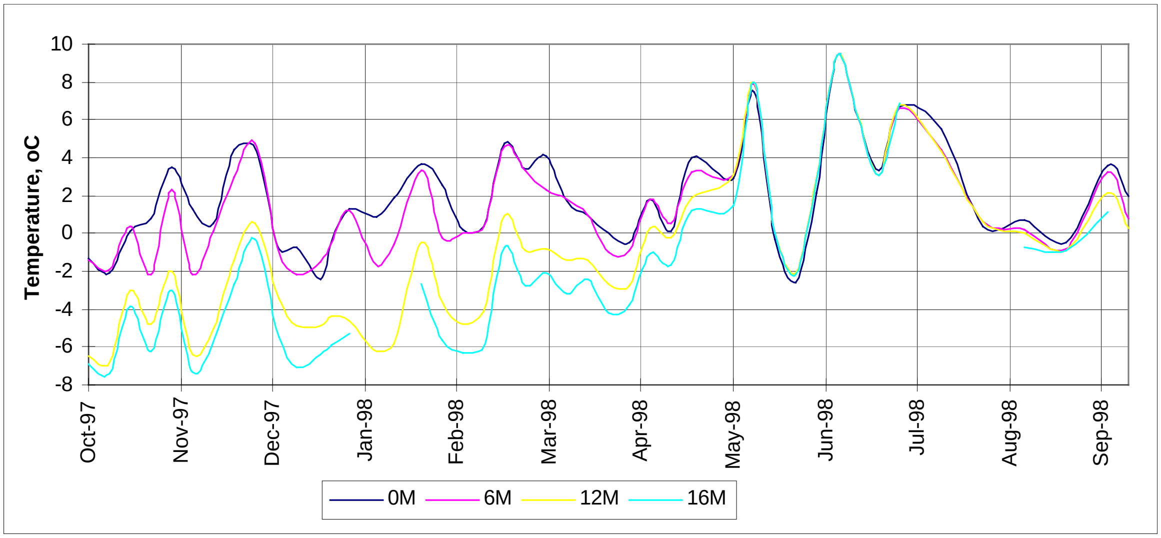
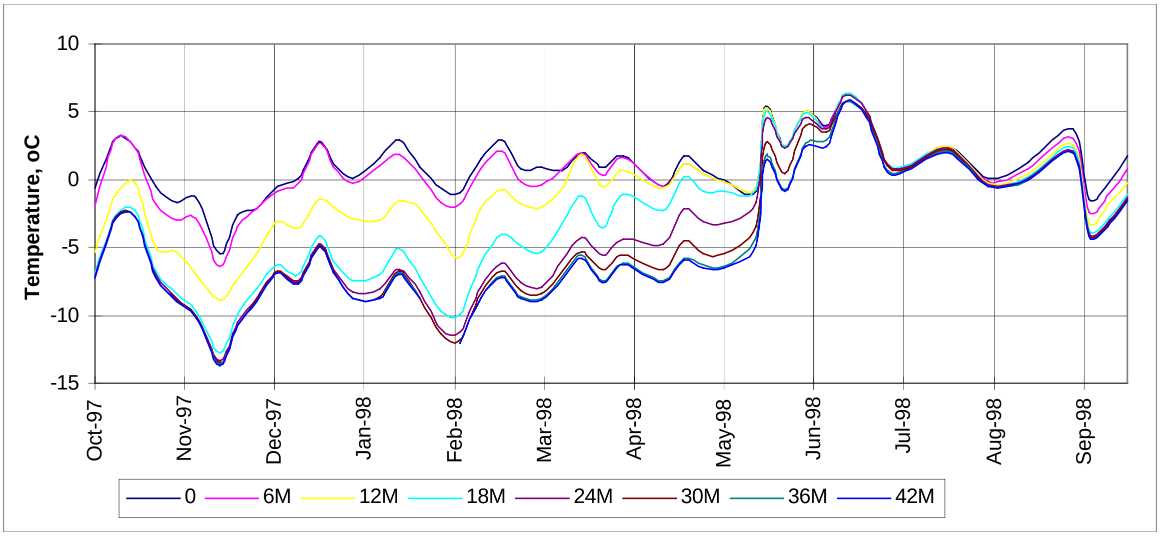


Figure 20: Differences in temperature between levels and inflow to Inanda dam



Dissolved oxygen

According to the aquatic life guidelines (DWAF), the target concentration of dissolved oxygen (DO) in ecosystems should not be less that 80% of saturation, the minimum allowable 60% and the lethal is less than 40% for sensitive species. There is no doubt that the Jana and Mielietuin dams will stratify with respect to DO with anoxic water, but the question is at what level will low DO concentrations develop. To estimate likely patterns in the dams, the Midmar and Inanda dam data have again been used and their typical DO profiles at 6 m depths over a year are shown in Figures 21 and 22.

Figure 21: Midmar dam dissolved oxygen profiles for 1997/98

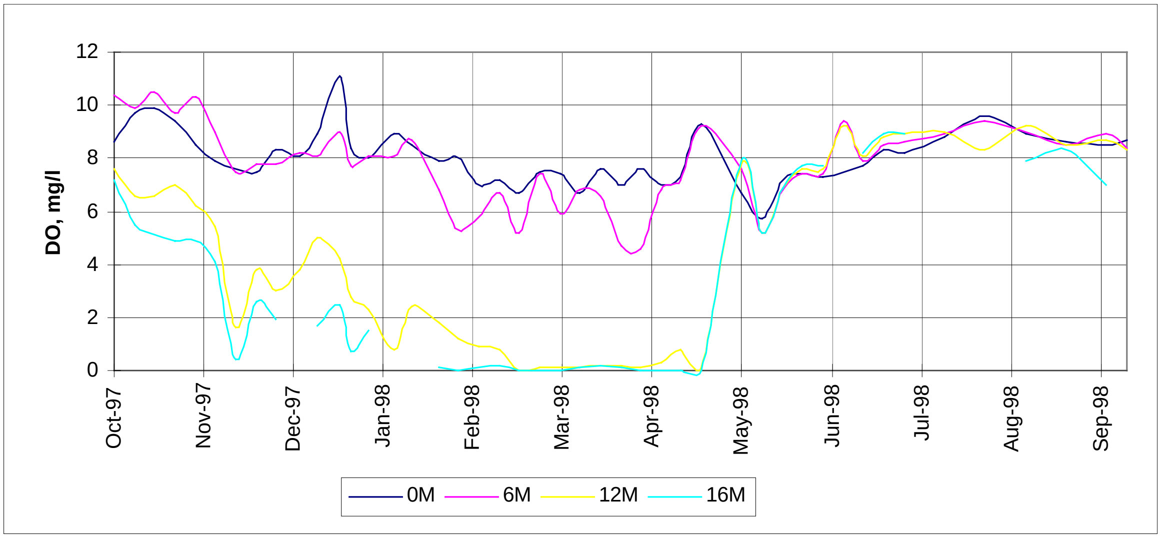
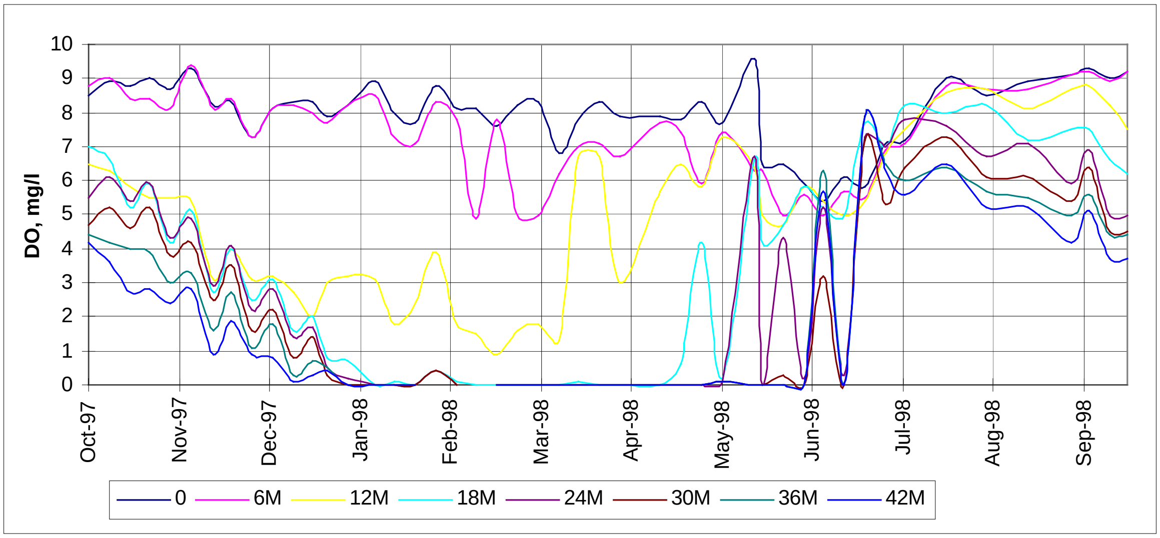


Figure 22: Inanda dam dissolved oxygen profiles for 1997/98



Six metre DO profiles for the water columns were chosen as it is believed that the Jana and Mielietuin dams will be able to release water from valves at these intervals. Figures 21 and 22 both show that the oxyclines, where there is severe oxygen depletion develop at between 6 and 12 m depths in the dams. In fact, although not shown, closer depth interval data show DO concentrations below 4 mg/ℓ, which is generally recognized as the lower limit for the protection of aquatic life, at the 8 to 10 m depths. These patterns are not unique to KZN dams as data for the Roodeplaat and Hartbeespoort dams show similar oxygen depletion at these depths (pers. Comm. C van Ginkel, DWAF). Should similar patterns develop in the Thukela dams, then release of aerobic water to the rivers will be restricted to the uppermost level drawoff. The data for Midmar dam show that low DO concentrations (0 - 4 mg/ℓ) occur at the 16 m depth for the period between November and April, but for Inanda dam this period is extended to June, 2 months longer. The reason for the longer period is probably due to the greater depth in the dam, which implies that for much deeper dams such as Jana and Mielietuin, the bottom waters may never become oxygenated as remain anoxic all year.

For mitigation of monthly releases of anoxic bottom waters, the release mechanism should be such that the water is rapidly re-oxygenated, which can be brought about by spraying the water into the tailponds below the dams. This mechanism is used at the Albert Falls dam in KZN and measurement has shown that near DO saturation concentrations are reached quickly in the receiving pond. Should this type of release not be possible, then re-oxygenation in the river will be slower, and it was found for Midmar dam release of bottom water that it took about 2.2 km river distance to reach a DO concentration of 6 mg/ℓ (Umgeni Water report, June 1999). Associated with the release of anoxic bottom water will be not only the presence of higher than normal concentrations of heavy metals such as iron and manganese as already discussed, but other reduced compounds such as sulphides which are toxic. Neutralization of the detriment effects of these compounds can partially be achieved through oxidation and hence the importance of rapid re-oxygenation of releases.

BASELINE AND FUTURE MONITORING

It is suggested that the following monitoring and modelling be set up to better assess the water quality that will develop in the Jana and Mielietuin dams and possible downstream impacts:

- That monitoring of the Thukela and Bushmans rivers be established at or as close as possible to the dam sites at weekly intervals in the summer months when flow is high. Monitoring as 2-weekly or monthly intervals in the low flow winter period should suffice. Preferable monitoring for water quality at these sites would be the establishment of permanent weirs with kiosks to enable flow recording and the installation of automatic sampling equipment to sample flow on a flow-weighted volumetric basis. This method of sampling would provide the most representative and accurate water quality data for the rivers.
- That monitoring at the existing DWAF stations used in this report be maintained to assess pollution levels, but that additional analyses of samples should be conducted for faecal bacteria (*E. coli*), turbidity, suspended solids, total phosphorus, iron, manganese, total organic carbon and occasional analysis for a range of other toxic metals.
- That monitoring of the Sundays, Mooi and Buffels rivers at suitable sites close to their confluences with the Thukela river be set up to characterize water quality from these catchments so that future water quality in the Thukela river when there is restricted flow from the dams can be estimated, and any potential problems for water users identified. A water quality model using this type of data may be appropriate for this purpose.
- That a more deterministic water quality model to predict the eutrophication status likely to develop in the Jana and Mielietuin dams be employed.

- That all point source discharges upstream of the dams be monitored for bacterial, organic and nutrient loads. This monitoring may already be in place, but its efficacy needs to be assessed and upgraded if necessary.

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Umgeni Water Report - Water quality assessment of the Midmar dam - The environmental impact of raising the impoundment wall and interbasin transfer from the Mooi river catchment, June 1999.

CREDENTIALS OF SPECIALIST

Dean Simpson, Nat. Chem. Tech. Dip., BSc (Chem), MSc (Eng), Pr. Sci. Nat., WISA (Fellow).

Thirty years experience in water related research at the CSIR involving diffuse pollution of rivers, dams, estuaries and urban catchments. Five years experience at Umgeni Water assessing water quality in the rivers and dams in the Umgeni Water operational area; predicting the water quality for new water resources developments (dams); providing operational advice on the operation of Umgeni Water dams for water abstraction and purification.

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APPENDIX 1a

LOCATION OF THE DWAF SAMPLE SITES, THE JANA AND MIELIERTUIN DAMS AND THE UMGENI WATER SAMPLE SITE, 150

LANDUSE MAP OF THE JANA DAM

LANDUSE MAP OF THE MIELIETUIN DAM

Figure 1: Location of DWAF and Umgeni Water sampling sites used for water quality in the Thukela river catchment

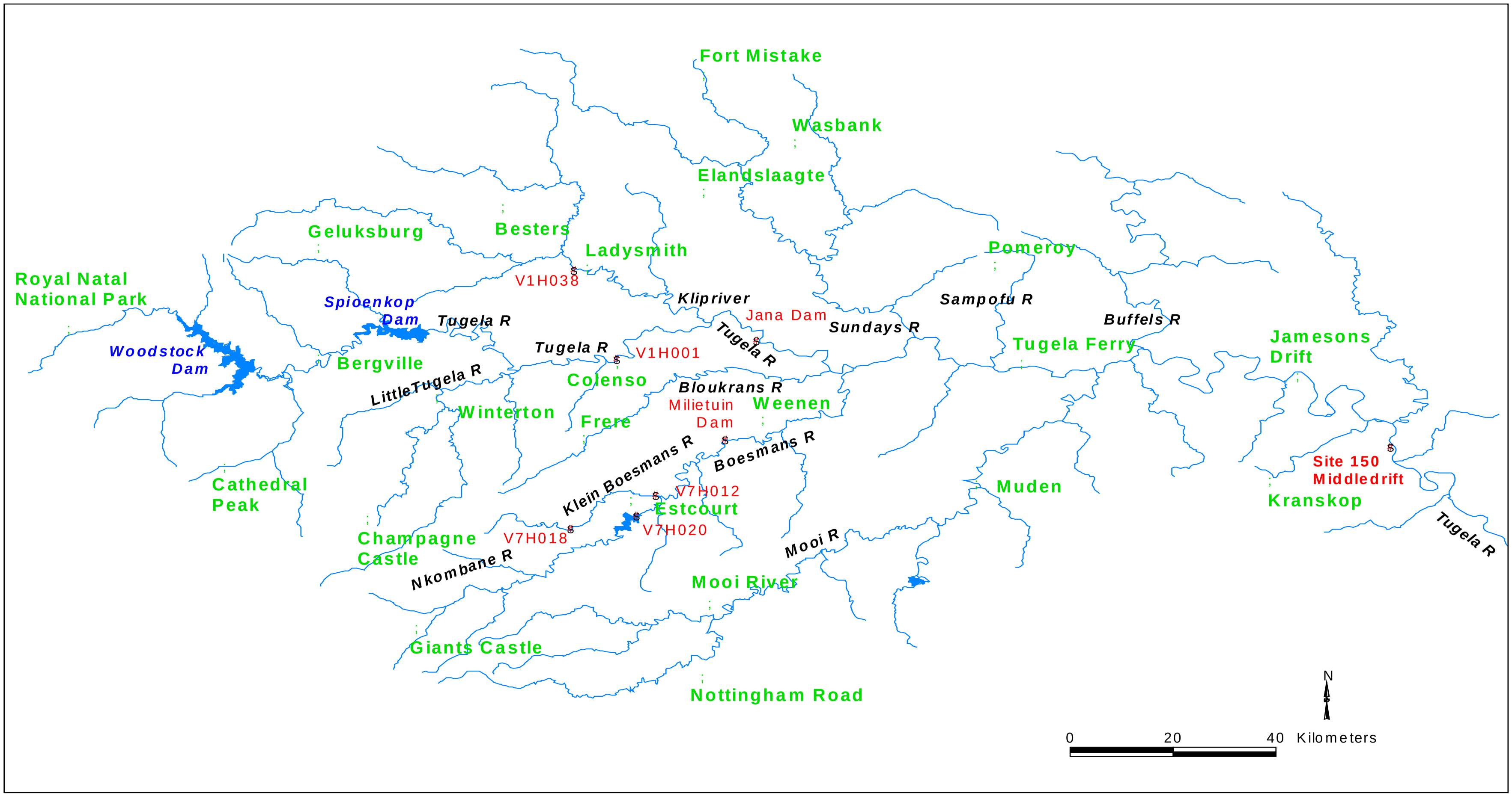


Figure 2: Landuse in the proposed Jana dam catchment

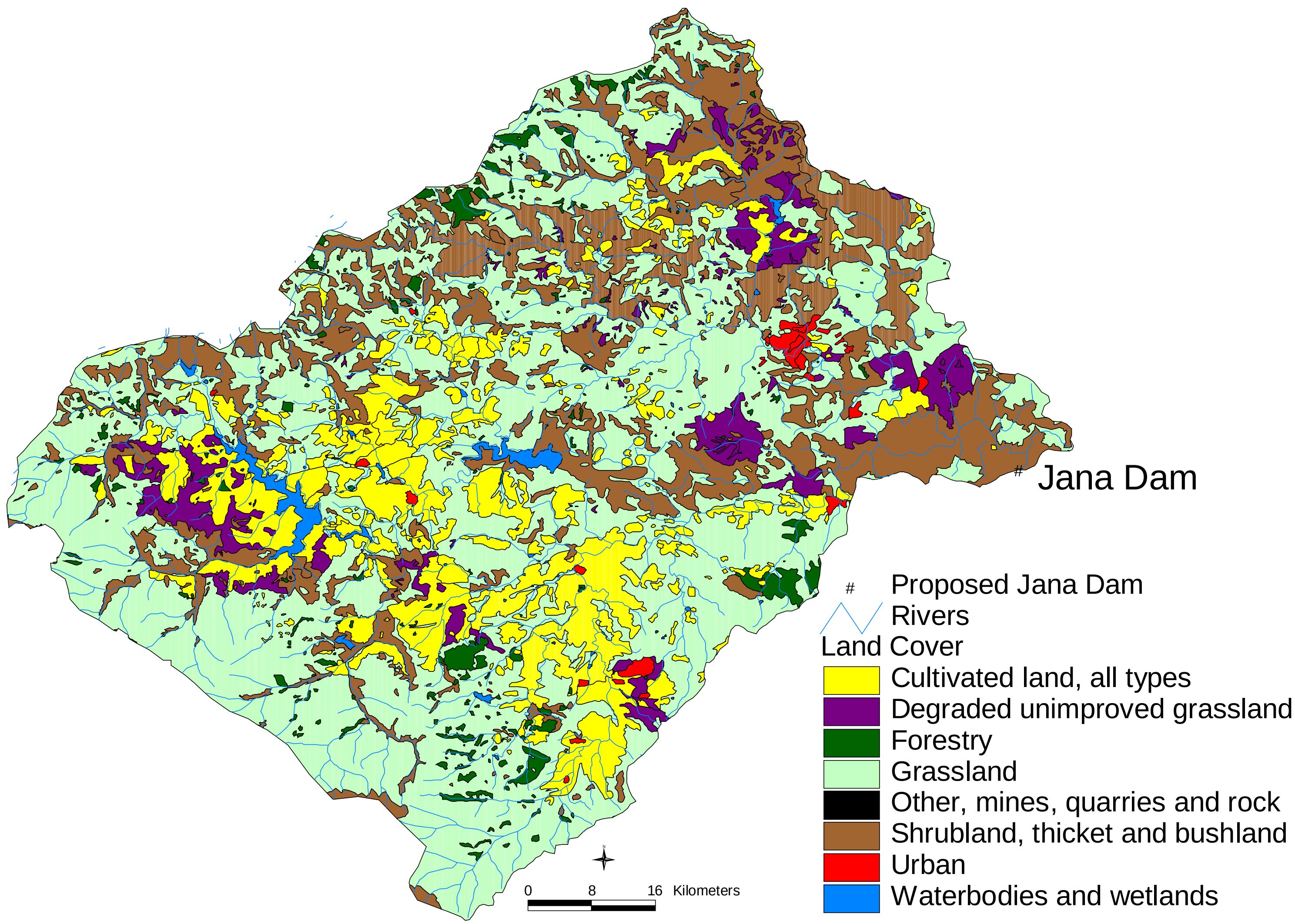
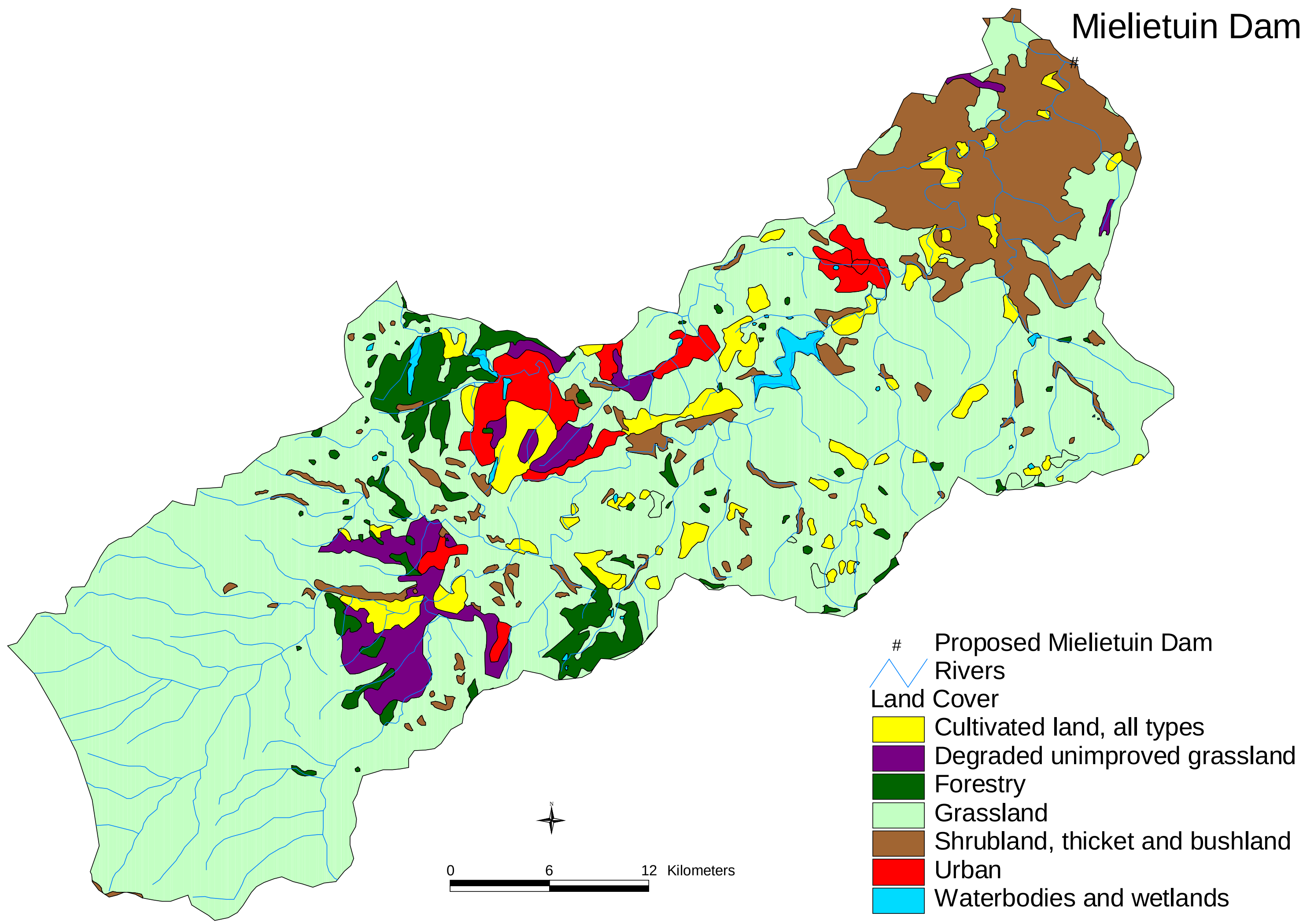


Figure 3: Landuse in the proposed Mielietuin dam catchment



APPENDIX 1b

ANALYTICAL DATA FOR THE DWAF STATIONS:

V1H001, THUKELA RIVER AT THUKELA DRIFT/COLENSO

V1H038, KLIP RIVER AT LADYSMITH

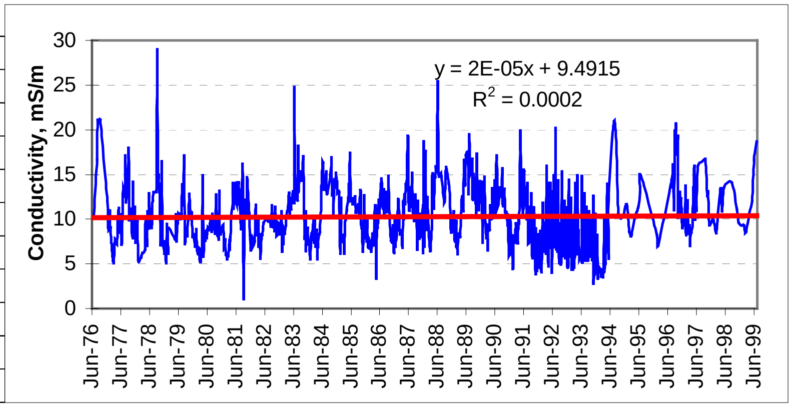
V7H018, LITTLE BUSHMANS RIVER AT SLOY/CRAIG

V7H012, LITTLE BUSHMANS RIVER AT ESTCOURT

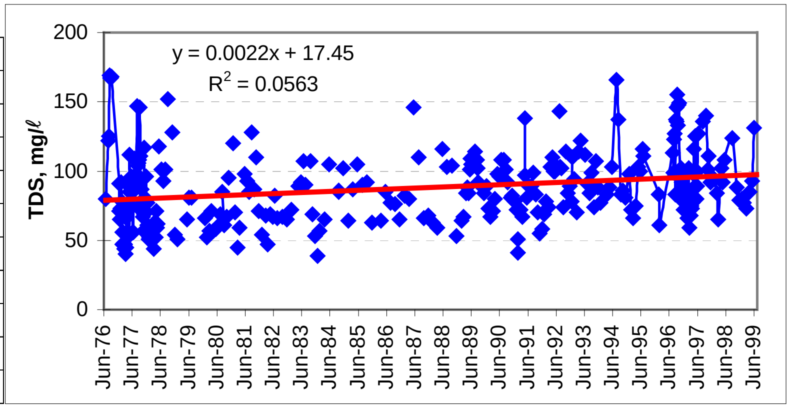
V7H020, BUSHMANS RIVER BELOW WAGONDRIFT DAM

DWAF SAMPLE STATION NUMBER V1H001 Tugela River at Tugela Drift / Colenso

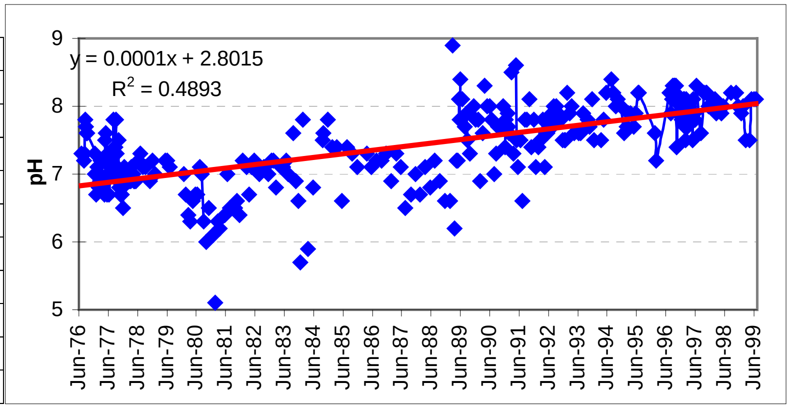
Conductivity (mS/m)	
N	891
0th percentile	1.1
25th percentile	7.6
50th percentile	9.9
75th percentile	12.5
90th percentile	14.6
95th percentile	16.5
99th percentile	20.3
100th percentile	29.0
Dates	06/76 - 07/99



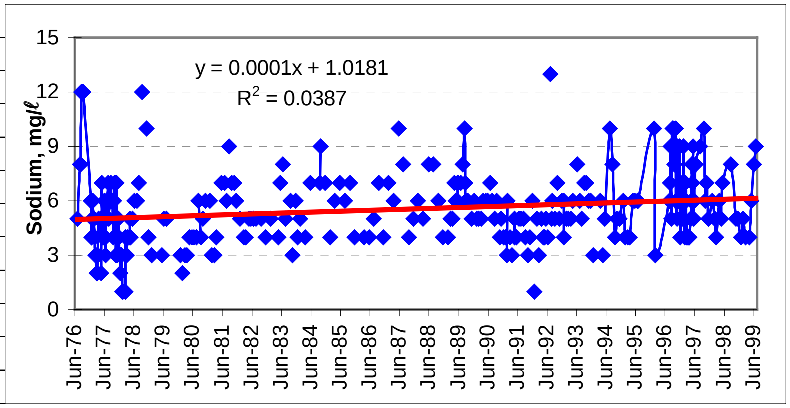
Total Dissolved Salts (mg/ℓ)	
N	304
0th percentile	39
25th percentile	69
50th percentile	85
75th percentile	102
90th percentile	123
95th percentile	138
99th percentile	167
100th percentile	169
Dates	06/76 - 07/99



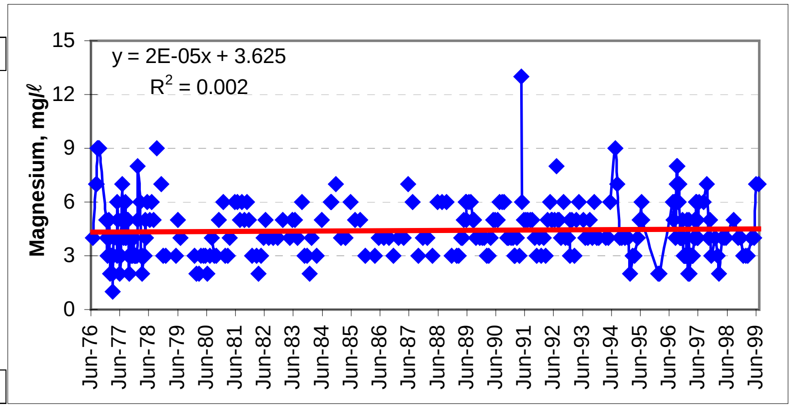
pH	
N	308
0th percentile	5.1
25th percentile	7
50th percentile	7.5
75th percentile	7.9
90th percentile	8.1
95th percentile	8.2
99th percentile	8.4
100th percentile	8.9
Dates	06/76 - 07/99



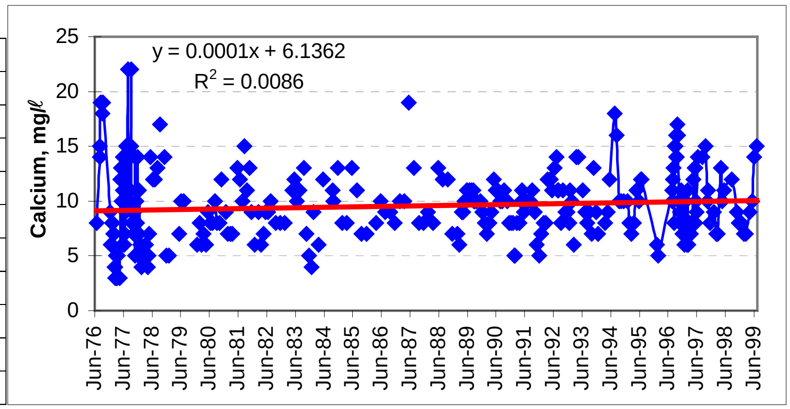
Sodium (mg/ℓ)	
N	305
0th percentile	1
25th percentile	3
50th percentile	4
75th percentile	5
90th percentile	6
95th percentile	7
99th percentile	9
100th percentile	13
Dates	06/76 - 07/99



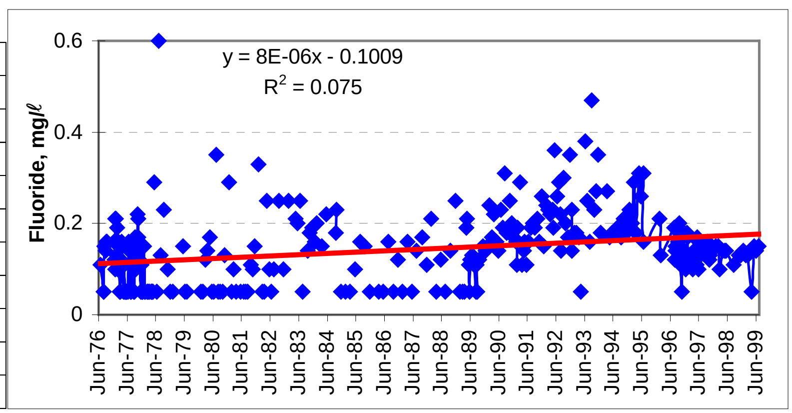
Magnesium (mg/ℓ)	
N	305
0th percentile	1
25th percentile	3
50th percentile	4
75th percentile	5
90th percentile	6
95th percentile	7
99th percentile	9
100th percentile	13
Dates	06/76 - 07/99



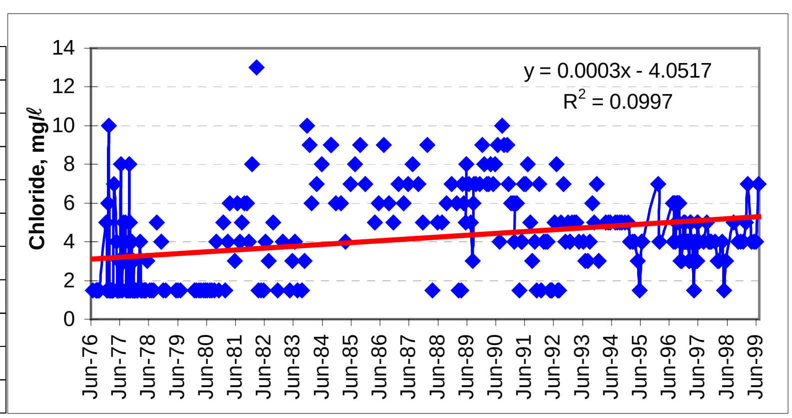
Calcium (mg/ℓ)	
N	305
0th percentile	3
25th percentile	8
50th percentile	9
75th percentile	11
90th percentile	14
95th percentile	15
99th percentile	19
100th percentile	22
Dates	02/66 - 07/99



Fluoride (mg/ℓ)	
N	305
0th percentile	0.05
25th percentile	0.10
50th percentile	0.14
75th percentile	0.18
90th percentile	0.24
95th percentile	0.29
99th percentile	0.36
100th percentile	0.60
Dates	06/76 - 07/99

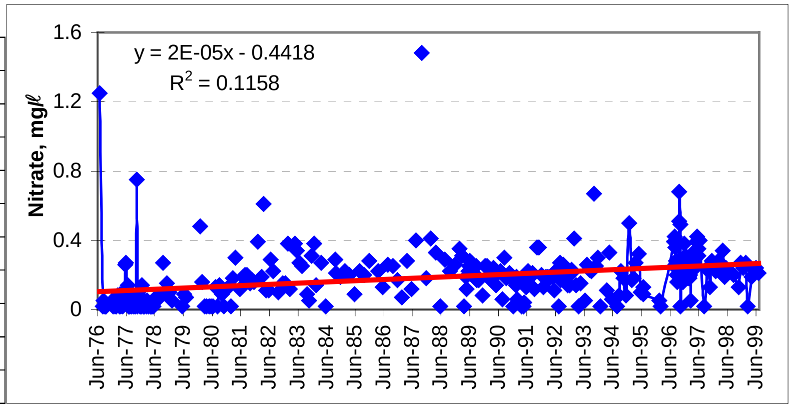


Chloride (mg/ℓ)	
N	305
0th percentile	1.5
25th percentile	1.5
50th percentile	4.0
75th percentile	6.0
90th percentile	7.0
95th percentile	8.0
99th percentile	10.0
100th percentile	13.0
Dates	06/76 - 07/99

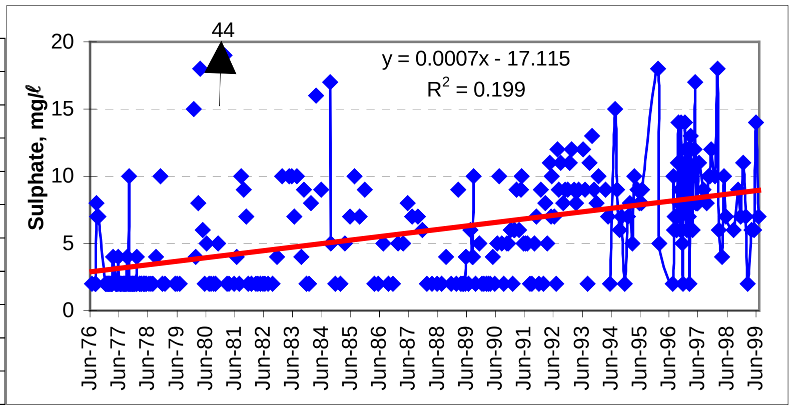


DWAF SAMPLE STATION NUMBER V1H001 Tugela River at Tugela Drift / Colenso

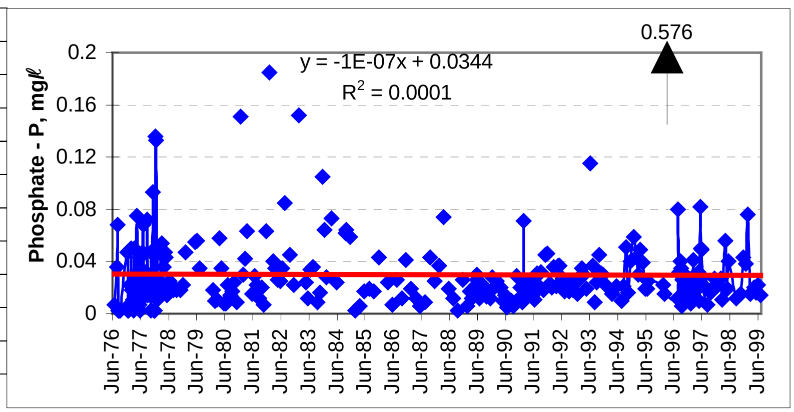
Nitrate (mg/ℓ)	
N	307
0th percentile	0.02
25th percentile	0.06
50th percentile	0.18
75th percentile	0.25
90th percentile	0.33
95th percentile	0.40
99th percentile	0.68
100th percentile	1.48
Dates	06/76 - 07/99



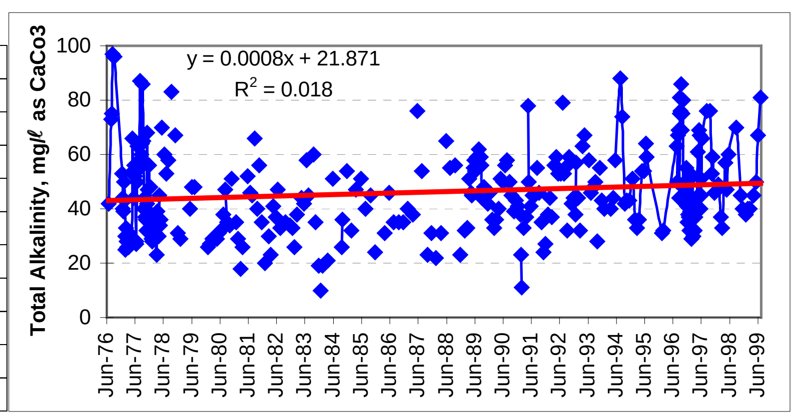
Sulphate (mg/ℓ)	
N	305
0th percentile	2
25th percentile	2
50th percentile	5
75th percentile	9
90th percentile	11
95th percentile	13
99th percentile	18
100th percentile	44
Dates	06/76 - 07/99



Phosphate - P (mg/ℓ)	
N	305
0th percentile	0.003
25th percentile	0.014
50th percentile	0.022
75th percentile	0.035
90th percentile	0.055
95th percentile	0.073
99th percentile	0.150
100th percentile	0.576
Dates	06/76 - 07/99

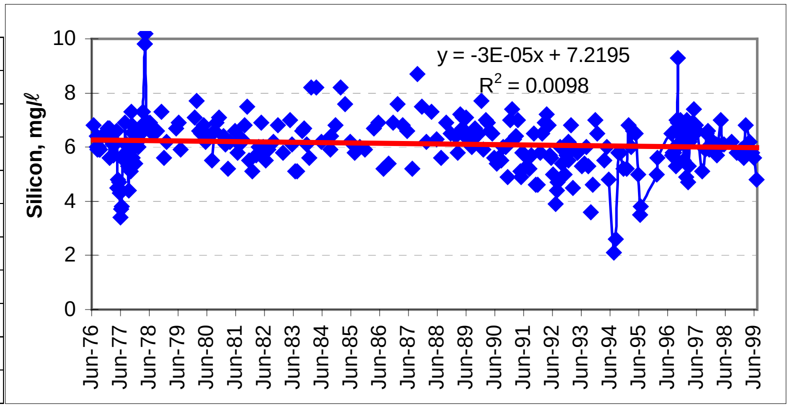


Total Alkalinity (mg/ℓ) as CaCO3	
N	307
0th percentile	10
25th percentile	35
50th percentile	44
75th percentile	55
90th percentile	67
95th percentile	76
99th percentile	96
100th percentile	97
Dates	06/76 - 07/99

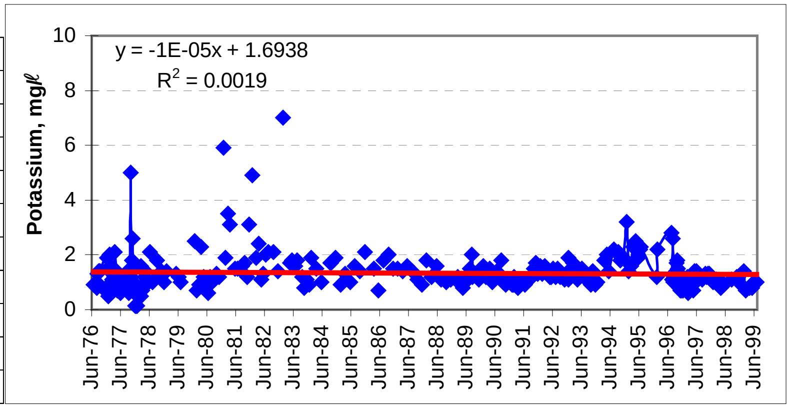


DWAF SAMPLE STATION NUMBER V1H001 Tugela River at Tugela Drift / Colenso

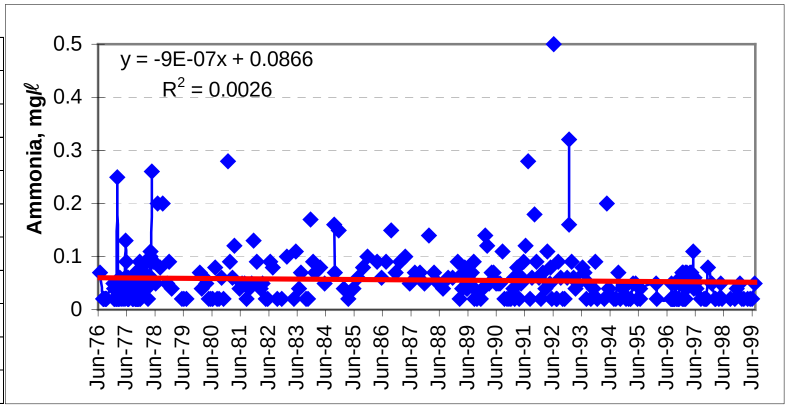
Silicon (mg/ℓ)	
N	305
0th percentile	2
25th percentile	6
50th percentile	6
75th percentile	7
90th percentile	7
95th percentile	7
99th percentile	9
100th percentile	10
Dates	06/76 - 07/99



Potassium (mg/ℓ)	
N	305
0th percentile	0
25th percentile	1
50th percentile	1
75th percentile	2
90th percentile	2
95th percentile	2
99th percentile	5
100th percentile	7
Dates	06/76 - 07/99

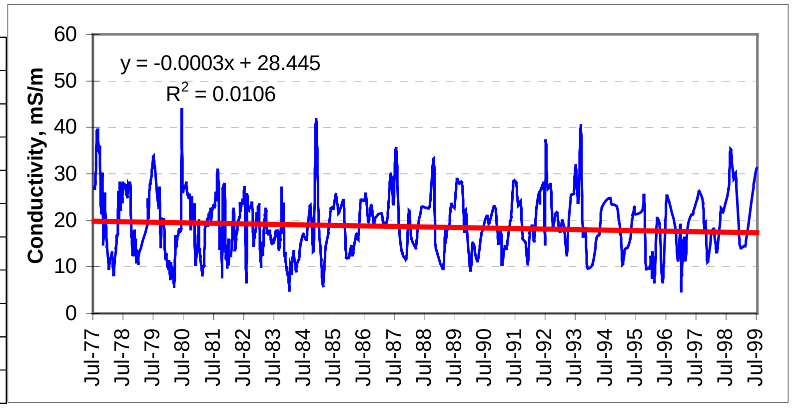


Ammonia (mg/ℓ)	
N	305
0th percentile	0.02
25th percentile	0.02
50th percentile	0.05
75th percentile	0.07
90th percentile	0.10
95th percentile	0.14
99th percentile	0.28
100th percentile	0.50
Dates	06/76 - 07/99

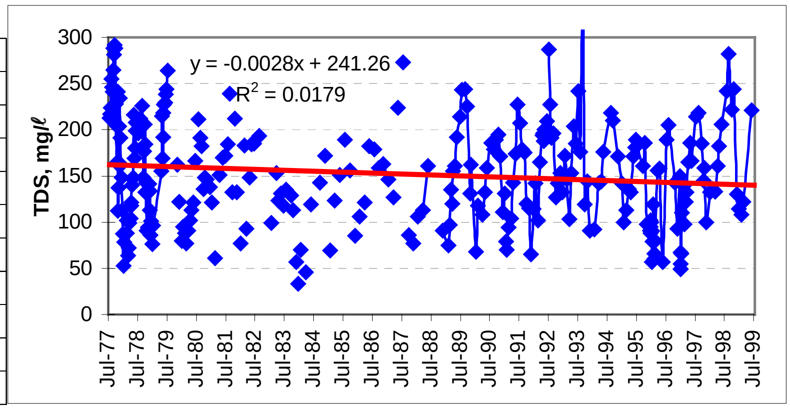


DWAF SAMPLE STATION NUMBER V1H038 Klipriver at Ladysmith

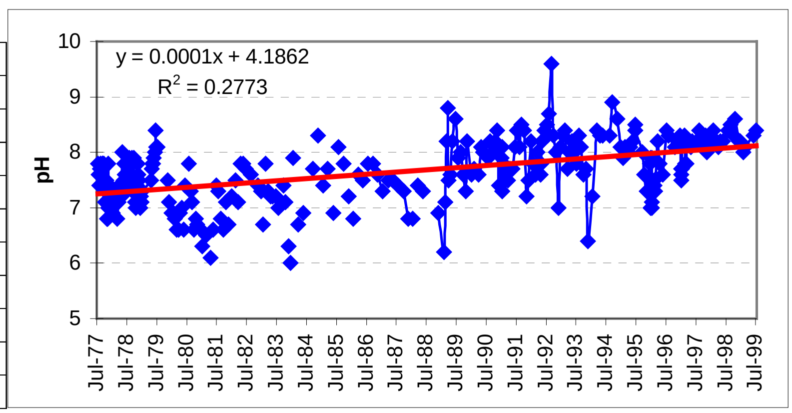
Conductivity (mS/m)	
N	485
0th percentile	4.8
25th percentile	13.9
50th percentile	18.0
75th percentile	23.4
90th percentile	27.6
95th percentile	29.9
99th percentile	39.1
100th percentile	44.2
Dates	07/77 - 07/99



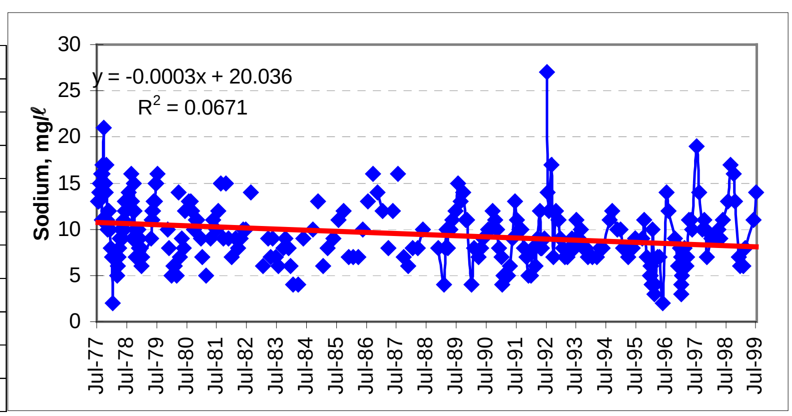
Total Dissolved Salts (mg/ℓ)	
N	291
0th percentile	33
25th percentile	109
50th percentile	147
75th percentile	192
90th percentile	225
95th percentile	244
99th percentile	288
100th percentile	357
Dates	07/77 - 07/99



pH	
N	296
0th percentile	6.0
25th percentile	7.3
50th percentile	7.7
75th percentile	8.1
90th percentile	8.3
95th percentile	8.4
99th percentile	8.7
100th percentile	9.6
Dates	07/77 - 07/99

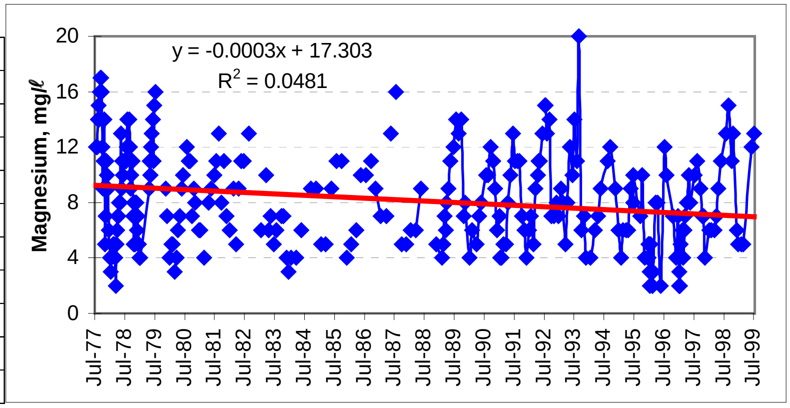


Sodium (mg/ℓ)	
N	292
0th percentile	2
25th percentile	7
50th percentile	9
75th percentile	12
90th percentile	14
95th percentile	15
99th percentile	17
100th percentile	27
Dates	07/77 - 07/99

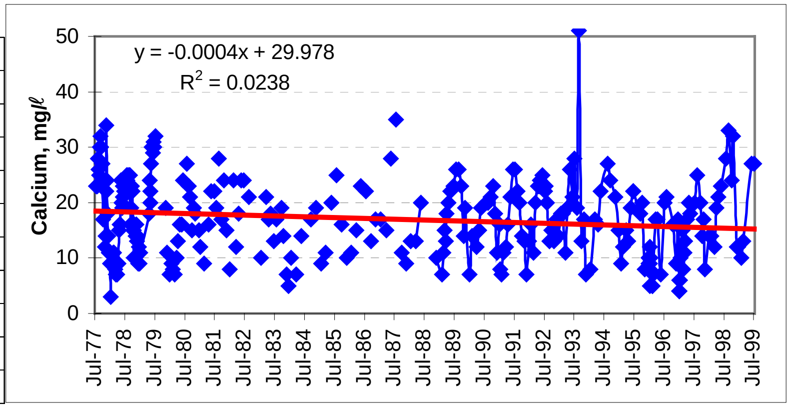


DWAF SAMPLE STATION NUMBER V1H038 Klipriver at Ladysmith

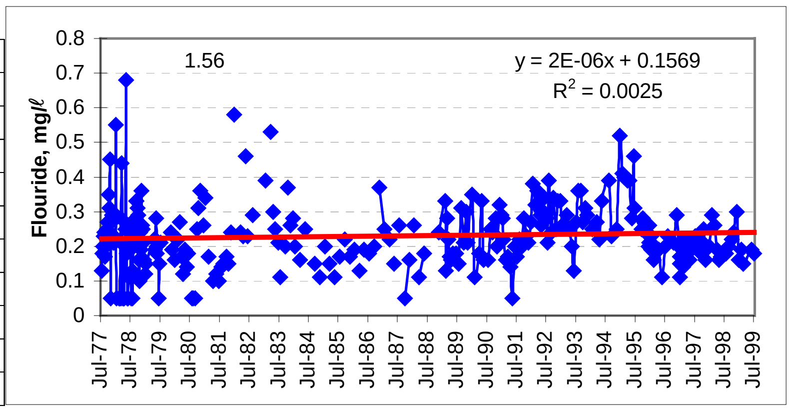
Magnesium (mg/ℓ)	
N	292
0th percentile	2
25th percentile	5
50th percentile	8
75th percentile	11
90th percentile	13
95th percentile	14
99th percentile	16
100th percentile	20
Dates	07/77 - 07/99



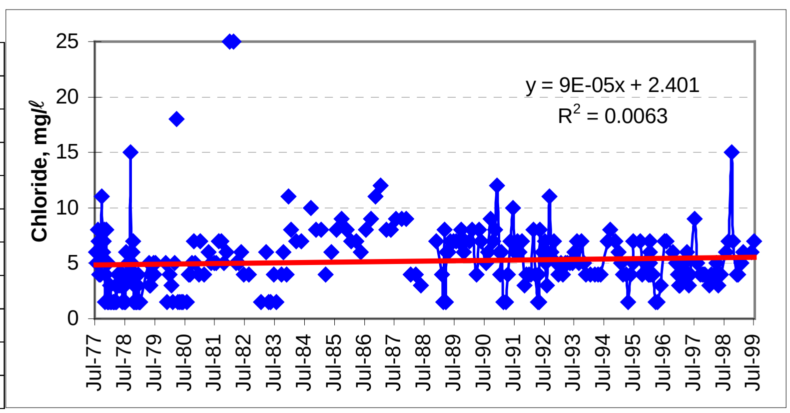
Calcium (mg/ℓ)	
N	292
0th percentile	3
25th percentile	11
50th percentile	17
75th percentile	22
90th percentile	26
95th percentile	28
99th percentile	33
100th percentile	51
Dates	07/77 - 07/99



Fluoride (mg/ℓ)	
N	292
0th percentile	0.05
25th percentile	0.17
50th percentile	0.21
75th percentile	0.27
90th percentile	0.34
95th percentile	0.39
99th percentile	0.55
100th percentile	1.56
Dates	07/77 - 07/99

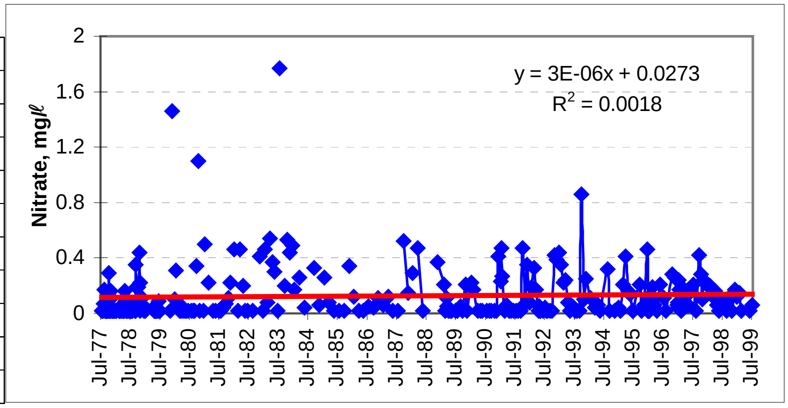


Chloride (mg/ℓ)	
N	292
0th percentile	2
25th percentile	4
50th percentile	5
75th percentile	7
90th percentile	8
95th percentile	9
99th percentile	15
100th percentile	25
Dates	07/77 - 07/99

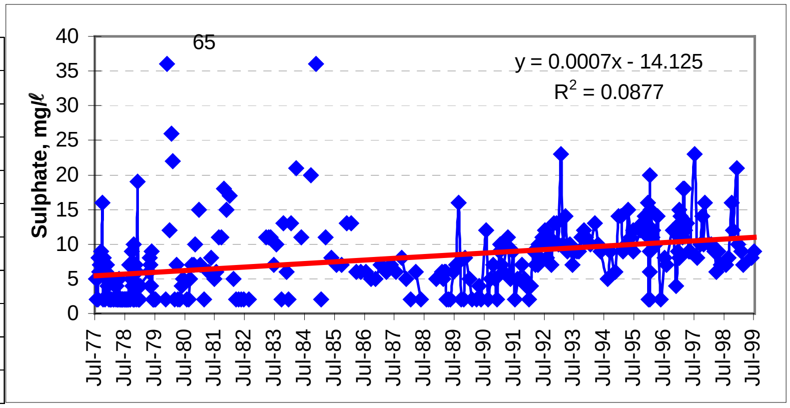


DWAF SAMPLE STATION NUMBER V1H038 Klipriver at Ladysmith

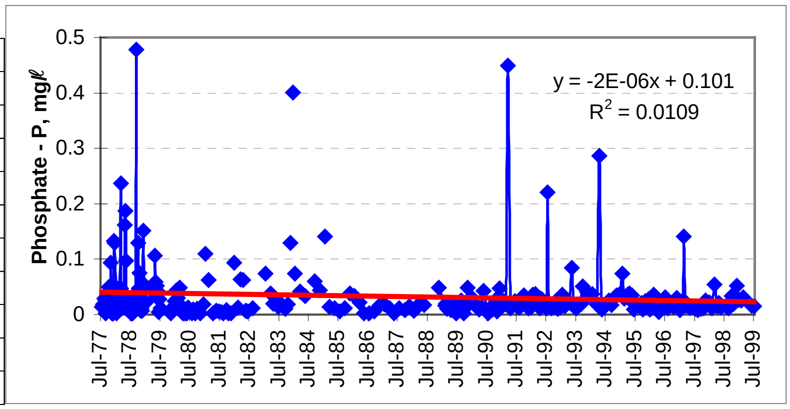
Nitrate (mg/ℓ)	
N	295
0th percentile	0.02
25th percentile	0.02
50th percentile	0.04
75th percentile	0.17
90th percentile	0.35
95th percentile	0.46
99th percentile	0.87
100th percentile	1.77
Dates	07/77 - 07/99



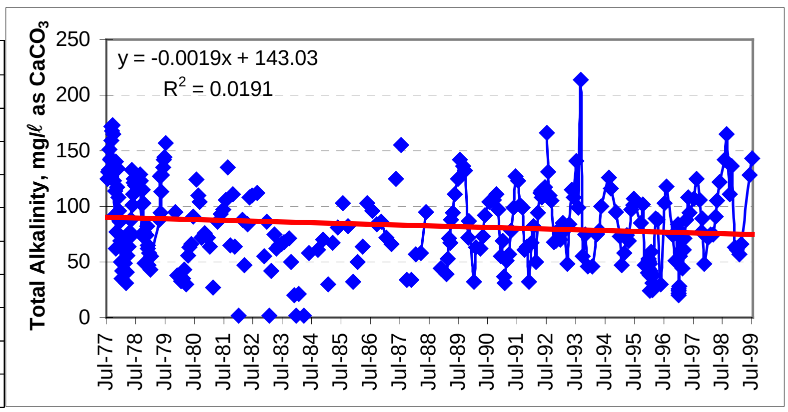
Sulphate (mg/ℓ)	
N	292
0th percentile	2
25th percentile	2
50th percentile	7
75th percentile	10
90th percentile	14
95th percentile	17
99th percentile	27
100th percentile	65
Dates	07/77 - 07/99



Phosphate - P (mg/ℓ)	
N	292
0th percentile	0.003
25th percentile	0.011
50th percentile	0.018
75th percentile	0.033
90th percentile	0.059
95th percentile	0.119
99th percentile	0.296
100th percentile	0.478
Dates	07/77 - 07/99

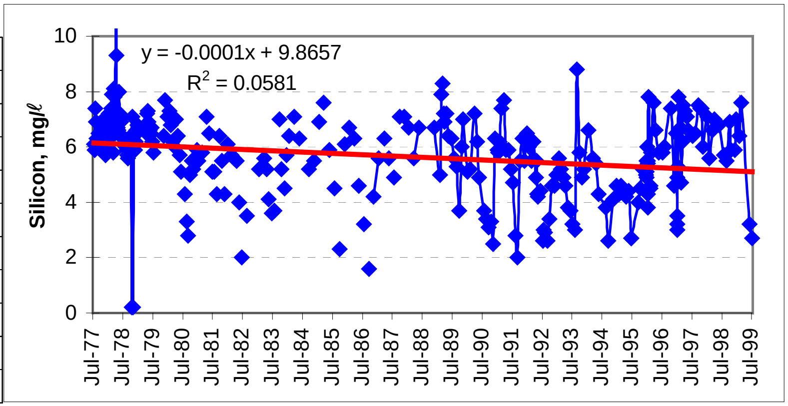


Total Alkalinity (mg/ℓ) as $CaCO_3$	
N	295
0th percentile	2
25th percentile	57
50th percentile	78
75th percentile	110
90th percentile	130
95th percentile	142
99th percentile	168
100th percentile	214
Dates	07/77 - 07/99

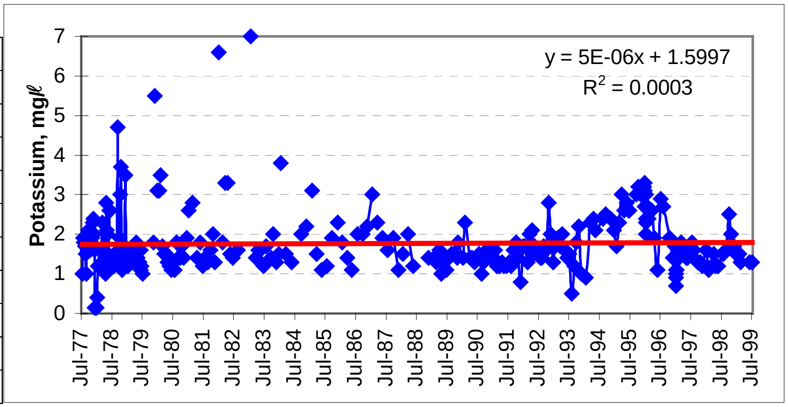


DWAF SAMPLE STATION NUMBER V1H038 Klipriver at Ladysmith

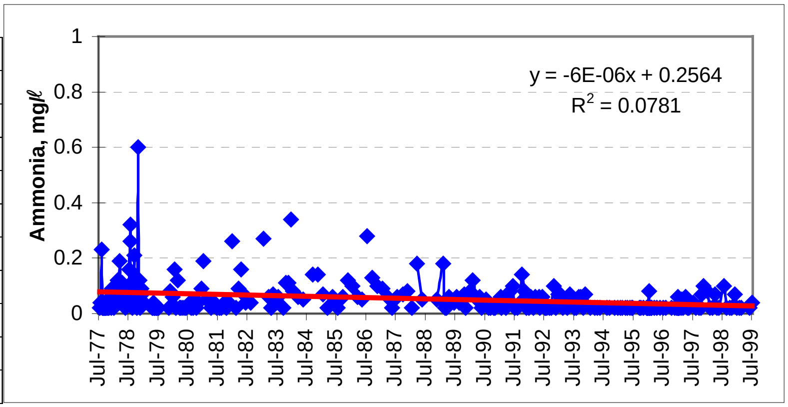
Silicon (mg/ℓ)	
N	292
0th percentile	0
25th percentile	5
50th percentile	6
75th percentile	7
90th percentile	7
95th percentile	8
99th percentile	8
100th percentile	11
Dates	07/77 - 07/99



Potassium (mg/ℓ)	
N	292
0th percentile	0
25th percentile	1
50th percentile	2
75th percentile	2
90th percentile	3
95th percentile	3
99th percentile	5
100th percentile	7
Dates	07/77 - 07/99

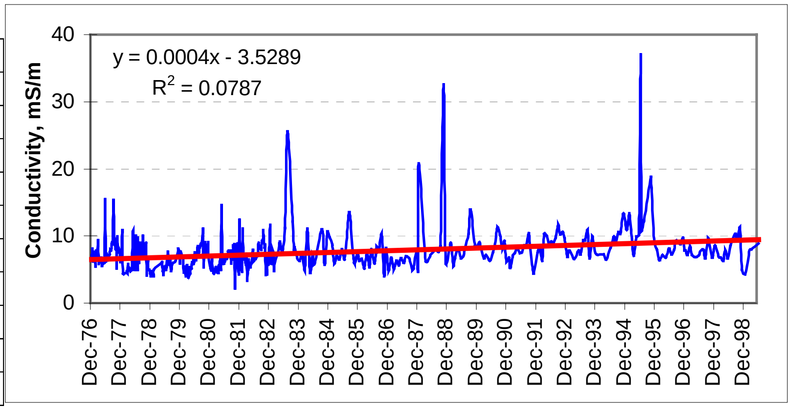


Ammonia (mg/ℓ)	
N	292
0th percentile	0.02
25th percentile	0.02
50th percentile	0.04
75th percentile	0.07
90th percentile	0.11
95th percentile	0.16
99th percentile	0.28
100th percentile	0.60
Dates	07/77 - 07/99

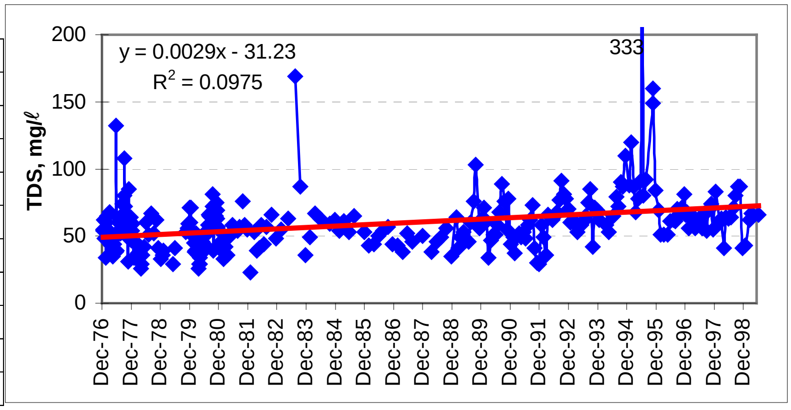


DWAF SAMPLE STATION NUMBER V7H018, Little Bushmans river at Loch Sloy/Craig

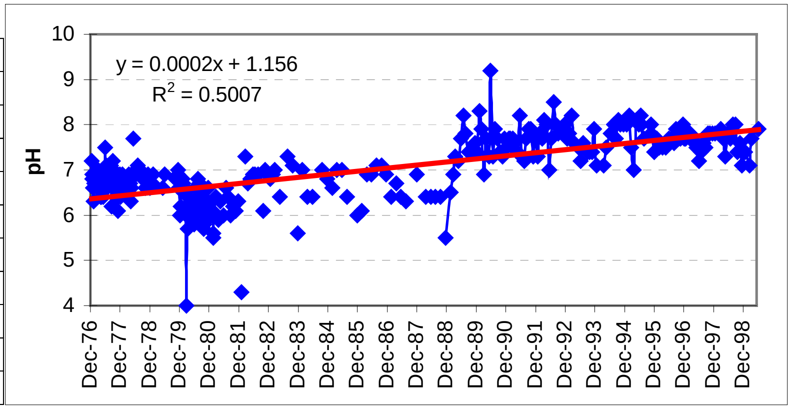
Conductivity (mS/m)	
N	460
0th percentile	2.0
25th percentile	5.9
50th percentile	7.1
75th percentile	8.4
90th percentile	10.1
95th percentile	11.1
99th percentile	18.7
100th percentile	37.0
Dates	12/76 - 06/99



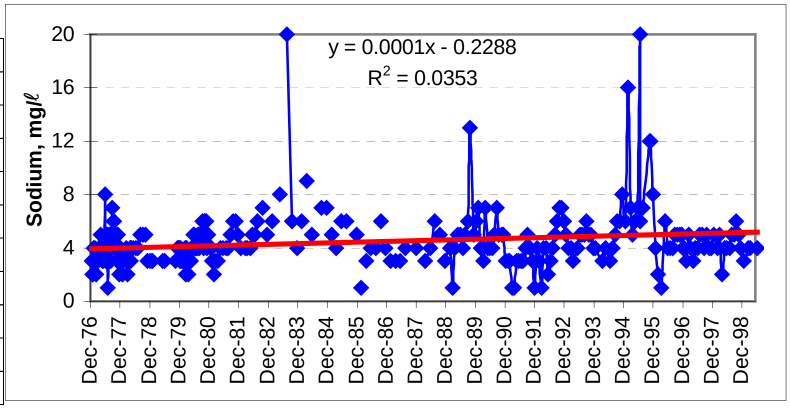
Total Dissolved Salts (mg/ℓ)	
N	307
0th percentile	23
25th percentile	45
50th percentile	56
75th percentile	66
90th percentile	78
95th percentile	87
99th percentile	148
100th percentile	333
Dates	12/76 - 06/99



pH	
N	310
0th percentile	4.0
25th percentile	6.5
50th percentile	6.9
75th percentile	7.6
90th percentile	7.9
95th percentile	8.0
99th percentile	8.2
100th percentile	9.2
Dates	12/76 - 06/99

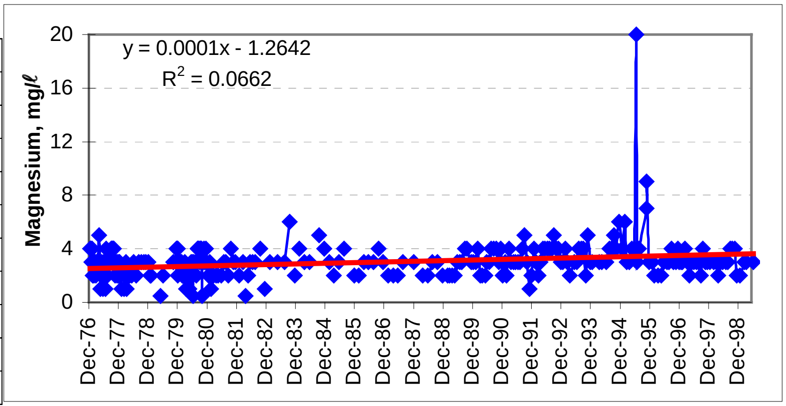


Sodium (mg/ℓ)	
N	307
0th percentile	1.0
25th percentile	3.0
50th percentile	4.0
75th percentile	5.0
90th percentile	6.0
95th percentile	7.0
99th percentile	12.9
100th percentile	20.0
Dates	12/76 - 06/99

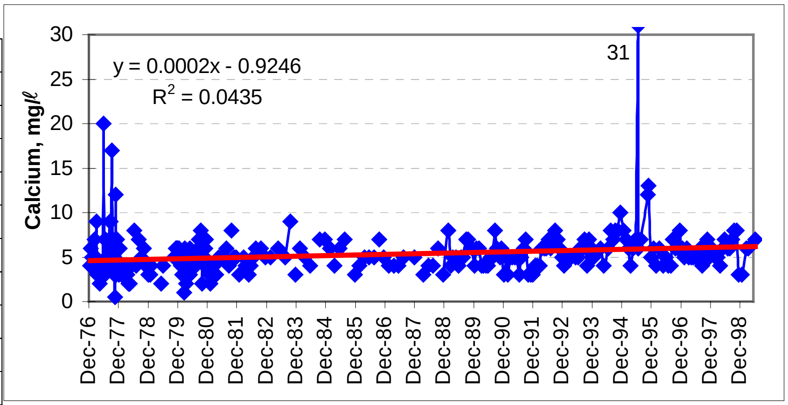


DWAF SAMPLE STATION NUMBER V7H018, Little Bushmans river at Loch Sloy/Craig

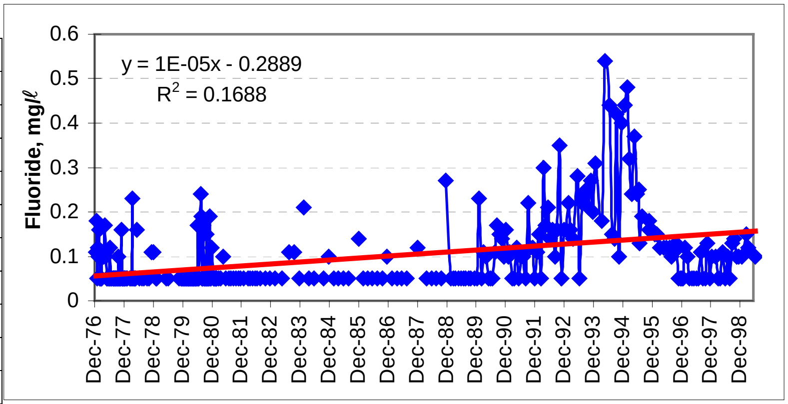
Magnesium (mg/ℓ)	
N	307
0th percentile	1
25th percentile	2
50th percentile	3
75th percentile	3
90th percentile	4
95th percentile	4
99th percentile	6
100th percentile	20
Dates	12/76 - 06/99



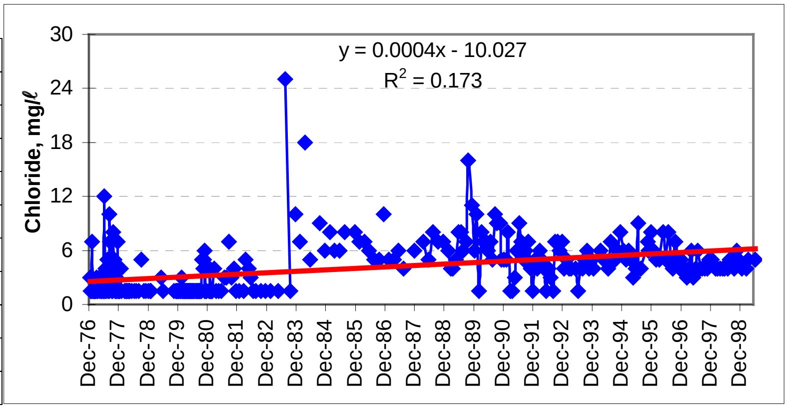
Calcium (mg/ℓ)	
N	307
0th percentile	1
25th percentile	4
50th percentile	5
75th percentile	6
90th percentile	7
95th percentile	8
99th percentile	13
100th percentile	31
Dates	12/76 - 06/99



Fluoride (mg/ℓ)	
N	307
0th percentile	0.05
25th percentile	0.05
50th percentile	0.05
75th percentile	0.12
90th percentile	0.19
95th percentile	0.25
99th percentile	0.44
100th percentile	0.54
Dates	12/76 - 06/99

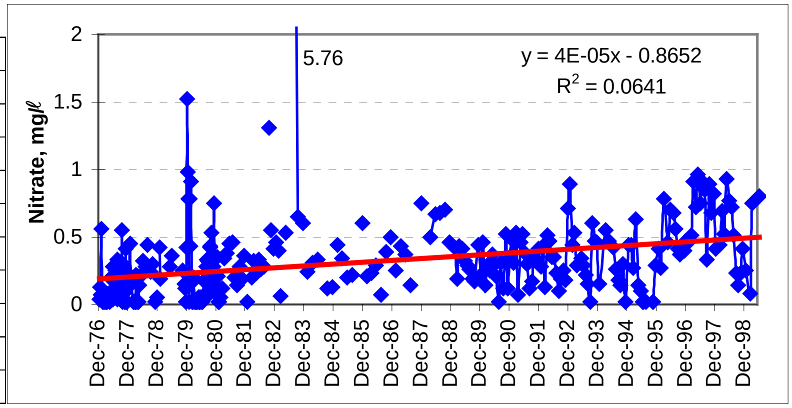


Chloride (mg/ℓ)	
N	307
0th percentile	1.5
25th percentile	1.5
50th percentile	4.0
75th percentile	5.0
90th percentile	7.0
95th percentile	8.0
99th percentile	11.9
100th percentile	25.0
Dates	12/76 - 06/99

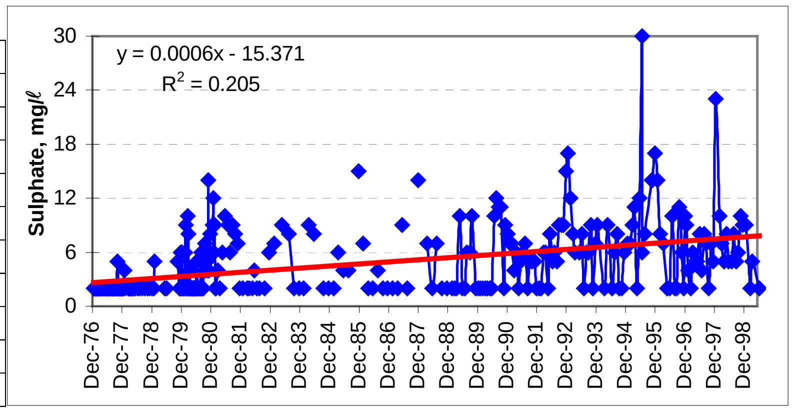


DWAF SAMPLE STATION NUMBER V7H018, Little Bushmans river at Loch Sloy/Craig

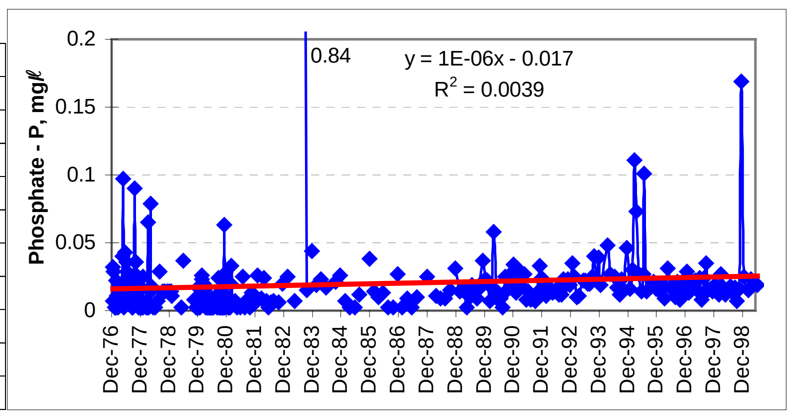
Nitrate (mg/ℓ)	
N	310
0th percentile	0.02
25th percentile	0.09
50th percentile	0.25
75th percentile	0.43
90th percentile	0.67
95th percentile	0.78
99th percentile	0.98
100th percentile	5.76
Dates	12/76 - 06/99



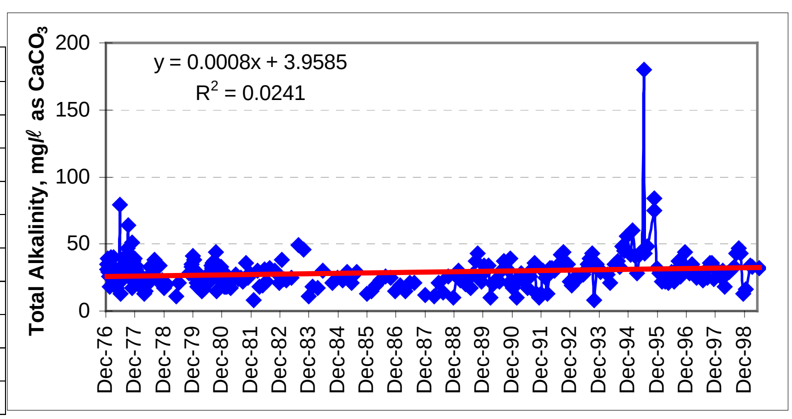
Sulphate (mg/ℓ)	
N	307
0th percentile	2.0
25th percentile	2.0
50th percentile	2.0
75th percentile	7.0
90th percentile	9.0
95th percentile	11.0
99th percentile	16.9
100th percentile	30.0
Dates	12/76 - 06/99



Phosphate - P (mg/ℓ)	
N	307
0th percentile	0.003
25th percentile	0.007
50th percentile	0.014
75th percentile	0.022
90th percentile	0.031
95th percentile	0.040
99th percentile	0.101
100th percentile	0.840
Dates	12/76 - 06/99

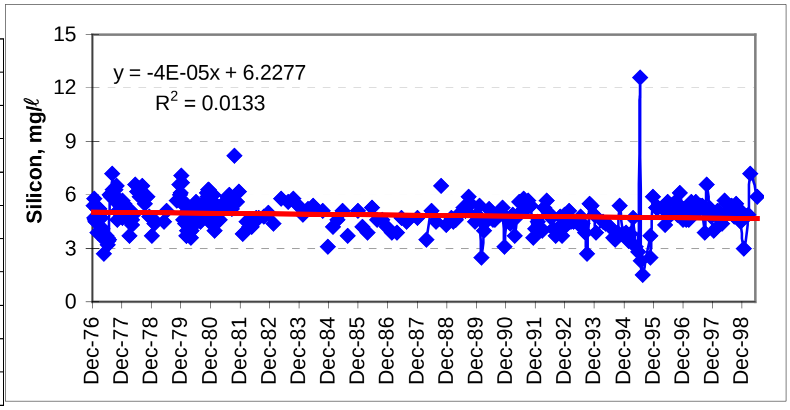


Total Alkalinity (mg/ℓ) as $CaCO_3$	
N	310
0th percentile	8
25th percentile	21
50th percentile	27
75th percentile	33
90th percentile	40
95th percentile	45
99th percentile	74
100th percentile	180
Dates	12/76 - 06/99

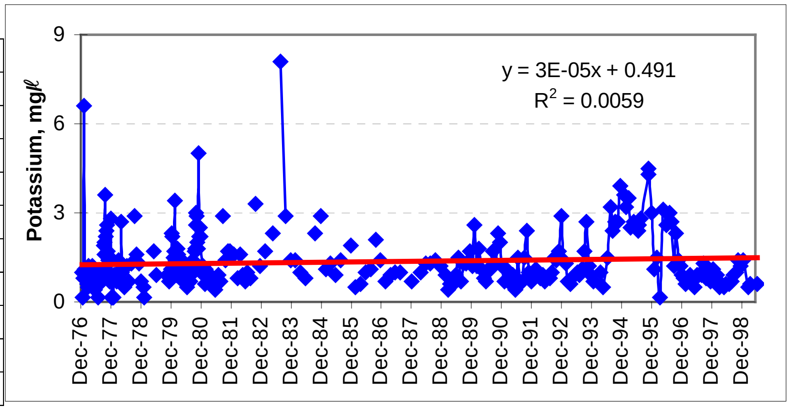


DWAF SAMPLE STATION NUMBER V7H018, Little Bushmans river at Loch Sloy/Craig

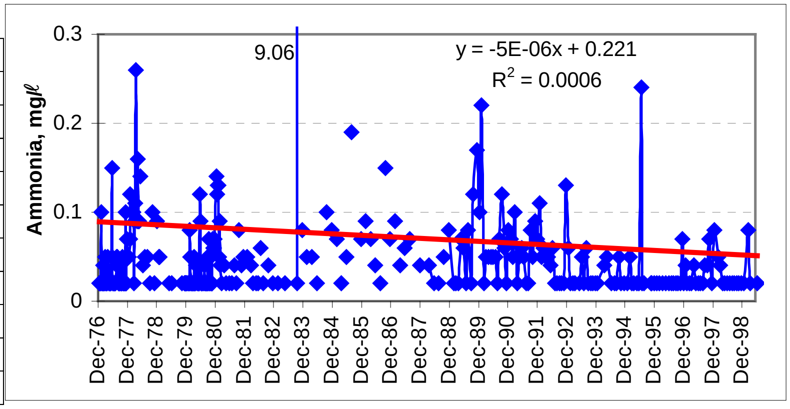
Silicon (mg/ℓ)	
N	307
0^{th} percentile	2
25^{th} percentile	4
50^{th} percentile	5
75^{th} percentile	5
90^{th} percentile	6
95^{th} percentile	6
99^{th} percentile	7
100^{th} percentile	13
Dates	12/76 - 06/99



Potassium (mg/ℓ)	
N	307
0^{th} percentile	0.2
25^{th} percentile	0.8
50^{th} percentile	1.0
75^{th} percentile	1.6
90^{th} percentile	2.6
95^{th} percentile	3.0
99^{th} percentile	4.5
100^{th} percentile	8.1
Dates	12/76 - 06/99

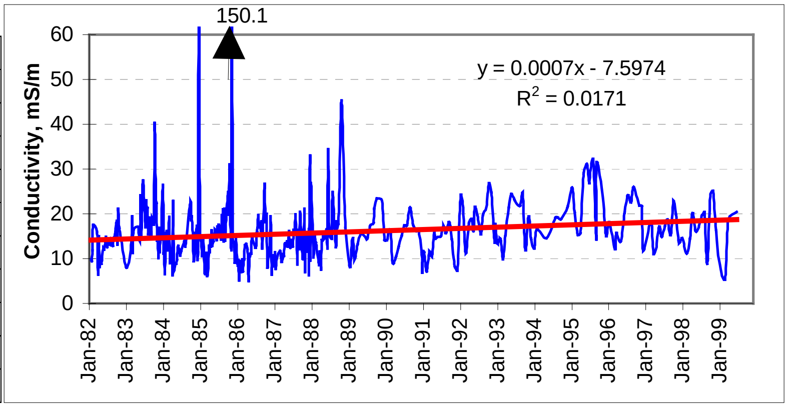


Ammonia (mg/ℓ)	
N	307
0^{th} percentile	0.02
25^{th} percentile	0.02
50^{th} percentile	0.02
75^{th} percentile	0.05
90^{th} percentile	0.09
95^{th} percentile	0.12
99^{th} percentile	0.22
100^{th} percentile	9.06
Dates	12/76 - 06/99

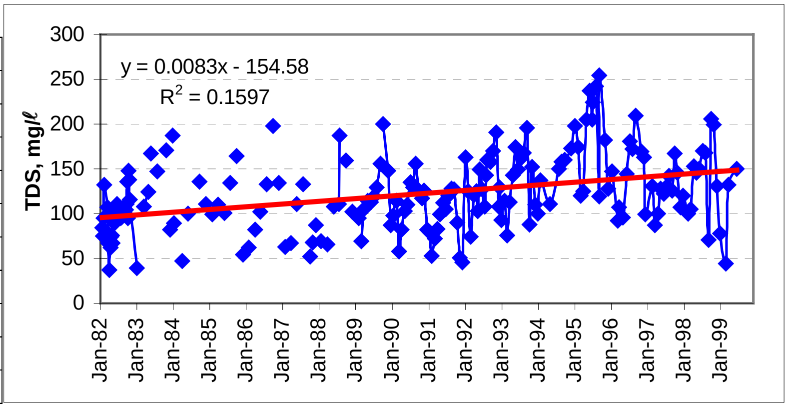


DWAF SAMPLE STATION NUMBER V7H012 Little Bushmans river at Estcourt

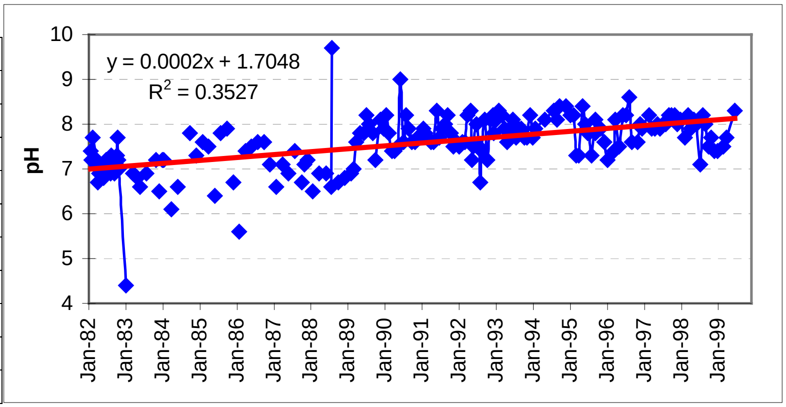
Conductivity (mS/m)	
N	417
0th percentile	5.0
25th percentile	11.6
50th percentile	14.6
75th percentile	18.0
90th percentile	22.7
95th percentile	25.2
99th percentile	34.2
100th percentile	150.1
Dates	01/82 - 06/99



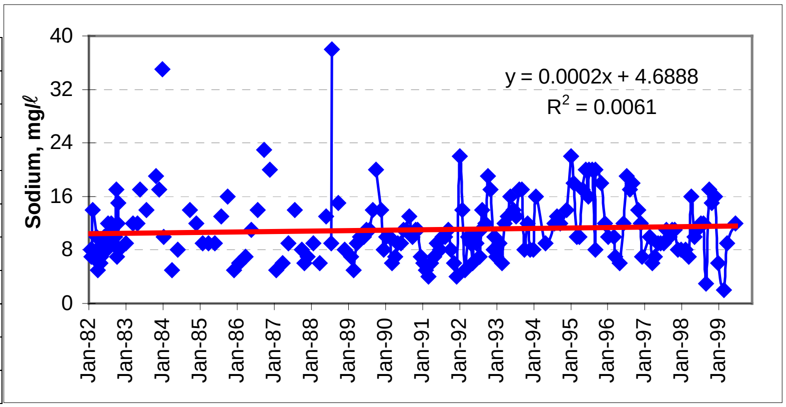
Total Dissolved Salts (mg/ℓ)	
N	198
0th percentile	37
25th percentile	96
50th percentile	114
75th percentile	148
90th percentile	173
95th percentile	198
99th percentile	237
100th percentile	254
Dates	01/82 - 06/99



pH	
N	198
0th percentile	4.4
25th percentile	7.2
50th percentile	7.6
75th percentile	8.0
90th percentile	8.2
95th percentile	8.3
99th percentile	8.6
100th percentile	9.7
Dates	01/82 - 06/99

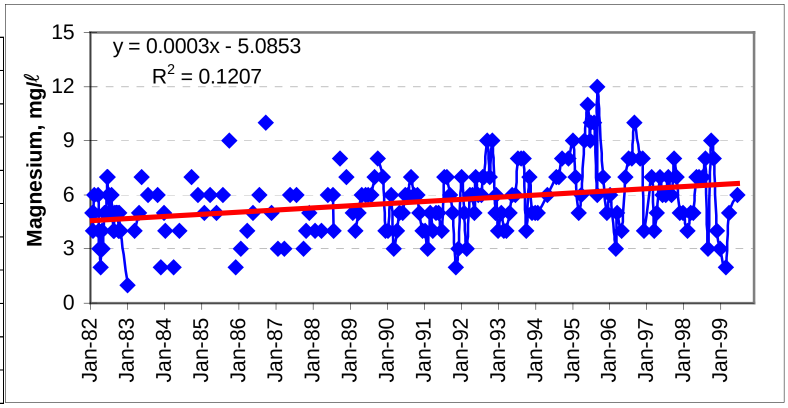


Sodium (mg/ℓ)	
N	198
0th percentile	2
25th percentile	8
50th percentile	10
75th percentile	13
90th percentile	17
95th percentile	20
99th percentile	23
100th percentile	38
Dates	01/82 - 06/99

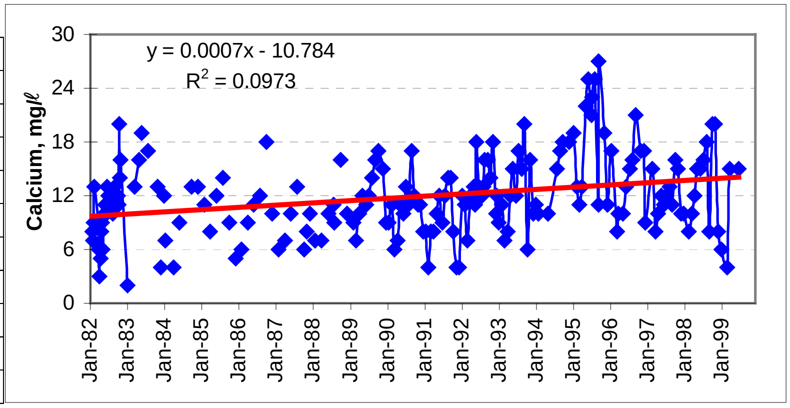


DWAF SAMPLE STATION NUMBER V7H012 Little Bushmans river at Estcourt

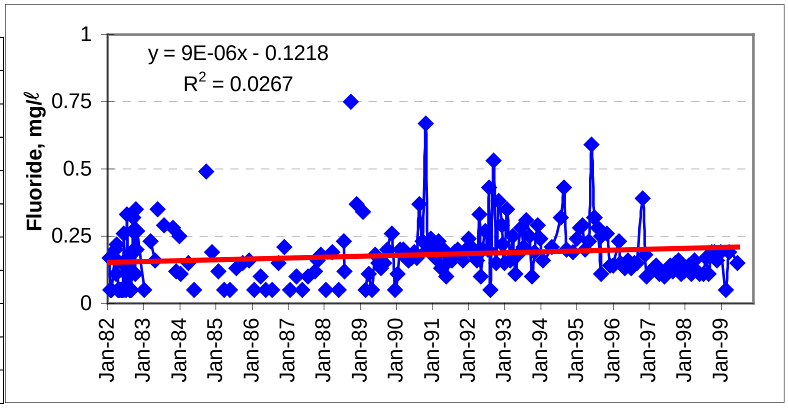
Magnesium (mg/ℓ)	
N	198
0th percentile	1
25th percentile	4
50th percentile	5
75th percentile	7
90th percentile	8
95th percentile	9
99th percentile	10
100th percentile	12
Dates	01/82 - 06/99



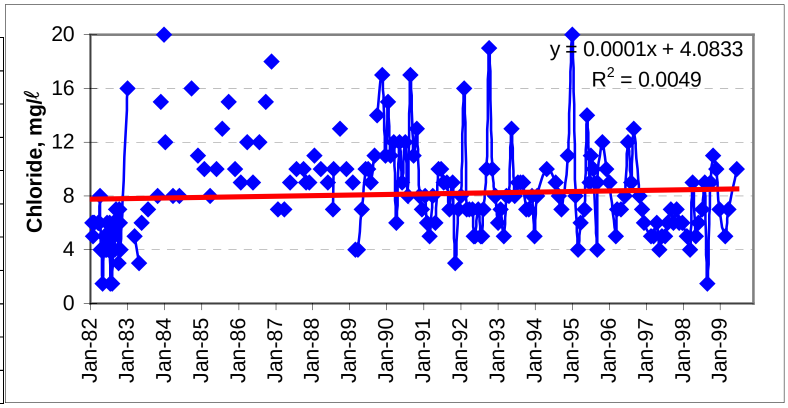
Calcium (mg/ℓ)	
N	198
0th percentile	2
25th percentile	9
50th percentile	11
75th percentile	14
90th percentile	17
95th percentile	20
99th percentile	25
100th percentile	27
Dates	01/82 - 06/99



Fluoride (mg/ℓ)	
N	198
0th percentile	0.05
25th percentile	0.11
50th percentile	0.16
75th percentile	0.23
90th percentile	0.32
95th percentile	0.37
99th percentile	0.59
100th percentile	0.75
Dates	01/82 - 06/99

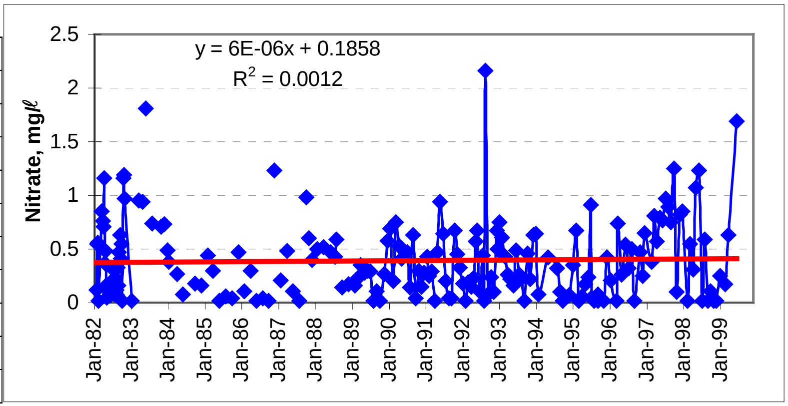


Chloride (mg/ℓ)	
N	198
0th percentile	2
25th percentile	6
50th percentile	8
75th percentile	10
90th percentile	12
95th percentile	15
99th percentile	19
100th percentile	20
Dates	01/82 - 06/99

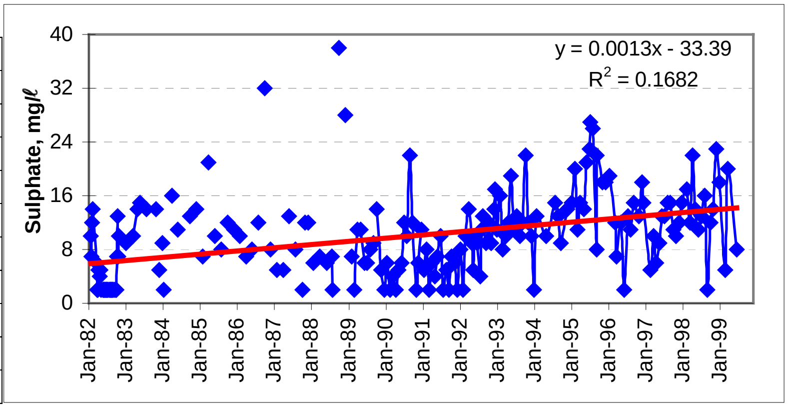


DWAF SAMPLE STATION NUMBER V7H012 Little Bushmans river at Estcourt

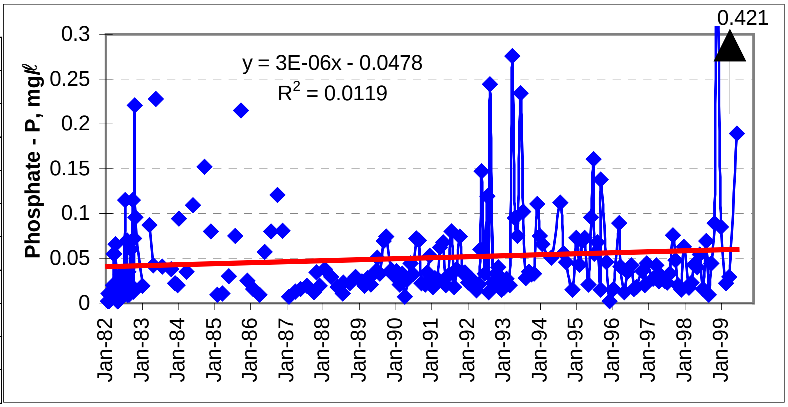
Nitrate (mg/ℓ)	
N	198
0th percentile	0.02
25th percentile	0.11
50th percentile	0.30
75th percentile	0.58
90th percentile	0.83
95th percentile	0.99
99th percentile	1.69
100th percentile	2.16
Dates	01/82 - 06/99



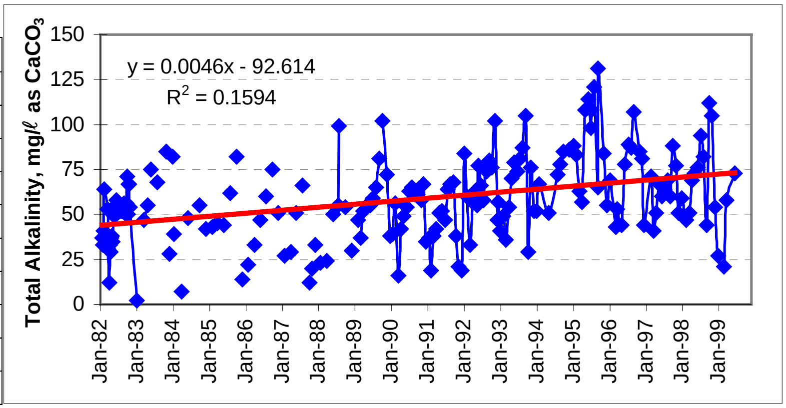
Sulphate (mg/ℓ)	
N	199
0th percentile	2
25th percentile	5
50th percentile	10
75th percentile	13
90th percentile	18
95th percentile	22
99th percentile	28
100th percentile	38
Dates	01/82 - 06/99



Phosphate - P (mg/ℓ)	
N	198
0th percentile	0.003
25th percentile	0.019
50th percentile	0.033
75th percentile	0.066
90th percentile	0.098
95th percentile	0.148
99th percentile	0.245
100th percentile	0.421
Dates	01/82 - 06/99

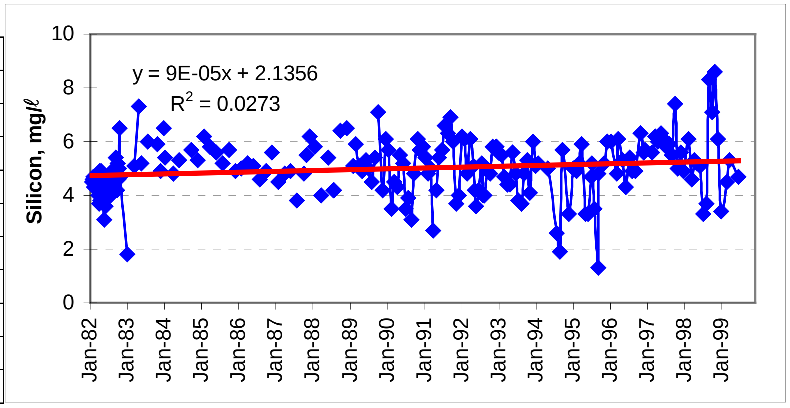


Total Alkalinity (mg/ℓ) as $CaCO_3$	
N	198
0th percentile	2
25th percentile	44
50th percentile	55
75th percentile	72
90th percentile	85
95th percentile	102
99th percentile	114
100th percentile	131
Dates	01/82 - 06/99

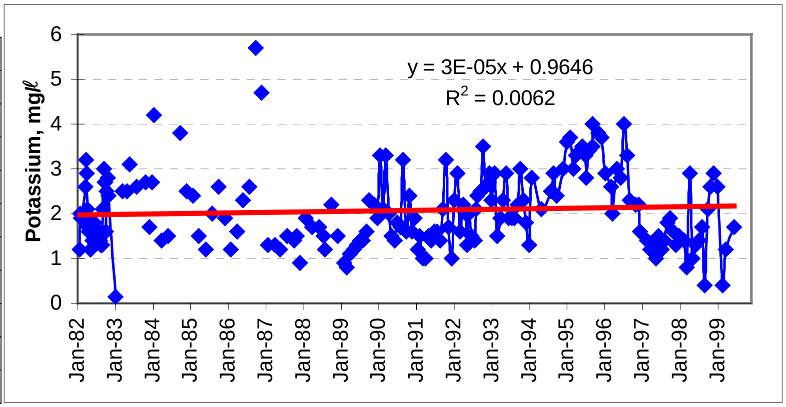


DWAF SAMPLE STATION NUMBER V7H012 Little Bushmans river at Estcourt

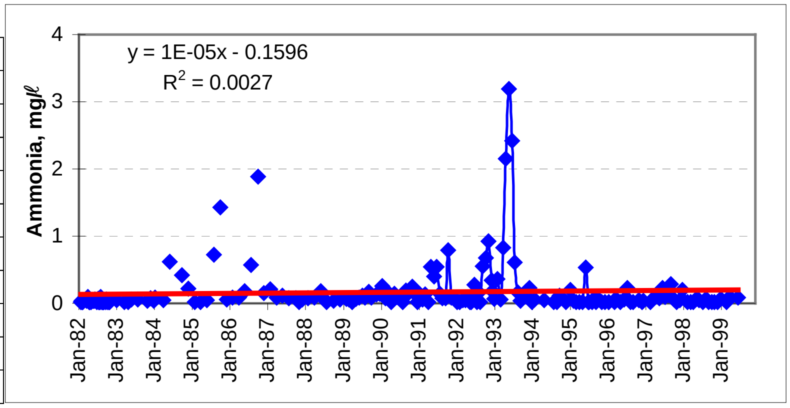
Silicon (mg/ℓ)	
N	198
0th percentile	1.3
25th percentile	4.4
50th percentile	5.0
75th percentile	5.7
90th percentile	6.1
95th percentile	6.5
99th percentile	7.4
100th percentile	8.6
Dates	09/82 - 06/99



Potassium (mg/ℓ)	
N	198
0th percentile	0.2
25th percentile	1.4
50th percentile	1.9
75th percentile	2.6
90th percentile	3.2
95th percentile	3.5
99th percentile	4.2
100th percentile	5.7
Dates	09/82 - 06/99

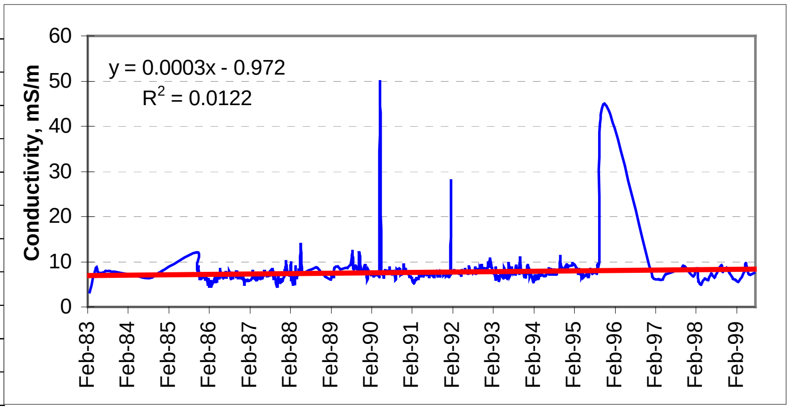


Ammonia (mg/ℓ)	
N	198
0th percentile	0.02
25th percentile	0.02
50th percentile	0.06
75th percentile	0.13
90th percentile	0.35
95th percentile	0.63
99th percentile	2.16
100th percentile	3.19
Dates	09/82 - 06/99

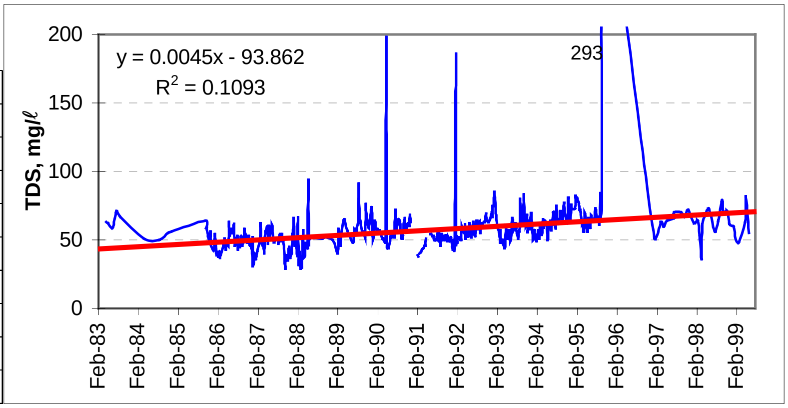


DWAF SAMPLE STATION NUMBER V7H020 Bushmans river below Wagondrift dam

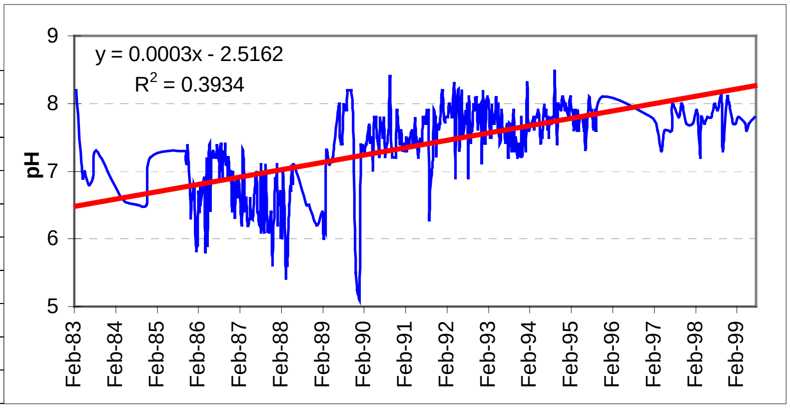
Conductivity (mS/m)	
N	476
0th percentile	3.2
25th percentile	6.7
50th percentile	7.4
75th percentile	8.1
90th percentile	8.9
95th percentile	9.3
99th percentile	12.3
100th percentile	50.0
Dates	02/83 - 07/99



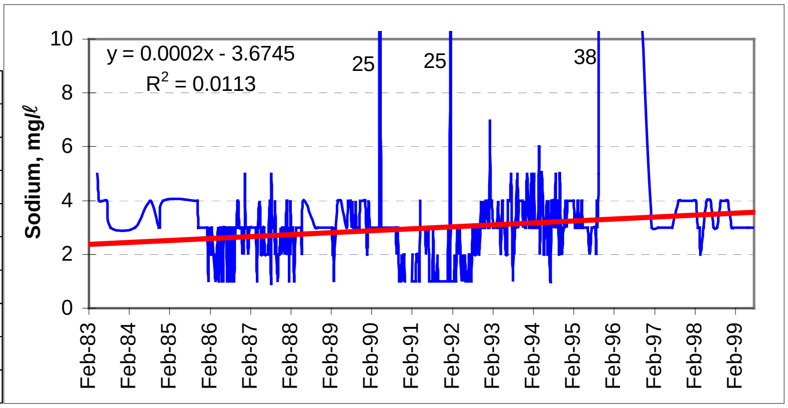
Total Dissolved Solids (mg/ℓ)	
N	466
0th percentile	28
25th percentile	50
50th percentile	55
75th percentile	63
90th percentile	70
95th percentile	75
99th percentile	87
100th percentile	293
Dates	02/83 - 07/99



pH	
N	476
0th percentile	5.1
25th percentile	7.1
50th percentile	7.5
75th percentile	7.8
90th percentile	8
95th percentile	8.1
99th percentile	8.2
100th percentile	8.5
Dates	02/83 - 07/99



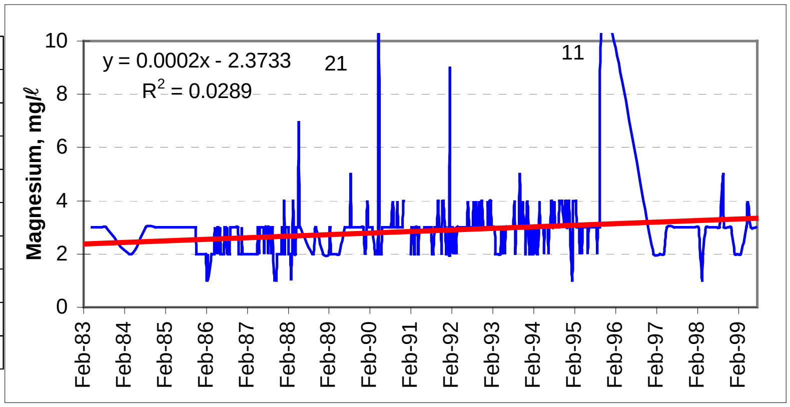
Sodium (mg/ℓ)	
N	467
0th percentile	1
25th percentile	2
50th percentile	3
75th percentile	3
90th percentile	4
95th percentile	4
99th percentile	5.34
100th percentile	38
Dates	02/83 - 07/99



DWAF SAMPLE STATION NUMBER V7H020 Bushmans river below Wagondrift dam

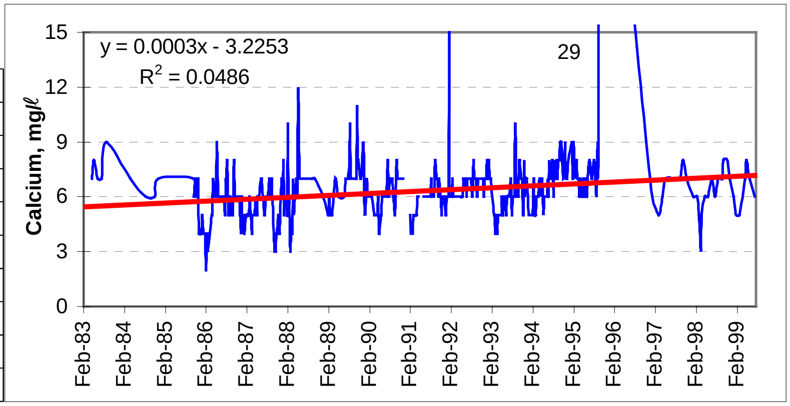
Magnesium (mg/ℓ)

N	467
0th percentile	1
25th percentile	2
50th percentile	3
75th percentile	3
90th percentile	4
95th percentile	4
99th percentile	5
100th percentile	21
Dates	02/83 - 07/99



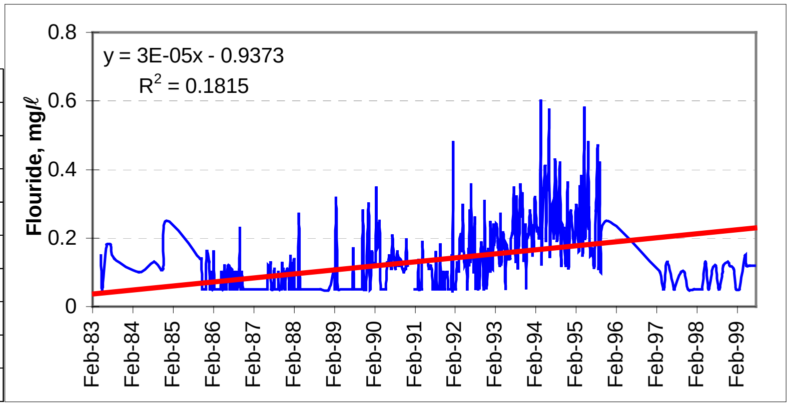
Calcium (mg/ℓ)

N	467
0th percentile	2.0
25th percentile	6.0
50th percentile	6.0
75th percentile	7.0
90th percentile	8.0
95th percentile	8.0
99th percentile	10.0
100th percentile	29.0
Dates	02/83 - 07/99



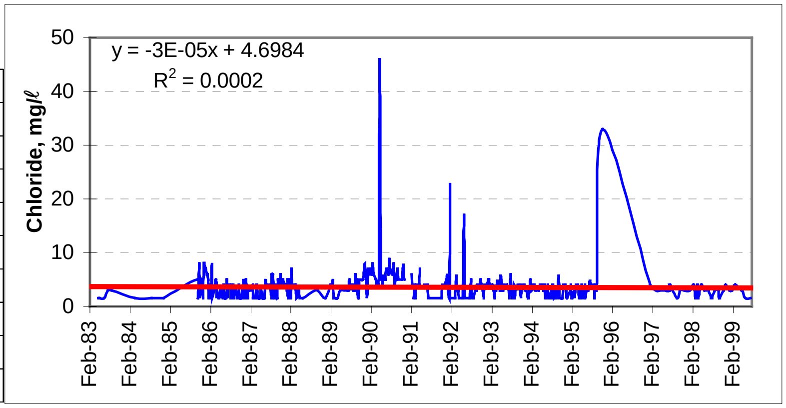
Flouride (mg/ℓ)

N	467
0th percentile	0.05
25th percentile	0.05
50th percentile	0.11
75th percentile	0.17
90th percentile	0.26
95th percentile	0.32
99th percentile	0.47
100th percentile	0.60
Dates	02/83 - 07/99



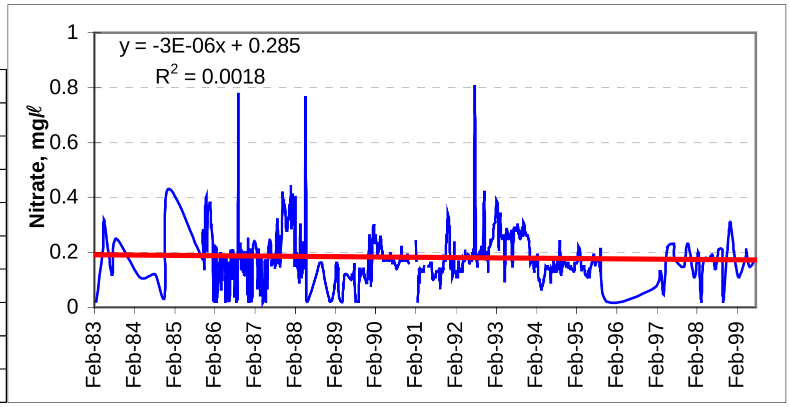
Chloride (mg/ℓ)

N	467
0th percentile	1.5
25th percentile	1.5
50th percentile	3.0
75th percentile	4.0
90th percentile	6.0
95th percentile	7.0
99th percentile	8.3
100th percentile	46.0
Dates	02/83 - 07/99

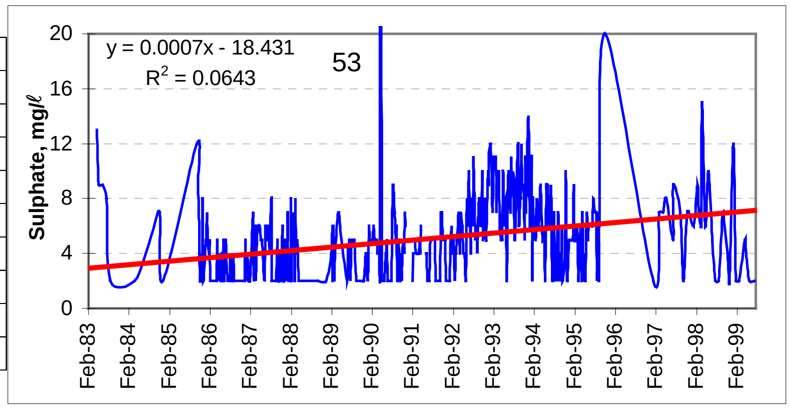


DWAF SAMPLE STATION NUMBER V7H020 Bushmans river below Wagondrift dam

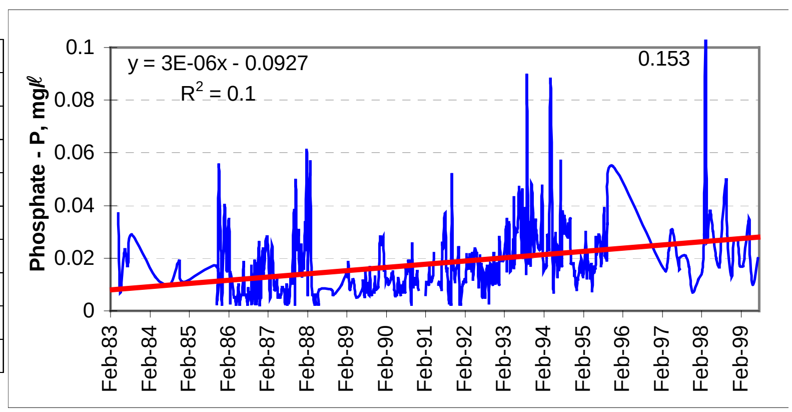
Nitrate (mg/ℓ)	
N	468
0th percentile	0.02
25th percentile	0.13
50th percentile	0.17
75th percentile	0.22
90th percentile	0.29
95th percentile	0.33
99th percentile	0.43
100th percentile	0.81
Dates	02/83 - 07/99



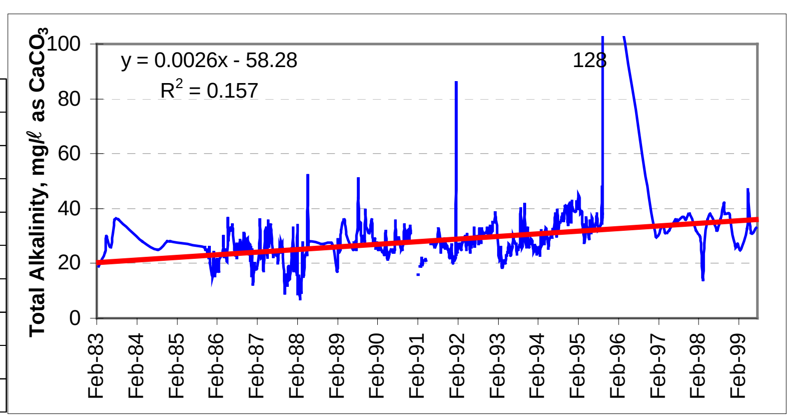
Sulphate (mg/ℓ)	
N	467
0th percentile	2.00
25th percentile	2.00
50th percentile	5.00
75th percentile	6.50
90th percentile	9.00
95th percentile	10.00
99th percentile	12.34
100th percentile	53.00
Dates	02/83 - 07/99



Phosphate - P (mg/ℓ)	
N	467
0th percentile	0.003
25th percentile	0.009
50th percentile	0.016
75th percentile	0.024
90th percentile	0.032
95th percentile	0.039
99th percentile	0.057
100th percentile	0.153
Dates	02/83 - 07/99



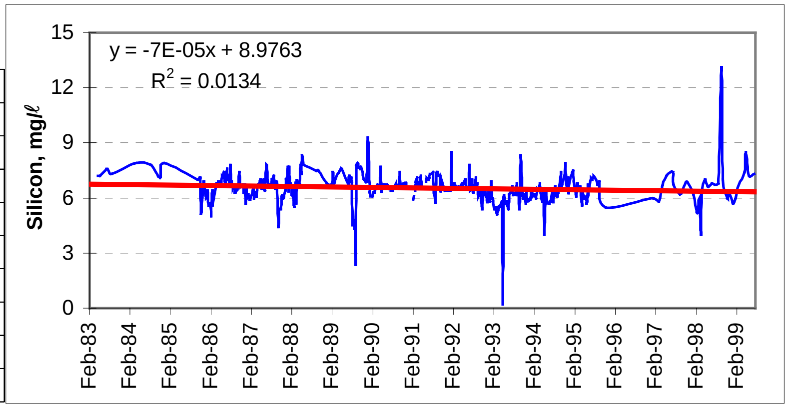
Total Alkalinity (mg/ℓ)	
N	468
0th percentile	7
25th percentile	24
50th percentile	27
75th percentile	32
90th percentile	36
95th percentile	39
99th percentile	47
100th percentile	128
Dates	02/83 - 07/99



DWAF SAMPLE STATION NUMBER V7H020 Bushmans river below Wagondrift dam

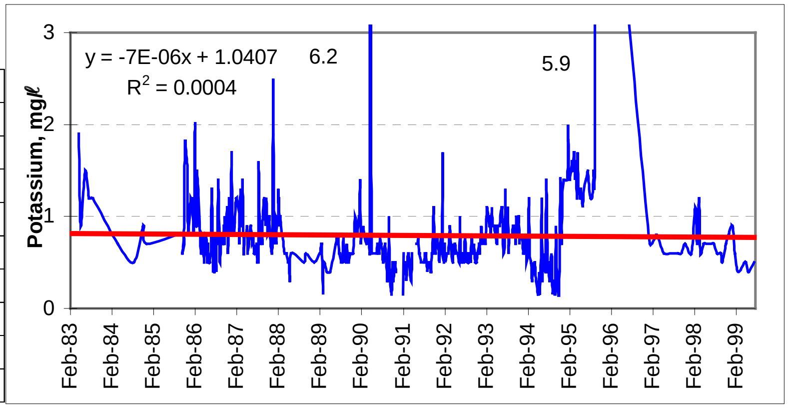
Silicon (mg/ℓ)

N	467
0th percentile	0
25th percentile	6
50th percentile	7
75th percentile	7
90th percentile	7
95th percentile	8
99th percentile	8
100th percentile	13
Dates	02/83 - 07/99



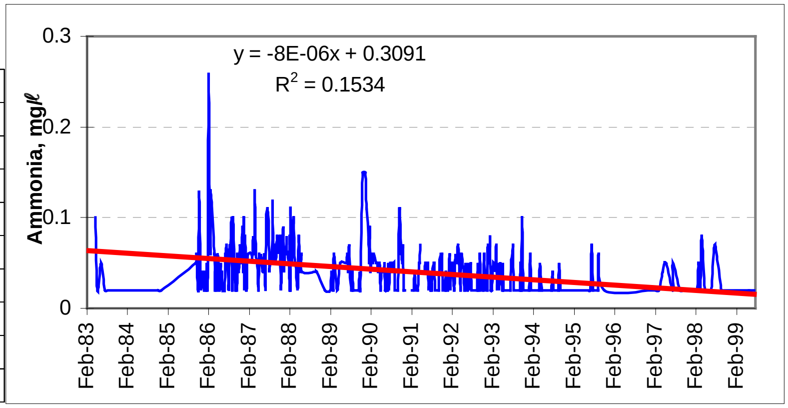
Potassium (mg/ℓ)

N	467
0th percentile	0
25th percentile	1
50th percentile	1
75th percentile	1
90th percentile	1
95th percentile	2
99th percentile	2
100th percentile	6
Dates	02/83 - 07/99



Ammonia (mg/ℓ)

N	467
0th percentile	0.02
25th percentile	0.02
50th percentile	0.02
75th percentile	0.05
90th percentile	0.07
95th percentile	0.09
99th percentile	0.13
100th percentile	0.26
Dates	02/83 - 07/99



APPENDIX 2

AQUATIC WEEDS

APPENDIX 2.
Aquatic Weeds

This report should be read in conjunction with the main report which contains the summary and other information. The report below contains only the details about aquatic weeds that are not relevant to the main report.

Introduction

As the most likely invader (already noted in the catchment of Lake Jana), and probably the most significant aquatic weed in South Africa (DWAF, Cilliers pers. comm.), Water Hyacinth will be discussed in most detail. Many of the environmental impacts highlighted by this weed would apply for any potential aquatic weed invasion of either of Lakes Jana or Mielietuin.

Habitat and water quality requirements

The literature indicates that Water Hyacinth is able to grow in a variety of freshwater habitats, many of which would be provided by each of the two proposed lakes. However from observation in the South African context it appears to be most successful in conditions ranging from sluggish flowing waters all the way through to large lakes. It is able to tolerate large water level fluctuations and wave action. Its current geographical distribution from the Equator to nearly 38◦ N and S represents a wide range of temperature regimes (optimum 25 to 27.5◦ C). It is also able to tolerate a wide range of atmospheric temperatures from as low as 1◦ C during winter to over 40◦ C in summer (Gopal 1987). The weed is also able to tolerate a wide range of water quality conditions from relatively clean oligotrophic lakes to highly polluted (nutrients and organic matter) as in sewage lagoons. The ecological amplitude exhibited by the weed is so large as to make it almost meaningless to summarise. Save to say that within KZN it has been shown to grow comfortably in the upper part of the Lake Inanda as well as the highly enriched (eutrophic) Lake Hammarsdale. If uncontrolled, under eutrophic water conditions it will also outcompete other aquatic weeds (e.g. Water Lettuce - *Pistia stratiotes*) due to its height dominance (long petioled leaves). Under some conditions *Salvinia molesta*, another of the more serious alien aquatic weeds, is reported as being able to coexist with Water Hyacinth.

Large fluctuations in water level appear to affect the growth and population size of Water Hyacinth although small fluctuations are insignificant. Drawdown in reservoirs increases the abundance of the weed - apparently increasing the likelihood of seed germination due to increasing nutrient availability by rapid decay and mineralization of submerged plants and other organic matter.

In the proposed lakes there would certainly be no light limitations to the growth of Water Hyacinth with water temperatures also unlikely to limit growth (optimum 25 to 27.5◦ C). Optimum pH range is 6 to 8 with a toxic threshold near pH 4.2. Based on the predicted water quality in the two lakes there would appear to be no pH limitation to the growth of this weed. It is generally and widely acknowledged that the weed is unaffected by a wide range of plant nutrients in the water (e.g. Gopal 1987). In general, the growth of the plant is directly correlated with the level of nutrient enrichment of the water body (e.g. Lugo *et al.* 1978) and hence all efforts should be maintained to limit the nutrient concentration in the two proposed lakes. There is some indication that a deficiency of calcium (<5mg/ℓ) may limit new plant production (apparently essential for seed formation, Talatala, 1974). This is below the naturally occurring levels (approximately 10-20mg/ℓ) found in the Thukela River monitored at Middledrift (UW site 150), and so is unlikely to limit the weed in this river system.

Dense weed mats (particularly Water Hyacinth) may provide suitable habitat for the establishment of more emergent marshy plant species, grasses and even tree seedlings.

Direct impacts

The major problem associated with alien aquatic weed invasion arises from their generally high growth rate resulting in huge amounts of biomass spread over the water surface. Natural aquatic vegetation may become suppressed as a result of this weed.

Evapotranspiration - although the literature is full of varying estimates (24-40%) of percentage increased water loss due to aquatic weed cover there is little doubt that these weeds do increase water loss from open bodies of water. The percentage loss is a function of specific weed infestation, local climate, topography, and water quality conditions (which govern the health and vigour of weeds).

Water hyacinth may reduce waterflow by 40 to 95% in irrigation canals (Bogart 1949; Guscio *et al.* 1965) which may cause flooding. Roughness coefficients of canals have also been shown to increase from 0.024 to 0.055 due to the growth of Water Hyacinth (Gupta 1973). The inlet to pumps and water abstraction towers may also become blocked/clogged.

As reported in Gopal (1987), the plant cover of aquatic weeds may provide obnoxious smells, and adds colouring matter and suspended particulate matter to the water. In general, cover by Water Hyacinth has been shown to lower water temperatures, pH, bicarbonate alkalinity, and dissolved oxygen content (often to zero), and increases the free carbon dioxide content, B.O.D, and nutrient levels (e.g. McVea and Boyd 1975). Water temperatures will also be affected - surface and bottom temperatures are similar both under weed mats and in the open although the drop in temperature under mats of weeds is more rapid due to the insulating effect of the mat.

Impacts on fish and other animals

With dense weed infestation the diffusion of oxygen into the water is nearly completely blocked. Shading reduces or completely eliminates photosynthetic activity. The combined effect of these two factors has a both direct and indirect effects on fish and other animals. Generally fish production is reduced (reduction/removal of the primary trophic layer - phytoplankton). Complete depletion in oxygen may also result in fish kills. In the shallows of the potential impoundment sites the spawning areas may also be unusable (e.g. Achmad 1971). Some reports (in Gopal 1987) have pointed to a change in the fish community as the airbreathing fish are able to survive and may even prefer such habitats. If the weeds do not develop a full complete cover to the water surface, they may prove useful in providing shelter to fish in the root masses (and possibly also providing food in the form of organisms and detritus associated with the weed roots) (Gopal 1987).

Impact on planktonic communities

The shading of the water column provided by aquatic weeds suppresses the growth and diversity of phytoplankton and submerged plants. Gopal *et al.* (1984) reported both qualitative and quantitative changes in the phytoplankton following invasion and formation of a complete cover by Water Hyacinth. Total phytoplankton densities reduced considerably and the densities of most species changed significantly. Generally chlorophycean (green algae) forms increased in dominance replacing the blue-green algae. Of interest in the Jana and Meilietuin context, species of the blue-green algae, *Oscillatoria*, *Microcystis* and *Anabaena* (traditionally associated with water treatment problems i.e. taste and odour and toxicity formation) disappeared completely. In the South African context (Lake Hartebeespoort) Scott *et al*. (1979) and Ashton *et al*. (1979) have also reported a general decline in density of phytoplankton and zooplankton. In ths case the dominance of blue-green algae (*Microcystis aeruginosa*) gave way to diatoms (*Cyclotella meneghiniana* and *Melosira granulata* var. *angustissima).*

Impacts on agriculture

Besides the physical clogging of irrigation canals, drains and pumps the only potentially significant impact of dense weed infestations noted here was the possible allelopathic effect of Water Hyacinth on certain crop plants (although the types were not those typically found farmed in the South African context). Cattle drownings may occur where animals mistakenly think the water is shallow or non-existent.

Human health impacts

As an example of the potential impacts of aquatic weeds on human health the literature indicates that Water Hyacinth provides both the habitat and food for several harmful animals and other vectors for disease such as malaria, encephalitis, schistosomiasis, filariasis etc. (in Gopal 1987). Gopal (1987) reports that there are indications that the Water Hyacinth may provide ideal sites for certain molluscs which may impart undesirable taste and odour to water supplies. Spira *et al.* (1981) have also shown that Water Hyacinth concentrates *Vibrio cholerae*, the organism responsible for cholera, around its roots. They consider the weed to have been responsible for cholera epidemics in countries like Bangladesh. Human drownings are also possible where there are apparently solid surfaces of aquatic plants.

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REVIEW

PROF J H O'KEEFFE, INSTITUTE FOR WATER RESEARCH, RHODES UNIVERSITY

REVIEW OF REPORT 1 FROM THE THUKELA WATER PROJECT : SPECIALIST STUDY ON THE ECOLOGICAL IMPACTS RELATING TO THE CREATION OF LAKE ENVIRONMENTS

GENERAL REVIEW:

Given the time constraints for this project, and its nature as a Feasibility-level extended scoping exercise, this report fulfills the terms of reference. The report provides a good initial description of the present conditions in the affected river reaches, the likely effects of the Jana and Mieletuin Dams, the conditions which are likely to pertain in the lakes behind the dams, and possible mitigation measures.

I have tried to read this report through the eyes of a manager charged with the further investigation and management of the ecological impacts of the dams. I have assessed each section of the report in the context of the 10 questions posed in my terms of reference from Jennifer Mander of the INR. In this review I shall not deal in detail with each question for each section of the report, but will confine myself to those aspects of the report which may not cover some of the questions entirely adequately.

As an overview, the report is clearly written, laid out and presented, with an encouraging absence of technical jargon except where necessary, and concise conclusions, carefully pointing out the limitations of the study and any uncertainties in predictions. The water quality appendix provides an abundance of detailed data and analysis for those wishing to examine the specific conclusions in detail. The other specialities could not provide this level of supporting detail, since they were not so fortunate in having a historical monitoring programme in the river for years before this study.

The team assembled to carry out this project have impressive qualifications and a wealth of experience in freshwater ecology and water quality. Their credibility for the task could not be bettered anywhere in South Africa. I am therefore quite comfortable in accepting the accuracy of their observations, and have not tried to examine in detail or validate the specialist work that has been done (in keeping with general comment No. 6 of the terms of reference sent to me).

SPECIFIC COMMENTS

All the sections of the report appear to me to comply with the terms of reference, within the context that I understand from the "Background document and environmental issues report" which accompanied the reports sent to me. Similarly, all the sections followed a logical train of thought, clarity in setting out and explaining the assessment process, and in explaining the results and conclusions that were drawn.

The Summary section is clear and concise, and adequately captures the main issues and conclusions of the report. I don't know that this section adequately captures the alternatives that were formulated as the framework for the environmental feasibility assessment process (question 6 in my terms of reference). This criticism may apply to much of the report, but I am not clear that I understand what is meant by "alternatives" in this context. Are the specialists being asked to come up with alternatives to the dams, or with ways to avoid or mitigate their impacts? If the former, they have not achieved this aim. If the latter, then there is some effort to describe mitigations, but not at any level of detail in this or other sections of the report.

The Structure of this document (section 1) is a useful "road-map" through the report, and clearly acknowledges the limitations inherent in each specialist section. The deficiencies acknowledged in this section are predominantly a lack of suitable data and time to collect more, but these deficiencies are inherent in all projects of this nature and broad resolution.

The Methods (section 2) are not described in detail or comprehensively, and require some faith in the specialists that they have applied the appropriate methods (justified in this case). It is probably not appropriate in a study of this broad resolution to insist on detailed descriptions of the methods. A specific criticism would be that "only superficial comments have been made" on the likely inhabitants of the lakes (section 2.4). Why? There is plenty of information on the invertebrate fauna of lakes of different trophic status, both from KwaZulu/Natal and elsewhere.

The Study area (3) is confined to a map, which is of limited use to those who do not know the area. Specifically, the names of the rivers have not been included, making it difficult to orient the reader.

The Water quality and environment in the inundated areas (section 4) is described in good detail, 'though the water quality section (4.3) fails to supply any data on the concentrations of inorganic salts in the water which will supply the two dams. The complex issues related to the effects of dams as discontinuities in river systems are only lightly touched upon. There is no summary or synthesis of the issues, and this may make conclusions difficult for non-specialists.

Section 5, the anticipated characteristics of the two dams, is an excellent and detailed prediction of the water quality conditions likely to be found in the proposed impoundments, using both the extensive data base on the river, and extrapolating from knowledge of other impoundments. Taken in conjunction with the specialist report on water quality in Appendix 1, this provides by far the most detailed analysis of the whole report. This is probably appropriate, since there is more historical data available for water quality than for any other aspect of the river, and the impoundment effects on water quality will arguably be the most critical consequences of the dams. Perhaps the one criticism would be that there is no detailed discussion of the proposed multiple outlet facility planned for the Jana Dam at least, nor of the characteristics of the stilling pond and weir below the dam, which I understand may have to be the height of Midmar dam, and will surely have its own effects on water quality.

Section 6, predicting the inhabitants of the proposed impoundments, is reasonably detailed in terms of the fish fauna, although I would have liked to see some description of the proposed eelways. The assessment is somewhat superficial for the other groups. For example, from my own rudimentary knowledge, I would guess that the lack of suitable riparian egg-laying sites would be the likely limiting factor for crocodiles in these steep-sided impoundments, but this is not mentioned. In respect of birds, how will the lakes become a significant habitat for water birds if there will be only "minimal littoral habitat" as a result of the steep sides of the impoundments?

Section 7, Impacts of the impoundments, covers the potential impacts adequately, 'though once again the descriptions could not be said to be comprehensive. The table (7.1) provides an excellent summary of the impacts, expressed in the standard EIA terminology.

Section 8, Suggested mitigations, are outlined, but once again at a level which is far from comprehensive. Very few methods are described by which the suggested mitigations could be implemented. In 8.4.2 the possibility of artificially destratifying the lakes is rejected because it would be "prohibitively expensive". This decision is surely the responsibility of the managing agency and not of the ecological consultant?

Section 9 on Monitoring could surely have contained more detail? This section is something of a wish-list, with little detail on methods, frequency, or specialist requirements which would assist the manager to judge what the priorities might be. Monitoring methods are fairly standardised, and could have been included in more detail. For example, the water quality monitoring suggested in the second bullet could have included suggested frequencies; the water quality model in the third bullet could have been specified; why is there a need to "assess the number of elvers moving upstream" (10th bullet), and how could this be done? Is it possible to implement the "elimination of aquatic weeds from catchments" (14th bullet), given the longevity of the seed banks of some species? I think this section does not provide sufficiently comprehensive suggestions for management decisions to be made.

CONCLUSIONS

The above specific criticisms are not a reflection of the overall quality of this report, which gives a perfectly acceptable overview of the ecological and water quality issues of the proposed dams. If the report is intended to flag the issues for further investigation, then it is at a reasonable level of detail for the proponent to make an informed decision on proceeding to the next stage of the TWP (to answer question 9 of my terms of reference). If the intention was to provide the managers with sufficient information in this report to plan the dam construction, the ecological mitigation measures, and the monitoring programme, then it would need more detail.

I would suggest that the task team consider the individual points raised here for each section of the report, and decide whether these need to be expanded in this report, or whether they can be carried over as requirements for the full EIA procedure.

THUKELA WATER PROJECT FEASIBILITY STUDY

DOWNSTREAM, AQUATIC AND RIPARIAN ECOSYSTEMS BASELINE STUDY

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SUMMARY

The contents of this report detail its purpose, its terms of reference, the methods used, the geographical limits of the study area, an overview of the past and present condition of the river, the expected major impacts of the Thukela[1] Water Project (TWP) on the river, mitigation of the impacts, and suggestions for further monitoring. The project was severely constrained by two major factors. Firstly, the concurrent reports that were planned to provide the basic hydrological and geomorphological data, on which this ecological report was to have been based, were only completed *after this* report and so did not provide the necessary information. Secondly, the project was carried out in the short space of just over two months during a late winter, low flow season. It is important that in the succeeding Environmental Impact Assessment (EIA) stage of the TWP these shortcomings be rectified. Of particular importance will be to work at a greater resolution where the changes to the ecosystem need to be determined for each of the affected reaches.

It is important to stress that this is an advanced scoping report and was not intended to be a full EIA. This will follow in the next phase of the project.

General background to the Thukela and Bushman's Rivers

- The Thukela River is peculiar in that at Harts Hill it enters a deep and steep gorge some 22km in extent, flattens out somewhat to Thukela Ferry, after which it enters another reach dominated by rapids some 34km long to Ngubevu. Thereafter its gradient is again lower.
- Where topography is gentle in the Thukela valley there is a dense human population density with accompanying livestock, so that the condition of the riparian zone is thoroughly degraded to the point where the vegetation is dominated by unpalatable species and a creeping fine grass. The riparian zone has been in this condition since at least the 1950s.
- Since the instream studies of the 1950s the rivers have been dammed and water diverted from the upper Thukela River to the Vaal River system. There are dams on the Bushman's, the Little Thukela, the Klip and the Buffalo Rivers and transfers of water from the Mooi and Thukela River at Middledrift to other systems. Comparison of the available data from the river ecosystems in the study area, before and after the construction of some of these dams, suggests that there has been little or no change in the biota as a result of these dams. This data is, unfortunately, at a coarse level and

[1] Thukela is used as the correct spelling but is synonymous with Tugela

does not suggest with any confidence that changes will not occur as a result of the TWP.

- At the Lake Mielietuin dam site the stony-bottomed Bushman's River is in a short gorge from which it emerges into the flatter area of the Weenen irrigation scheme. Below Weenen it enters a second hard-bottomed gorge with a large waterfall.

Likely causes of impact resulting from the TWP

- Eight of the greatest causes of impact of the proposed dams on the Thukela and Bushman's Rivers are likely to be:-
  - "shrinking" of the downstream rivers (less water, less habitat, less biota);
  - changes in flow regime and the resulting affects on the river morphology;
  - changes in river water temperature;
  - the pulsing flows resulting from the monthly testing of the discharge valves (280m^3/s discharged for five minutes from Lake Jana);
  - changes in water quality;
  - changes in silt loads;
  - changes in turbidity;
  - plankton abundance in water released from the dams.
- Mitigation of the impact of altered flow regimes can be achieved through determining and implementing the maintenance flow requirements required to maintain the river ecosystem (the IFR process).
- Impacts due to the monthly testing and servicing of valves on the dam walls could be severe. Several valves, each of which could be tested one after the other, could replace the proposed single discharge valve. The number of valves should be arrived at from a study of the attenuation of flow peaks at a number of distances below the dam. Alternately, the tailpond below the dams could be designed to catch the test release and to release this slowly to the river.
- Selective withdrawal of water from specified depths could mitigate the undesirable aspects of altered water quality in the released water. This will need to be modelled to estimate the benefits of doing this.
- The impacts of dissolved manganese and ammonia, and their persistence downstream, have not been quantified, but it is likely that at times the concentrations will exceed the guideline values for the protection of aquatic life.
- Mitigation of changes in the silt dynamics of the river might be achieved through the channel-forming floods included in the IFR, but the achievement of this goal in a river as long as the Thukela is by no means certain. It will not be possible to mitigate the

loss of sediment in the reaches a short distance below the dams, which will have significant negative impacts on the ecosystem.

- The occurrence of large quantities of plankton in the river immediately downstream of the dam is unlikely to require mitigation, as the impact would be confined to a few kilometres below the dams. Large populations of filter feeding invertebrates would strip them from the water.
- The barrier effect on fish migration imposed by the two dams does not appear to be serious. On the Thukela, natural barriers at the headwaters of Jana Dam normally prevent the passage of fish from moving upstream. The advent of Jana Dam will move this barrier some distance downstream with resultant loss of habitat but no disruption of genetic transfers between up and downstream. Mielietuin Dam occurs a short distance above a natural barrier, so the only genetic discontinuity will be between the fish isolated between that barrier and the river upstream of the dam. It will be possible to occasionally (~ 5 years?) transfer fish by road to alleviate this problem. Nevertheless, it is important that the dam walls do not negatively impact on fish spawning as fish attempting to migrate could accumulate at the foot of the wall in unfavourable circumstances.

The existing fauna and flora of the Thukela and Bushman's Rivers

Fish

Historical and current fish distribution data show that 20 indigenous and seven alien species inhabit the Thukela and Bushman's Rivers. These include two Red Data and two endemic fish species. A survey in October 1999 revealed that all fish were scarce in riffle habitats from Jameson's Drift to Mandini, this possibly being related to the low flows and possible elevated TDS and conductivity levels. Riverine habitats were inspected briefly from the air and appear to be in good condition, having recovered well after the 1984 and 1987 floods. The possible impact of the proposed Jana and Mielietuin Dams on fish migration, as well as on fish habitat and behaviour throughout the system, were considered.

Impacts on fish:

- The loss of water from the system would have a significant adverse impact on fish habitat, and consequently on fish ecology, throughout the middle and lower reaches of the Thukela. The minimal inflows from the Mooi and Buffalo Rivers are unlikely to be enough to maintain the lower Thukela's instream habitat and fish populations at natural levels. Mitigation through effective releases from the upstream dams would be essential and will need to be determined through a more comprehensive IFR process than the one before, which did not consider the lower reaches of the river.

- The endemic species, *Barbus natalensis* and *Labeo rubromaculatus,* occur throughout the river system. IFR releases will need to cater for these fish.
- The Red Data species, *Myxus capensis* and *Taenioides jacksoni,* only occur in the estuarine region of the river. Little is known of their requirements but the IFR would need to cater for them.
- Carp predominate in existing impoundments, as well as in the Thukela above Colenso and in the middle reaches of the Bushman's River. An increase in carp populations in the Thukela and Bushman's Rivers, resulting from less variable flows, could be viewed as an advantage to subsistence fishermen, but would adversely affect all indigenous fish populations. The loss to nature conservation should be seen as the overriding consequence.
- Fish migrations are unimpeded throughout the middle and lower reaches of the system, but are halted by the cascade below Harts Hill Falls on the Thukela, Little Niagara on the Klip River and the Bushman's waterfall. Migrations have therefore historically not taken place much above the two proposed impoundments. Jana and Mielietuin Dams will thus have little impact on fish migrations in both rivers.
- Eels could disappear from the upper reaches of both rivers unless the elvers are able to surmount the dam walls.
- Fragmentation of fish populations could impact on their genetic structure in the Bushman's River, but this will be easily mitigated by the occasional transport of fish from below the dam to above it.
- Fish will tend to accumulate below the dams (water quality permitting), which may have some impact of their breeding. Water releases in close proximity to the dams will have to take this into consideration.
- Riverbed degradation and scouring will occur immediately below both dams.
- Riverbed aggradation is likely to occur in the middle and lower Thukela.
- Scouring will deepen and enlarge the pool habitats for fish, but will reduce the incidence of cobble beds where fish can spawn.
- Aggradation will reduce pool depths, limiting available fish habitat, especially in the dry season, and will smother cobble-spawning beds.
- Low flow periods will become prolonged and the high TDS and conductivity conditions that then develop may limit fish populations, especially in the lower reaches of the Thukela. The contribution of high conductivity water emanating from tributaries that flow through mining areas should be investigated and added to this

investigation.

- Reduced flows will aggravate the adverse effects of the Mandini Paper Mill effluent on the lowest reach of the Thukela River. Control of this effluent will become more important.
- Lake Mielietuin could act as a nutrient sink, improving water quality conditions in the Bushman's River at Weenen. The same applies to Lake Jana but to a lesser extent.

Crocodiles

- Crocodiles are widespread but not common in the system. It needs to be determined what impacts the regulation of the rivers will have on their populations.

Invertebrates

Maintaining permanent flow and ensuring correct seasonal distribution of high and low flow regimes is important for the invertebrate population. Due to the lack of information on the specific needs of different species, it is suggested that the future flow regime should be managed in order to maintain existing biotope diversity. Success at doing this could be monitored by measuring the diversity of selected aquatic macroinvertebrates, especially species with narrow requirements. This report contributes to the development of a baseline on which this type of monitoring could be based.

Even with the limited data available it was possible to note that no serious deterioration of diversity has occurred in the lower reaches of the Bushman's or Thukela Rivers since the 1950s and 1960s, despite the development of the dams in the upper reaches. Ephemeroptera and Trichoptera are still diverse and are the dominant taxonomic groups.

Impacts on the invertebrates:

- The downstream zonation of aquatic macroinvertebrates observed in the Thukela River will be disrupted, which will be reflected by changes in species and relative abundance.
- Colder water discharged from the bottom of the dams at regular intervals will have a negative effect on the macroinvertebrate biota for some distance downstream. Irregular temperature fluctuations will upset the biological rhythms of many species and aquatic insects will fail to pupate, metamorphose or emerge. Certain adaptable species will become abundant and become pests, which will be costly to control.
- Bottom releases of anoxic water will be toxic to some riverine biota. This would impact on diversity as only resilient species would survive.

- Due to armouring of the river downstream of the dams and reduced input of detritis, species community structure will be disrupted with no detrital feeding species. Such conditions will favour bedrock dwelling species, i.e. certain species of Simuliidae and hydropsychid Trichoptera. Subtle changes in species dominance and a gradual change in the functional ecological role of species will occur.
- Less sediment in the water will lead to a greater clarity of water with more algal and plant growth on substrates downstream of the impoundments. Greater clarity of the water will make species more vulnerable to predators dependant on vision. This will lead to subtle changes in species composition.
- Clear water in the lakes would lead to the development of algal blooms. Phyto and zooplankton will increase and be released into the river downstream. This will favour filter feeding simuliids and hydropsychids.
- Much further downstream of the dams, lower flows will lead to increased sedimenting of riffles and a loss of braided sections of river. This will lead to a reduction in the heterogeneity of substrata and reduction in species diversity. This will modify the river ecology leaving fewer but dominant species, which will periodically develop into pest population sizes.
- As a management proposal for the Thukela River, it is recommended that efforts should be made to maintain conditions that will enhance the diversity of filter feeding species in the riffle and running water biotopes.
- Maintenance of sediment free substrata and prevention of clogging of interstices in riffles should be managed.
- A monitoring programme should be implemented to document changes and to improve management of the lakes once constructed.

Riparian vegetation in the Thukela and Bushman's rivers

The Thukela system is far from pristine. The phytodiversity of the riparian vegetation has been drastically reduced by years of mismanagement. Most of the sweetveld grasses, which may have constituted a good grazing resource, have been lost from the flood plains. Currently, the flood plains support virtually monotypic stands of *Cynodon dactylon*, which remains an important resource to local herdsmen.

Grazing pressure in most of the reaches has heavily impacted the hygrophilous species of the Thukela. This has resulted in a reduction in stands of *Phragmites* and hygrophilous fringes of Juncaceae and Cyperaceae. Because of these negative impacts, the effect of altered flow regimes may be masked in heavily grazed reaches.

Most of the biodiversity along the river occurs in the shrubby vegetation of the rocky reaches. However, apart from *Vittelariopsis dispar*, most of these species are widespread.

In terms of the ethnobotany of the river, a few species are worthy of mention. *Trichilia emetica* is a valued tree and occurs sporadically in the lower reaches. *Vitellariopsis dispar* is a narrow endemic to the Thukela and its tributaries. In addition, fruit of this species are harvested by local communities. Poor implementation of this project could result in the extinction of this species. *Sclerocarya birrea* occurs sporadically in the riparian vegetation and is valued for its fruits, kernels and bark.

Impacts on the riparian vegetation

A very serious potential problem, within the development, is the invasion of exotic species due to the envisaged ecological disruptions. This will lead to rapid degradation of a system already under considerable stress. The critical weed species that require careful monitoring and control are *Acacia mearnsii, A. dealbata, Caesalpinia decapetala, Lantana camara, Chromolaena odorata* and *Cardiospermum* spp.

As a result of reduced flooding and sustained low flows, the river banks could in many places become dominated by reeds. In some areas, this trend will be countered by grazing pressures from the local cattle.

Instream flow requirements

It is important to appreciate that the IFR process that has previously been conducted did not focus on the rivers below the two dam sites and down to the sea. Mitigation of the changes that are likely to take place in the river will be possible to a large degree by a proper implementation of the outcome of a full IFR investigation (situated within the determination of the environmental reserve). Unfortunately, current knowledge of the existing Thukela River ecosystem is insufficient to be able to state with more confidence, the conditions that must be created in the river and whether these can be met by the IFR. Without this information, it is necessary to take a precautionary approach and to mimic the natural flow regime (albeit with less water) on which the natural biota is structured. It also needs to be stressed that the IFR will only be effective if investigations continue AFTER construction, whereby there is monitoring and continual refinement of the IFR releases so as to ensure and optimise their efficiency.

Sustainability of the proposed developments

According to Dr Mark Everard (UK Environmental Agency and The Natural Step), one of the conditions of sustainable use of a resource is that "The physical basis for the productivity and diversity of nature must not be systematically diminished". This project will need to assess this matter, based on a full EIA, to determine if this condition is being met. In some respects habitat will be lost, not only because of reduction in the size of the river, but also because of sedimentation. On the other hand, in some areas predominantly inhospitable habitats will be replaced by those that are more productive and diverse (e.g. due to scouring, some sand bed river may be replaced by riffles).

The greatest challenge that needs to be met in answering "if this project is sustainable" is to assess what biodiversity changes will occur, and what will be the significance of these. With the level of information contained in this report, this is not possible for many species about which very little is known, but also because much of the diversity has not yet been collected and documented. Nevertheless, with the limited information available, it appears that, with proper mitigation of the impacts, no serious deterioration of the river would take place as a result of the TWP. Some cautions are:

- Despite the developments of the water resources of the Thukela Basin that have already taken place, preliminary studies indicate that there have been no detectable changes in the river ecosystem, except in the immediate downstream vicinity of the upstream dams. Unfortunately, the impacts are likely to be cumulative. It is difficult to say when the cumulative impacts will become unsustainable, leading to rapid deterioration of the system.
- Fish species extinctions are unlikely to be caused by the developments, but some populations will undoubtedly diminish. This would be a significant loss both to nature conservation and to subsistence fishermen. Alien species would also increase, placing further stress on the system.
- The riparian vegetation in the Thukela Basin is in a poor state and has been for some time. The sustainability (or possible improvement?) of the riparian vegetation following the construction of the envisaged dams will depend on the operating rules relating to water releases.
- With proper management of river flows and water quality, it should be possible to maintain a healthy invertebrate population without any serious loss of species or diversity. Further survey work is required to ascertain if there are any species or populations of special importance that cannot be catered for in the developments.

1 PURPOSE OF THIS DOCUMENT AND TERMS OF REFERENCE FOR THE STUDY

1.1 Introduction and background

The Department of Water Affairs and Forestry (DWAF), as the responsible institution for the management of South Africa's water resources, has commissioned the Thukela Water Project Feasibility Study (TWPFS) with a view to further augmenting water supply to the Vaal River System from the Thukela River catchment.

The proposed scheme comprises the construction of two large dams, Lake Jana on the Thukela River and Lake Mielietuin on the Bushman's River, with linking aqueducts comprising either an open canal and/or a pipeline from the proposed dams to the existing Drakensberg Pumped Storage Scheme.

1.2 Terms of reference for this baseline study

The purpose of this Baseline Study was to determine the impact of the proposed Thukela Water Project (TWP) on the downstream aquatic and riparian ecosystems and their biodiversity. The rationale for this study was that, in addition to changes in flow which may directly impact upon biota, changes in flow and sediment supply might also bring about a change in patterns of sedimentation and erosion. This in turn will result in changes to downstream geomorphology and, therefore, the availability of habitat for river biota. Water quality changes resulting from the release of impoundment water may also affect downstream biota. The physical barrier of the dam and impoundment may also have consequences for the migration and dispersal of upstream and downstream riverine biota. This Baseline Study had the following objectives:

1.2.1 Collation of baseline information from previous studies and the IFR determination, focusing on the biodiversity and functioning of the downstream aquatic and riparian ecosystems.

1.2.2 An aerial reconnaissance to identify, map and describe significant aquatic and riparian habitats in the downstream reaches giving consideration to changes likely to occur resulting from the regulation of the river.

1.2.3 Necessary field surveys in order to determine the characteristics of important habitats and the communities they support and to verify or add to data obtained from previous studies.

1.2.4 An evaluation of the aquatic and riparian biodiversity of the downstream reaches giving an indication of the occurrence or likely occurrence of Red Data or other important species was required.

1.2.5 Based on consideration of all techniques and data sources, an assessment was required of the impact of the proposed TWP on the aquatic and riparian ecosystems, and biodiversity of the downstream reaches of the Thukela and Bushman's Rivers (Table 1.1). The scenario which includes the IFR/EFR releases was to be seen as a mitigatory measure and impacts were to be stated before and after mitigation.

1.2.6 Further opportunities for mitigation were to be identified, and where these are identified, impacts of the project before and after mitigation were to be stated.

1.2.7 Specific consideration was to be given to the identification of requirements for further investigation. Similarly, guidelines for both baseline (pre-dam) and post-dam monitoring were to be provided.

Table 1.1: Conventions for definitions and used in the description, evaluation and assessments of environmental impact

Category	Description or Definition
Type	A brief written statement, conveying what environmental aspect is impacted by a particular project activity or action, or policy or statutory provision.
Magnitude and Intensity	The severity of the impact
very high	- Complete disruption of process; death of all affected organisms; total demographic disruption
high	- Substantial process disruption, death of many affected organisms; substantial social disruption
moderate	- Real, measurable impact, which does not alter process or demography
low	- Small change, often only just measurable
no effect	- No measurable or observable effect
unknown	- Insufficient information available on which to base a judgement
Extent / Spatial Scales	The geographical extent or area over which the direct effects of the impact are discernible, i.e. the area within which natural systems or humans directly endure the effects of the impact.
International	- Southern Africa
National	- South Africa
Regional	- KwaZulu-Natal and the Thukela catchment, the uThukela region
Local	- dam basin, conveyance servitude, river reach, specific site locality
Duration	The term or time period over which the impact is expressed, **not** the time until the impact is expressed. Where necessary the latter must be specified separately.
short term	- up to 5 years (or construction phase only)
medium term	- 5 to 15 years (or early commissioning and operational phases)
long term	- > 15 years (or operational life)
Sign	Denotes the perceived effect of the impact on the affected area
Positive (+)	Beneficial impacts
Negative (-)	Impacts which are deleterious
Certainty	A measure of how sure, in the professional judgement of the assessor, that the impact will occur or that mitigatory activity will be effective
Improbable	- low likelihood of the impact actually occurring
Probable	- distinct possibility that the impact may occur
Definite	- impact will occur regardless of prevention measures
Significance	An integration (i.e. opinion) of the type, magnitude, scale and duration of the impact. Judgements as to what constitutes a significant impact require consideration of both context and intensity. It is the assessor's best judgement of whether the impact is important or not within the broad context in which its direct effects are felt. (see Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823)
High	- Could (or should) block the project/policy; totally irreversible (-ve impact) or provides substantial and sustained benefits (+ve impact)
Medium	- Impact requires detailed analysis and assessment, and often needs substantial mitigatory actions.
Low	- Impact is real but not sufficient to alter the approach used. Probably no mitigation action necessary.

Some Explanations and Definitions

1 Environmental impact - An environmental change caused by some human act. (DEA 1992. *The Integrated Environmental Procedure*. Vol 5)

2 Environmental impact - Degree of change in an environment resulting from the effect of an activity on the environment whether discernable or undesirable. Impacts may be the direct consequence of an organisation's activities or may be indirectly caused by them. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

3 Affected environment - Those parts of the socio-economic and bio-physical environment impacted on by the development. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

4 Environmental issue - A concern felt by one or more parties about some existing, potential or perceived environmental impact. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

5 Environment - means the surroundings within which humans exist and that are made up of:
- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of (i) and (ii) and the interrelationships among and between them;
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being National Environmental Management Act No 107 of 1998).

6 Significance - (See Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823. Also in, DEA 1992. *The Integrated Environmental Procedure*. Vol 4)

7 Significance - "The definition of significance with regard to environmental effects is a key issue in EIA. It may relate *inter alia* to scale of the development. To sensitivity of location and to the nature of adverse effects." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 13).

8 Significance - "Once impacts have been predicted, there is a need to assess their relative significance. Criteria for significance include the magnitude and likelihood of the impact and its spatial and temporal extent, the likely degree of recovery of the affected environment, the value of the affected environment, the level of public concern, and political repercussions." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 124).

9 Significance -" The question of significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective - technical, conceptual or philosophical - the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant." (Beanlands, G. 1983. *An ecological Framework for Environmental Impact Assessments in Canada*. Institute for Resource and Environmental studies. Dalhausie University. Sections 7: 43)

10 Environment - Surroundings in which an organisation operates, including air, water, natural resources, flora, fauna, humans and their interrelation. (ISO 14001. 1996). Note - Surroundings in this context extend from within an organisation to the global system.

11 Environmental aspect - Element of an organisation's activities, products or services that can interact with the environment. (ISO 14001. 1996). Note - A significant environmental aspect is an environmental aspect that has a or can have a significant environmental impact.

12 Environmental impact - Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services. (ISO 14001. 1996)

1.3 Overall limitations and constraints

The overriding limitation on this project was the short time allocation for the work, and that all fieldwork was carried out during an inappropriate season. Work on the project commenced on the 16 August 1999 and the final report was submitted in draft on the 9 November 1999. All survey work was thus carried out in the late part of winter, prior to the first spring rains, which meant that river flows were low (exceptionally) and plants were still overwintering. Without the time or opportunity to properly survey the river environment, the conclusions contained in this report must be treated as circumspect.

Coupled with the above time limitations, was the availability of other information. This report was produced *prior* to other reports that were designed to provide information on the geomorphological and hydrological changes likely to occur after construction of the dams. These primary driving factors of the river ecology were thus unknown, which makes the conclusions of this report even more circumspect and of a general nature. The following phases of the project, which will include a full EIA, will be able to refine these conclusions.

(Post Script: After the compilation of this report, reports on the geomorphology and hydrology became available but the inclusion of their data will be the function of the next phase of the investigation. These are Birkhead and Wadeson (2000) and Jewitt (2000)).

1.3.1 Limitations to the water quality investigation

To estimate the water quality likely to enter the proposed impoundments, and thus to model the quality of the future impoundments and thus the downstream releases, the available chemical analysis data for five DWAF monitoring stations above the proposed impoundment sites were extracted. Data that is more comprehensive was available from the Umgeni Water site at Middledrift, which lies below both the dam sites (the results of this investigation are presented in Dickens, 1999a, the report on the proposed impoundments).

The maximum frequency of analysis in the DWAF database was considered too low to adequately characterise water quality and to evaluate pollutant loads. A weekly sampling frequency, particularly during the summer months, would be considered essential for this purpose. The paucity of the data was considered a severe limitation. The Umgeni Water database provided important data monitored on a weekly basis but only at the one site.

Analyses for total phosphorus, turbidity, suspended solids and bacteria (*E. coli*) were not conducted on any of the routine DWAF samples, which is considered to be a serious omission in characterising water quality in the catchments. The lack of data for turbidity/suspended solids concentrations and bacteriological analyses, such as for *E. coli* means that estimating the extent of diffuse pollution to rivers from informal settlements without sanitation and sewage was limited.

Information describing the anticipated quality of water releases from the proposed impoundments is contained in Dickens (1999a). Unfortunately, no information was available stating how water would be released from the two impoundments (quantity, scour or surface spills or variable abstractions), which has meant that the quality of the water released to the river could only be speculated. Furthermore, no hydrological information was available to enable the modelling of the water quality from the impoundments to the sea. Clearly, the quality of water released from the impoundment would change by natural river processes and also by the addition of water from catchment run-off and tributaries. It was impossible to say how far down the river the impoundment release water quality would persist although some indications have been given. This has meant that the ecological assessments at the various sites down the river have had to be done relating to water quality in general terms only.

1.3.2 Limitations to the faunal investigation

Limited data for fish populations already existed, mostly in the database of the KwaZulu-Natal Nature Conservation Services (KZNNCS). The limited time available enabled limited further collections at a time when the river was at its lowest level for some time. This meant that the distribution of fish was probably not representative of times when flows are more generous, or of other seasons. Furthermore, the KZNNCS were only able to provide the services of Mr Mike Coke for the basic data and information provision, which necessitated the co-option of Dr Jim Cambray in the very late stages of the project to interpret the data. Assessment of possible impacts resulting from the impoundments was also severely constrained by the lack of geomorphological and hydrological information and could thus only be of a general nature.

The limited time available for invertebrate surveys has meant that only a part of the diversity of the river has been documented. The timing of the survey did not coincide with the time of maximum diversity and a full range of seasons was not surveyed which would have provided further information. Fortunately, an unanalysed collection made in 1985 by Brian Fowles, then of the CSIR, was available for analysis and contributed greatly to the information available. A further limitation was the short time available for identification of the specimens collected, which in many cases could not be done to the species level. Many specimens had to be sent to various specialists for identification, so have not been useful to this report. The analysis of the invertebrate data was also based on the river zones defined by Oliff (1960a), which are not synchronous with the reaches defined by the geomorphologist on this project (Wadeson, 1999). In time, these two approaches will have to by synchronised.

1.3.3 Limitations to the floral investigation

This study provides a brief overview of the riparian vegetation on the Thukela River system below the intended impoundment sites. Population physiognomy, phenology and biodiversity were covered within the confines of the limited budget. The initial brief was to conduct a pilot study which was to be used in a feasibility assessment. Such studies are precursory and based on superficial data. Clearly, an impact assessment is a much more rigorous study and will require considerably more time to complete. In addition, impact assessments need to be conducted across, at the very least, one full average season otherwise cryptophytic herbs will be overlooked and this is where the bulk of biodiversity lies. The current survey was conducted during an early season drought and this has seriously limited the ability to assess plant phenology, especially the recruitment of seedlings and their importance on bank stabilisation. In addition, it is exceedingly difficult to identify sterile specimens of the Cyperaceae and Juncaceae, both of which contribute considerable diversity to the system.

Thus, the following points are inadequately addressed within this report:

- Species of conservation importance (2.1 in Terms of Reference)
- Rare and threatened species (2.4 in Terms of Reference)
- Species with significant traditional importance (2.3 in Terms of Reference)

From the biodiversity data gathered in the descriptive phase, outlined above, putative projections are made of ecological shifts that may result from changing flow regimes and associated geomorphological shifts. These possible shifts in vegetation composition and physiognomy are reliant on the accuracy of the scant geomorphological information that was available. No access to hydrological data has been possible which severely compromises the predictive value of this document.

1.3.4 Limitations to the overall river assessment

In order to assess the river ecosystem as a whole, its importance and sensitivity and the impacts that may occur, Dr Mark Chutter was asked to use his considerable expertise in a very high level way. Besides past experience with the Thukela River, his only source of information was the aerial survey conducted over one day, and a very brief look at the draft baseline study reports. For this he had a very limited time and budget. Some information was also available in the previous IFR reports, in particular the habitat integrity assessment conducted by Neels Kleynhans (Heinsohn, 1995).

2 METHODS AND APPROACH

2.1 Introduction

The overall objective of this project was to describe the historical and current status of the river ecology and to suggest how things could change in response to the development of the two upstream impoundments.

Describing the historical and current river environment was possible using comprehensive reports done in the 1960s, together with more current databases held in various places. Only limited time and budget was available to add to these databases in an attempt to provide new and relevant information. In order to “fast track” this process, an aerial survey by helicopter was conduced in August 1999, together with the specialist authors of this report (with the exception of Dr Cambray and Mr Simpson). Several landings were made along the length of the river from the sites of the present impoundments to near Elandskop. Unfortunately, logistical problems prevented the journey from reaching the estuary.

It was hoped that all of the specialist investigations would be linked to detailed geomorphological and hydrological descriptions for eighteen predefined reaches along the two rivers. Unfortunately, the detailed information from these was unavailable at the time of conducting the investigations and writing this report. Preliminary geomorphological descriptions of several reaches along the two rivers were made available by Roy Wadeson but the information was insufficient to allow proper interpretation of available biological data. Lack of this information, and a need to interpret current data, meant that some of the investigation has referred instead to the river zones described by Oliff (1960a). These are fewer in number and much broader than the reaches submitted by Wadeson, which means that not all of the information is in a form that is directly comparable (Table 2.1 and Figure 3.1).

Table 2.1: The overlap between the zones described by Oliff (1960a) and reaches by Wadeson (1999)

Oliff (1960) Zone No.	Wadeson (1999) Reach No.
6. The Rejuvenated Zone - from Hart’s Hill below Colenso to Ngubevu and, by inference, on the Bushman’s from Estcourt to the Thukela.	5.2, 5.3, B1, B2, B3, B4, B5, B6, 6.1, 6.2, 6.3
7. The Valley Sand Bed Zone - from Ngubevu to the top of the estuary.	(Fraction of 6.3), 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9

2.2 Approach to the faunal investigation

2.2.1 Fish

Historical distribution data held by the KwaZulu-Natal Nature Conservation Services, (KZNNCS), dating back to 1963, was reviewed and a week-long follow-up survey was conducted in early October 1999 when drought conditions prevailed. Low flows, together with possible higher conductivities, especially in the lower half of the river, reduced the collection of fish in the riffles where sampling by means of an electroshocker was necessary. Early collections were made using gill nets, seine nets and rotenone (a fish poison). Reference specimens from many sites have been lodged with the Albany Museum and JLB Smith Institute in Grahamstown. Riverine habitat conditions were assessed visually, water temperatures were recorded at most sites and pH and conductivity levels were recorded at a few sites in the mid-1990s.

2.2.2 Invertebrates

Between 1953-1961, Mr W.D. Oliff and colleagues undertook hydrobiological surveys of Natal rivers which included the Thukela and Bushman’s Rivers (Oliff, 1960a, 1960b; Brand *et al.*, 1967). Mr B.K. Fowles, then of the CSIR, commenced a re-survey of Oliff's sites in 1984-1985 and, although the survey was completed, there was insufficient time to analyse the samples (Fowles, 1986). Collecting techniques employed in these surveys were the same as those used by Oliff (1960a, 1960b). During 1999, due to time constraints, only brief surveys were undertaken: a one-day helicopter survey and a one-day motor vehicle survey in August 1999, as well as a six-day follow-up collecting trip in October 1999.

During the late winter - spring survey of 1999, four sites along the Bushman’s and 14 sites along the Thukela River were surveyed using a variety of nets and techniques which included collection from all biotopes and from the air. River flow at this time of the year is normally low, prior to the high summer flows, which allowed easy access to the main river channel. This season is characterised by increasing water temperatures and the emergence of the adult stages of many aquatic insects and is, therefore, a favourable time for collecting adult macroinvertebrates by means of light traps.

Identification of selected animals was carried out at the Albany Museum, while certain groups have been sent away to specialists for more detailed identification. The remainder of samples, which could not be identified in the present survey, will be stored for sorting and identification later. All material collected will be stored and curated in the Albany Museum, Grahamstown. Material will be stored under the Thukela River catalogue (TUG) or the Bushman's River catalogue (BUS). The collection contributed about 800 separate catalogue entries and about 15000 specimens.

An attempt has been made to relate the data from previous reports to current data and to suggest the changes that may take place in the river because of the TWP.

2.3 Approach to the riparian vegetation survey

An aerial survey of the river was undertaken and this allowed spot sampling from seven selected reaches, including some inaccessible areas. The aerial survey was invaluable in gaining an overall perspective of the riparian plant communities. The current impacts on the riparian vegetation, with respect to grazing, were placed into context by a broad overview of the adjacent vegetation. The continuity of vegetation types was recorded on data sheets from the helicopter and these were cross-referenced with diversity data generated on the ground.

Fieldwork was delayed for as long as possible, within the tight time constraints, due to the seasonal dormancy of the vegetation (identification of dormant plant material is often impossible). Site visits were conducted in late September and October. Community structure of the riparian vegetation was recorded and the species diversity was sampled for each reach. Where necessary material was tagged and identified at Natal University Herbarium (NU). This allowed a broad overview of the current vegetation status within the designated reaches. This survey did not concentrate on any specific sites because the monitoring process, with respect to riparian vegetation, should be holistic and not based solely on data from selected transects. This data was cross-referenced with the available (but minimal) geomorphological and hydrological data to provide insight into potential shifts which may occur in terms of floristic composition and physiognomy of the riparian vegetation.

Special attention was given to the status of exotic species along the watercourse and their potential as problem species with changing flow regimes.

2.4 Approach to the overall ecological assessment

Use was made of Dr Mark Chutter to apply his considerable expertise to give a high-level assessment of the river and the potential changes. The approach was to use impressions gained from the aerial survey, a broad knowledge based on many years of working with rivers and impoundments, the information provided by the baseline studies on geomorphology, water quality, fish, invertebrates and the riparian zone (from this report) and the older reports from Oliff (1960a, Thukela; 1960b, Bushman's) and Edwards (1967). Because of the scarcity of hard data and his remoteness from the project, of necessity his views on occasion differed with others as they were the result of judgment and opinion and not fact. His approach was to consider the river as it is in 1999 and the factors governing its ecology. He started with the assumption that neither the Thukela nor the Bushman's Rivers are presently in a natural state, if for no other reason that there are impoundments in their courses upstream of the study area. He then considered the likely major impacts of the impoundments on the rivers and the manner in which they could be mitigated. Also included in this section was the information provided in the 1995 IFR Starter Document (Heinsohn, 1995), in particular the sections by Kleynhans on habitat integrity and by Alletson on the importance of the river.

3 STUDY AREA

This report deals with the Thukela and Bushman's Rivers from below the proposed impoundment sites to the upper reaches of the estuary (see map of the study area, Figure 3.1; photographs of the Thukela River, Figures 3.2-3.7; and photographs of the Bushman's River, Figures 3.8-3.10). Figures 3.2 – 3.10 show sections of the two rivers that are representative of the reaches proposed by Wadeson (1999).

The reaches according to Wadeson (1999) are:
Thukela River:

5.3 Zingela farm & Kaisha farm & Thukela Estates
6.1 Bloukrans to the Sundays River
6.2 Jolwayo weir & Thukela Ferry
6.3 Ngubevu
7.1 inaccessible
7.2 Jameson's Drift
7.3 Shu Shu Island
7.4 Middledrift
7.5 inaccessible
7.6 Emabhobhane
7.7 Emabhobhane
7.8 Essiena farm & Mandini
7.9 Harold Johnson

Bushman's River:

B1 Weenen Nature Reserve
B2 Weenen
B3 inaccessible
B4 inaccessible
B5 inaccessible
B6 Darkest Africa & Nkasini Bridge

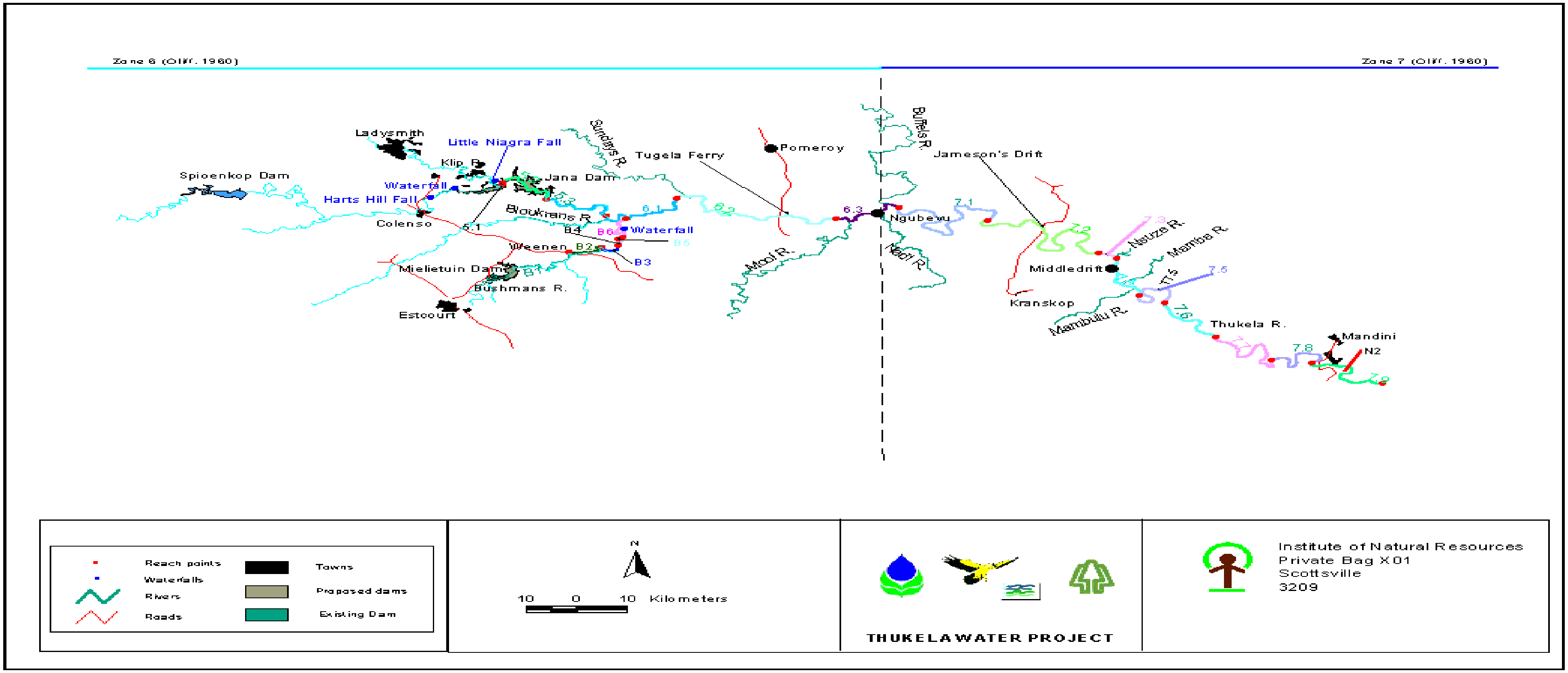

Figure 3.1: Map of the study area showing the reaches defined by Wadeson (1999) and the zones defined by Oliff (1960)

Photographs of the Thukela River Reaches - August 1999

Figure 3.2: Zingela (Jana Dam) - 5.2

Figure 3.3: Tugela Estates - 5.3

Figure 3.4: Bloukrans to Sundays - 6.1

Figure 3.5: Tugela Ferry - 6.2

Figure 3.6: Jameson's Drift - 7.2

Figure 3.7: Essiena - 7.8

Photographs of the Bushman's River Reaches - 1999

Figure 3.8: Mielietuin - B1

Figure 3.9: Weenen - B2

Figure 3.10: Darkest Africa - B6

4 DESCRIPTION OF THE HISTORICAL AND CURRENT THUKELA AND BUSHMAN'S RIVER ENVIRONMENTS AND ECOLOGY

4.1 General description

A useful account of the Thukela River environment is given by Oliff (1960a). In overview, the Thukela River drains about a third of the province of KwaZulu-Natal. To the west, the river and its tributaries rise in the high rainfall area of the KwaZulu-Natal and Lesotho border, while the northern tributaries rise in a lower rainfall area. The central part of the basin has a much lower rainfall. In the headwaters the terrain is mountainous, but this topography rapidly changes to an open inland plain where the gradient of the river is low.

At Harts Hill (just below Colenso) the river enters what Oliff named a Rejuvenation Zone. From this point downstream to near the coast, the river flows in a rugged valley, in which the rainfall is relatively low and summer temperatures are high. The Rejuvenation Zone commences with a 22km gorge where the channel gradient is high and the channel is dominated by rapids. Lake Jana site is situated within this gorge. There is a second reach dominated by rapids, starting at Thukela Ferry and extending for 34km to Ngubevu. Sand bed reaches of gentle gradient are found between the two reaches dominated by rapids.

From Ngubevu the river enters Oliff's Valley Sand Bed Zone, which extends to the estuary. Rapids are short and composed mainly of boulder beds and bedrock without loose stones. The riverbed is predominately composed of sand.

An important factor, which has a major impact on the Thukela River, is the presence of large rural populations in the open parts of the valley (above Thukela Ferry) and below Ngubevu. In these areas, the human population probably exceeds the carrying capacity of the valley. The riparian zone of the river has been overexploited to the point where only poisonous and unpalatable plants and a creeping grass, *Cynodon dactylon,* are found. Very occasionally, there are vegetable plots close to the river channel. The riverbanks are not as stable as they would be if they were better vegetated.

At most places in the study area fire and overgrazing are thought to be the dominant factors governing the composition of the modern riparian zone of the Thukela River. From the little reported by Oliff (1960a) on the riparian zone, this was also the case when he made his study of the river. Oliff (1960a) also reported on the water quality and the macro invertebrate fauna of the Thukela River. His findings provide a baseline of conditions some 45 years ago.

The water resources of the Thukela Basin have been developed through the construction of major impoundments and weirs on the upper Thukela (Woodstock, Spioenkop, Driel Barrage - transfer to Vaal River), the Buffalo (Zaaihoek - transfer to Vaal, Chelmsford), the Klip (two impoundments), the Bushman's (Wagondrift) and the Mooi (transfer scheme to Mgeni) Rivers. The retention of silt by these impoundments must have had an impact on the Thukela River all the way to the sea. The impact of this has not been taken into account in consideration of the present state of the river, primarily because data does not exist to compare the river prior to the impoundments. The exception is the invertebrate work, which was well documented before the construction of the impoundments. A little information also exists which hints at the quality of the riparian vegetation. Similarly, the impact of reduced flows in the Thukela River ecosystem due to the transfer of water to other catchments has not been considered.

Lakes Woodstock and Spioenkop (and indeed all the other impoundments in the Thukela basin) were built on the Thukela River after Oliff completed his studies and might be expected to have had an impact on the downstream river channel and the composition of its biota. However, as reported by de Moor and T. Edwards in the macro invertebrate and riparian vegetation sections of this report, the river appears to be little changed since Oliff and D. Edwards made their studies. It must, however, be pointed out that the lower of these impoundments, Lake Spioenkop, is a considerable distance of the study area. There is an obvious development of reed beds in the river immediately below and for some distance downstream of this impoundment.

While Lakes Woodstock and Spioenkop must trap large quantities of silt, the stored water is not silt free and the river water remains slightly turbid. On the helicopter inspection of the study area the river remained turbid as far downstream as the Buffalo River confluence, whereafter there was a marked increase in the transparency of the river water, possibly because of the sandy riverbed which trapped the finer sediments. The Buffalo River was not turbid at this time. It is pertinent that the inspection was undertaken in August, when river waters in the summer rainfall area are near their greatest annual transparency.

The flow of the Thukela River upstream of Middledrift has to supply sufficient water to allow for the transfer of water to the Mhlatuze River (in the order of $10m^3/s$). This may have a major impact on the level of dry season flows, particularly under drought conditions.

A useful account of the Bushman's River environment is given by Oliff (1960b). He described how the Bushman's River enters a zone of steep gradient below Estcourt that terminates in the gorge, just upstream of Weenen, which is the proposed site for Lake Mielietuin. The Weenen Nature Reserve occupies the left bank of the river in the gorge below the Mielietuin site. Below the gorge, the nature of the riverbed changes with a reduction in the gradient of the river in the broad valley in which Weenen lies.

There is extensive irrigation at Weenen. In the irrigation area, exotic trees and plants have invaded large parts of the riverbanks. The riverbed has large areas of fine particulate matter and is likely to be unstable (Wadeson, 1999). Below Weenen the river enters a second gorge in which there is a high waterfall. Upstream of the waterfall bedrock dominates the river channel and there is little true riparian vegetation. There is a stable pool-rapid reach within the gorge below the waterfall, which extends almost to the Thukela confluence.

The waterfall is sufficiently high to be a complete barrier to the upstream migration of all fish other than eels. It used to represent the upstream limit of distribution of the barbel, *Clarias gariepinus*, but the species has been introduced to the upper river.

Cattle ranching is the main landuse between Estcourt and Mielietuin. Intensive irrigation agriculture characterises the Weenen area but ranching is again prominent where the river enters the gorge with the waterfall. Downstream of Estcourt there are no areas previously belonging to KwaZulu. Nevertheless, overgrazing has taken place in the Bushman's River valley as evidenced by large areas of bare shale with dongas.

In the 1950s, W.D. Oliff (Oliff, 1960b) made an extensive survey of organic pollution in the Estcourt area. His lowermost sampling point was near Weenen. He found that the Bushman's and its tributary, the Little Bushman's, were heavily polluted by organic matter. Oxygen depletion due to high demand from organic matter was considerable. The invertebrate communities of the most polluted sections were severely impacted by the pollution. The biological responses to the pollution included the prolific growth of benthic algae, which indicates that nitrogen and phosphorus levels in the river were elevated.

During site inspections for the IFR determinations in the lower valley at Darkest Africa, algal growths on the riverbed were abundant. Nevertheless, the invertebrate fauna of this area remains diverse (de Moor, this report) and shows no obvious change from that reported by Oliff some 40 years ago. This, despite the fact that since the completion of Lake Wagondrift, water has been allowed to flow down the river to meet the needs of irrigation farmers at Weenen.

4.2 Importance of the Thukela River ecology

As part of the 1995 IFR investigation, Alletson reported on the importance of the Thukela River ecology (Heinsohn, 1995). Considering the uniqueness, condition, biodiversity and the role of the catchment, Alletson rated the reach from Jana Dam to above the Bushman's to be an important section of river. Downstream to below the Mooi River, the river has a moderate to low importance, but below the Buffalo again becomes important.

Alletson considers the Bushman's River from Mielietuin to the Thukela to be an important river as it is atypical of the southern tributaries of the Thukela.

4.3 Habitat integrity of the Thukela River

Kleynhans (Heinsohn, 1995) conducted and assessment of the habitat integrity of the river downstream of Spioenkop Dam. The information provided by this report can be summarised for the Instream Habitat as follows:

- Downstream of Colenso the flow of the river is reduced by 45% compared to its virgin flow. With greater distance below the proposed dam, the river approaches its virgin flow so that there is only a 20% reduction below the Buffalo River. This suggests that the impacts of water abstraction are already moderately large, but diminishing downstream.
- Flow regulation already exists in the Thukela, but below Colenso is gradually ameliorated by the inflow of tributaries. Cessation of flow has not been recorded.
- Bed modification was considered moderate below Jana Dam, but large between the confluence with the Bushman's and the Buffalo Rivers. Overgrazing and removal of riparian vegetation were considered as the main cause of the degradation. From the Buffalo downstream, bed modification was moderate due to inaccessibility.
- Impact of channel modification was less serious and was considered low.
- Water quality impacts were considered moderate and are ameliorated by the turbulent river flows.
- Exotic macrophytes were found near Colenso, but there was no impact lower down in the river.
- Exotic fish, in particular carp, have caused a small impact on the river, especially near Tugela Ferry.
- No solid waste sites were observed (although they must be present, but away from the river).
- The habitat integrity from Jana Dam to the Bushman's River was considered largely

natural with little modification. Downstream of this to the Buffalo the integrity of the river habitat decreases mainly due to bed modifications. Below the Buffalo, the integrity increases again.

The Riparian Zone was considered separately to the instream zone reported above.

- From just above the Bushman's to the Mooi River confluences the riparian zone was considered to be seriously modified in many places by farming activities and overgrazing of the riparian zone.
- Invasions by exotic vegetation were not found to be a problem.
- Bank erosion was minimal down to the Bushman's confluence but thereafter increased considerably down to the Buffalo confluence.
- From the Bushman's to the Buffalo confluences channel modification was moderate. Downstream of this the impact was small.
- It was felt that there was currently no impact by the current flow modification on the riparian zone. Likewise, alterations in water quality were not judged to be having any impact on the riparian zone.
- The total assessment of the riparian zone is that from Jana to the Bushman's confluence, the riparian zone is largely natural with few modifications. Downstream from this, the impact deteriorates significantly, but then recovers in the lower reaches of the river.

The habitat integrity of the Bushman's River below Mielietuin Dam was largely good despite some erosion and agricultural practises. Near Weenen, parts of the river were severely impacted. Downstream of this, the topography becomes very rugged and the impacts reduce considerably. Nearer to the confluence with the Thukela River, agricultural pressure begins to re-assert an impact.

4.4 Invertebrates in the Thukela River from source to estuary, 1953 - 1999

A full description of the invertebrate survey, with an assessment of the historical data is contained in Appendix 1.

The surveys conducted by Oliff (1960) and colleagues produced an extensive list of species (Appendix 1). This was compiled over a number of years, comprising numerous visits to various regions along the river systems and included extensive summertime collecting with hand nets and other techniques. Analysis of selected taxa gathered during the present survey is presented here (Appendix 1, Tables 4 & 5). With the limited time available for collecting and the requirements of other specialists to assist with the identification of many of the taxa, it was not possible to present an exhaustive review of the taxa that were found along these rivers. More intensive sampling would be needed in the summer, and preferably extending over several years, to ensure coverage of species found during different seasons and during average and wet or dry years. Odonata in particular would require specialist collecting techniques to allow proper assessment of the species present.

The main purpose of the 1985 survey carried out by B.K. Fowles was to compare the community or assemblage of macroinvertebrates with the surveys carried out in the 1950s. The techniques used were thus carefully selected to be similar although there were differences which would have had a negative affect on the comparison as different techniques and equipment would tend to favour different organisms, thus skewing the results. Details are presented in Appendix 1.

Because of time constraints, the level of identification of many of the invertebrate groups (Ostracoda, Cladocera, Copepoda, certain Diptera, Coleoptera and Hemiptera) could not be carried down to species level in this study. For other invertebrate groups (Ephemeroptera, Trichoptera and Diptera (Simuliidae)), current taxonomic knowledge far surpasses that available in the 1960s which means that greater resolution has been achieved.

The following points of interest have been extracted from the detailed report, which is presented in Appendix 1.

- Planorbid snails were found at several sites during the 1985 and 1999 surveys (Table 4) but not in the 1953/54 survey. Increasingly lower flows in the river will favour these snails and may lead to an increase in those species that are intermediate hosts of bilharzia.
- It was noted that no freshwater crabs (Potamonautidae) were collected during 1985. In 1999 only two *Potamonautes sidneyi* were collected by Mike Coke at Jameson's Drift while they were more plentiful in small tributaries, and several *Varuna litterate* were collected at Essiena farm in Reach 7.8. Freshwater prawns, *Macrobrachium vollenhoveni*, were found in riffles and stony runs about 10km downstream of the proposed Lake Jana site. This species becomes progressively more abundant at all sites in riffles further downstream and may be inhabiting the niche often occupied by crabs.
- The dragon and damselflies are represented in this region by 162 species (Pinhey, 1984, 1985) but practical reasons made it impossible to survey this group adequately during the 1999 survey. Only nymphal Odonata collected are incorporated in Table 4.

A nymph of *Paragomphus* was found at most sites surveyed in 1985 and 1999. *Zygonyx* sp., usually associated with stony substrates in swift-flowing water, were found at most sites in the Thukela River.

- The data in Table 4 shows a better collection of Ephemeroptera during the latter survey. The Thukela and Bushman's Rivers show a rich diversity of Ephemeroptera (Tables 4, 5 and 6). All except one of the South African families, the Teloganodidae, are found in these rivers. Two species of burrowing mayflies were collected in the 1953 survey but not during the 1985 and 1999 surveys. These species require a sand/clay substrate in which they make U-shaped burrows and are dependent on flow regime as changes can alter the nature of the substrate and hence their preferred biotope.
- Little information on the flow requirements of the Baetidae has been recorded. Generally, species such as *Baetis harrisoni*, *Pseudocloeon glaucum*, *P. vinosum*, *Cheleocloeon excisum* and *Afroptilum sudafricanum* are widespread and able to survive under a variety of conditions, whereas the *Demoreptus* species tend to be more specific in their flow requirements, needing fairly rapid flow and clean water. *Potamocloeon macafertiorum* has long slender claws typical of psammophilous species, and occurs in reaches where the flow is slower and the substrate sandy.
- The Caenidae are a family still needing major taxonomic revision. The most interesting found is *Clypeocaenis umgeni*, which has filtering hairs on its legs and mouthparts. This species inhabits faster flowing water compared to many of the other members of the Caenidae which generally live in slower flowing regions or out of the current, where silt deposition occurs.
- In the family Leptophlebiidae, only the tolerant *Euthraulus elegans* was collected in the 1999 surveys, as was the case in the earlier surveys.
- The flat-headed Heptageniidae cling to stones in moderate to fast-flowing current and their distribution and abundance may also be affected by changes in flow conditions in a river. They were recorded lower downstream in 1985 and 1999 than in the 1950s.
- Sisyridae, *Ceraclea (Pseudoleptocerus*) sp. and *Xenochironomus* sp., all associated with freshwater sponges, had not been recorded previously. It is unlikely that freshwater sponges and their associated fauna are a recent introduction in the river, but an increase in the abundance of these species would indicate changes in the general river ecology. This species was recorded only along the rejuvenated river zone and also in the lower Bushman's River. A greater abundance of fine filter-feeding organisms, such as freshwater sponges and Simuliidae, would indicate an increase in detritus and associated bacteria in the system.

- During 1953/55, 1985 and 1999 respectively 23, 11 and 18 species of Trichoptera were recorded along the main Thukela River. Only seven species were found during both 1953/54 and 1999 which suggests that some shift in species has occurred.
- All the aquatic moths collected belong to the family Pyralidae. Rock-dwelling species feed on diatoms and algae, other species feed on aquatic and submerged plants. One and three different species respectively were collected in the 1985 and 1999 surveys.
- During 1953/55, 1985 and 1999 respectively 7, 7 and 8 species of Simuliidae were recorded along the main Thukela River (Table 8). Only three species were found during both 1953/54 and 1999. This is partially due to more accurate identification of simuliid larvae during the 1985 and 1999 surveys. The presence of *Simulium dentulosum* and *S. debegene* in Zone 5 (above Lake Jana) during the 1953/54 survey is indicative of strong torrential flows.
- The data shows that there are four rare species of mayfly which occur only below the proposed Lake Jana dam site and which are thus threatened by the development. Besides this, several other species were confined to below the impoundment sites. Future work should concentrate on these species to document their flow and habitat requirements.
- Even with the limited data available, it is possible to conclude that no further serious deterioration of water quality has occurred in the lower reaches of the Thukela since the 1960s. A rich diversity of hydropneustic aquatic insects indicates that the water was of a relatively good quality.

4.5 Invertebrates in the Bushman's River from source to confluence with the Thukela River, 1953 - 1999

- The macroinvertebrate faunal diversity in the Bushman's River (Appendix 1, Table 5) was not as rich as that of the Thukela River. Not all samples from the recent surveys have been analysed and the data presented reflects only a preliminary assessment of what was found.
- Freshwater sponges and associated Sisyridae larvae were also recorded for the first time in this river system. No freshwater crabs, Potamonautidae, were collected in either the 1985 or the 1999 surveys. Atyidae and Palaemonidae were recorded in 1999.
- Only five species of Baetidae were identified from the Bushman's River sites from the 1999 survey, as opposed to 13 species reported by Oliff (1960). However, a few interesting species not reported by Oliff include *Cloeodes inzingae*, *Demoulinia crassi*

and *Pseudocloeon aquacidium*, but these may have been overlooked in the past. *Demoulinia crassi* is known to occur in still, deep stretches of rivers, and like the *Potamocloeon* species (not recorded from the Bushman's River), it dwells on the surface of sandy substrates where it collects detritus upon which it feeds.

- No burrowing mayfly species have been recorded from this river. They could possibly have already been excluded by the effects of pollution in the 1950s or, alternately, have been missed during collection.
- Perlidae (stoneflies) were recorded for the first time in 1999. This may indicate some improvement in water quality, or they simply were not collected previously. This is, however, unlikely as they are bold, easy to collect insects.
- The reports written between 1960 and 1967 recorded 11 species of Trichoptera. In the 1985 and 1999 surveys respectively 4 and 10 species of Trichoptera were recorded, light-trap collecting producing five of these records. Of the ten species recorded in 1999 only four were also recorded prior to 1967. This either indicates a significant change in species composition or it reflects differences due to the use of different sampling techniques.
- The number of simuliid species recorded for 1960, 1967, 1985 and 1999 were 5, 0, 1 and 10 respectively. This reflects a more intensive survey for these species and a greater level of identification during the most recent survey. Of particular note was the rich diversity of *Simulium (Metomphallus*) species, *S. medusaeforme, S. hargreavesi*, *S. vorax* and *S. wellmani*. These species are indicators of swift flowing water and their species diversity reflects heterogeneous substrate types and a diversity of flow conditions. Species in the subgenus *Simulium (Pomeroyellum*) were also represented by three species. Their affinities and flow requirements are discussed later. The most interesting find was a single larva of *Simulium lumbwanum* (found at Site 4, Reach B6, on the Bushman's River), a species that is phoretic (hitches a ride!) on Heptageniidae mayflies. Further research is needed to investigate this discovery.
- Even with the limited data available, it is possible to conclude that no further serious deterioration of water quality has occurred in the lower reaches of the Bushman's River since the 1960s. A rich diversity of hydropneustic aquatic insects indicates that the water was of a relatively good quality, especially at the lowermost site in the Bushman's River.

4.6 Fish in the Thukela and Bushman's Rivers

Under natural conditions, the Thukela River harboured 21 indigenous fish species, whilst over the past 30 years a further seven alien species have been introduced into or have invaded the river (Table 4.1). The indigenous fish include two Red Data species (*Taenioides jacksoni*, bearded eel goby and *Myxus capensis*, freshwater mullet), both limited to the river mouth region, one Thukela River system endemic species (*Labeo rubromaculatus,* Thukela labeo), which is widespread throughout the study area, and one KwaZulu-Natal endemic species (*Barbus natalensis,* scaly), which is also widespread throughout the study area. Numerically, the scaly forms approximately half the fish population of the river, *Labeo rubromaculatus* a quarter and *Clarias gariepinus* and *Labeo molybdinus* much less.

Of the alien fish, carp, *Cyprinus carpio,* have become the most widespread species since their introduction into Lake Spioenkop and currently are common in the slow-flowing sections of the Thukela between that impoundment and Colenso. However, a few have also found their way into the middle and lower sections of the river where anglers very occasionally catch them. Carp are not adapted to fast-flowing waters and therefore are not currently a problem in most of the Thukela River. Carp have been present in the Bushman's River since their introduction into Lake Wagendrift at Estcourt. Specimens were found in Weenen Nature Reserve as early as 1986 and by 1999 they were common in the slow-flowing reaches above that Reserve.

Bass, although present in impoundments in the catchment area, have only occasionally been found in the rivers themselves.

Of concern is the invasion of the extreme headwaters of the main Thukela by three Free State fish species, *Barbus aeneus, Labeo capensis* and *L. umbratus*, where they have invaded Lake Kilburn through the Thukela-Vaal Pumped Storage Scheme pipeline, despite its 550m altitude difference and whirling turbines. These species pose potential hybridisation and habitat-competition threats to the endemic Thukela labeo, *Labeo rubromaculatus*, and the endemic scaly, *Barbus natalensis,* throughout the Thukela Basin.

Instream fish habitat and fish populations:

Instream habitat appeared to be satisfactory in the Thukela River at the several sites physically inspected and also throughout the system, as seen from the air. Habitat in the Bushman's River looked good from the air, in terms of physical variety, but the rock substrate proved on inspection to be thickly coated with algal slime, indicating eutrophication.

Barriers to migration:

Several waterfalls, the Harts Hill and Boiling Pot Falls below Colenso and the Little Niagara Falls below Ladysmith marked the upstream limits of the natural distribution of *Clarias gariepinus* in the Thukela and Klip Rivers. However, this species has in recent years been introduced into Lake Spioenkop and into the Klip River at Ladysmith and it has since spread throughout the upper reaches of the Thukela and Klip Rivers. A few kilometres below Harts Hill Falls, at the Ezakheni abstraction weir, another fall (not marked on the maps) is probably the first significant natural barrier that fish migrating up the Thukela would encounter. The Bushman's Falls, near the Bushman's/Thukela confluence similarly mark the upstream limit of the natural distribution of *Clarias* in that river. Here again, they have in recent years been introduced into Lake Wagendrift and have since then invaded the whole middle section of the Bushman's River. There is one 'fairly significant' weir at Jolwayo, above Thukela Ferry but, as seen from the air, this now comprises an impassable concrete section only against the right bank where water is taken off for an irrigation canal. The centre and left bank sections appear to comprise only a roughly-built wall which fish should be able to bypass at moderate and high flows. A second weir a few kilometres further downstream, near Thukela Ferry, is much lower and appears not to constitute a migration barrier. Thus, fish migration is currently unimpeded from the Thukela River mouth right up to the Ladysmith waterworks falls, and not much further on the tributaries above the sites of the impoundments. This means that the proposed impoundments will do little to alter the access of fish to the upper rivers.

Spawning habitat:

Both *Barbus natalensis* and *Labeo rubromaculatus* require clean shallowly inundated cobble beds for spawning. Under natural conditions, such areas are widely available throughout the length of the river, although rather less common in the lowest sand bed reaches. Spawning has been observed in Reach 5.3 at Zingela rafting camp in September. The occurrence of good numbers of juvenile fish throughout the system from time to time indicates that breeding is usually successful.

Illegal activities:

Some illegal gill netting is reported to happen regularly in the Lake Jana basin area.

Table 4.1: Fish species distribution in the Thukela and Bushman's Rivers

		Thukela River Distribution															Bushman's River Distribution			
	River reach	5.3	5.3	5.3	6.1	6.2	6.2	6.3	7.2	7.3	7.4	7.6/7	7.8	7.8	7.9	7.9	B1	B2	B6	B6
	Site	Zin	Kai	Teb	TE	Jol	TF	Ngu	Jam	Shu	Mid	Ema	Ess	Man	Har	TM	WR	WT	Dar	Nka
Scientific name	**Common name**																			
Anguilla marmorata	giant mottled eel								+											
Anguilla mossambica	longfin eel	+	+		+	+	+	+	+	+	+	+	+	+	+	+				
Anguilla bengalensis	African mottled eel				+				+								+			
Gilchristella aestuaria	estuarine round-herring														+	+				
Barbus anoplus	chubbyhead barb																+			+
Barbus natalensis	scaly	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Barbus trimaculatus	threespot barb		+	+					+	+	+	+					+			+
Barbus viviparus	bowstripe barb			+		+				+	+									+
Cyprinus carpio	carp													+			+			
Labeo molybdinus	leaden labeo	+	+	+	+	+	+		+	+	+		+	+					+	+
Labeo rubromaculatus	Thukela labeo	+	+	+	+	+			+	+		+		+	+			+		+
Amphilius natalensis	Natal mountain catfish	+	+			+														
Clarias gariepinus	sharptooth catfish	+	+	+	+	+			+	+	+	+	+	+	+					+
Micropterus punctulatus	spotted bass																+			
Myxus capensis	freshwter mullet															+				
Oreochromiss mossambicus	Mozambique tilapia			+	+					+	+		+	+	+	+				
Tilapia sparrmanii	banded tilapia																			+
Eleotris fusca	dusky sleeper													+	+					
Awaous aeneofuscus	freshwater goby		+							+	+	+	+	+	+					
Glossogobius callidus	river goby														+	+				
Glossogobius giuris	tank goby														+	+				
Taenioides jacksoni	bearded eelgoby															+				

Site names:

Dar	Darkest Africa farm	Ema	Emabhobhane	Ess	Essiena farm	Har	Harold Johnson Nature Reserve
Jam	Jameson's Drift	Jol	Jolwayo	Kai	Kaisha farm	Man	Mandini
Mid	Middledrift	Ngu	Ngubevu	Nka	Nkasini bridge	Shu	Shu Shu Island
TE	Thukela Estates IFR2	Teb	Thukela Estates bridge	TF	Thukela Ferry	TM	Thukela mouth
WR	Weenen Nature Reserve	WT	Weenen town	Zin	Zingela farm		

4.7 Crocodile

Crocodile have been reported from the confluence of the Thukela and Little Thukela Rivers. A single 1.5m crocodile is reported to be present near the Klip-Thukela confluence. Another was seen at Zingela in 1995 and a large specimen has been seen in the Bushman's River at Darkest Africa. One large specimen was seen during the aerial survey in the river a few kilometres below Jameson's Drift. Doubtless, there are others elsewhere in the system, particularly in the areas less disturbed by humans.

4.8 Riparian vegetation of the Thukela Basin

A list of species recorded in the current survey is presented in Appendix 2.

The plant ecology of the Thukela Basin was covered comprehensively by the studies of Edwards (1963, 1964 & 1967) who outlined synecology and some of the process-driven changes in the vegetation. The vegetation of the Thukela Basin below the impoundment sites is Valley Bushveld (Acocks, 1988) excluding the short coastal stretch downstream from Mandini. These two vegetation types (Bushveld and Coastal) are the result of dramatic differences in climate with average rainfall of 800-1000mm in the small coastal belt and between 600 and 800mm in the drier interior.

Edwards (1964) suggests that most of the Thukela Valley was formerly dominated by sweetveld grasses but the steep topography and high evaporative rates, in combination with gross mismanagement, have caused dramatic shifts in the composition of the vegetation. Acocks (1988) includes the vegetation in his Northern variation of Valley Bushveld, which is dominated by xerophytic tropical elements such as *Euphorbia ingens, E. tirucalli, Dombeya cymosa, Dalbergia obovata, Acacia nilotica* and *A. robusta*. This northern variation of Valley Bushveld is characterised by open savannah with a far higher percentage of grasses than its southern counterparts. The floristic shifts in the vegetation, which are the product of reduced fires and overgrazing, have reduced its suitability for grazing because the toxic and unpalatable plant species have become dominant. The result is that grazing pressure on the riparian vegetation has intensified to the extent that in certain reaches only the most toxic or resilient species remain along the river margins.

Edwards (1967) subdivides the hygrophilous vegetation into:

(i) Hygrophilous estuarine vegetation - Dominated by reedswamp communities of *Phragmites communis* and *Typha capensis* which are up to 100m wide in places. These stands are almost monotypic but include the pteridophyte, *Equisetum ramosissimum*, and the hygrophilous grass, *Leersia hexandra*. Peripheral to the reedswamp community, *Juncus* *rigidus* occurs. Sedge communities occur in vlei areas flanking the *Phragmites* beds and these are dominated by species which are more resilient to burning (*Pycreus polystachys, Cyperus natalensis*, *Fimbristylis obtusifolia*, *Kylinga alata*, *Mariscus dregeanus* and *Bulbostylis contexta*). In areas protected from fire, arborescent species invade the *Phragmites* beds and these form estuarine woodland dominated by *Hibiscus tiliaceus* and *Barringtonia racemosa*.

(ii) Coastal riverine vegetation is dominated by *Phragmites* beds in the slower flowing parts of the river where the reduced velocity and sandy substrate allows them to encroach. The coastal stretch east of Mandini is less prone to fires due to the tropical conditions and higher rainfall. *Phragmites* communities have probably increased due to the reduced incidence of fires. In reaches of very slow flow and in backwaters the large sedges, *Cyperus dives* and *Cyperus latifolius,* sometimes form dominant stands. In areas protected from fire the succession into riverine tree species may occur, typical species include *Mimusops obovata, Acacia karroo, A. robusta, Phoenix reclinata, Strelitzia nicolai, Rauvolfia caffra, Ilex mitis, Salix mucronata, Ficus sur, Syzygium cordatum* and *Syzygium guineense*. Slightly inland, these species are augmented by *Bridelia micrantha, Macaranga capensis, Ficus sycamorus, Ficus capreifolia* and *Combretum erythrophyllum*.

(iii) Thukela Valley in the interior, where hygrophilous vegetation is virtually limited to riverine habitat due to the sharp ecological discontinuity between the river and its xeric surroundings. Edwards (1967) delimits three riparian zones typical of the riparian vegetation of the interior:

(a) Lower Fringing Zone - submerged during high flows
(b) Middle Zone - fringing during high flow regimes and submerged in floods
(c) Upper Zone - fringing during floods (phreatic by our definition).

Edwards (1967) outlines 4 basic types of riparian vegetation which characterise the Thukela Valley:

(a) Reedswamp and fringing hygrophilous communities
(b) Ruderal and hygrophilous grass communities
(c) Open hygrophilous tree and shrub communities
(d) Riverine and streambank woodland.

These community definitions are useful to a limited extent but the distinction between them is difficult where they are stages in a succession.

Thus, the floristic components of Communities c & d overlap to the extent of forming a continuum which defies classification within the proposed hierarchy.

(a) Reedswamp and fringing hygrophilous communities

Pennisetum natalense and *Cyperus marginatus* are pioneers to *Phragmites*-dominated communities. This climax vegetation is heavily impacted by overgrazing and flood damage. In many areas *Phragmites* populations have been replaced by *Cynodon dactylon* which is less susceptible to trampling and grazing. Rarely, populations are dominated by *Cyperus fastigiatus* and *Miscanthidium junceum.*

(b) Ruderal and hygrophilous grass communities

These communities are indicative of high levels of disturbance and are thus susceptible to invasion by pioneer vegetation (often exotic). The following weeds are encountered: *Xanthium strumarium, Zinnia peruviana*, *Tagetes minuta*. The hygrophilous grass component includes *Arundinella nepalense, Hemarthria altissima, Beckeropsis uniseta, Imperata cylindrica, Paspalum distichum, P. dilatatum* and *P. urvillei.* Under severe grazing pressure these give way to virtually monotypic lawns of *Cynodon dactylon*.

(c) Open hygrophilous tree and shrub communities

These tree communities are described by Edwards (1967) as indicative of intense disturbance. It is unclear whether these patches are relictual or if they represent the initial stages of forest succession. The species composition includes *Salix woodii (= S. mucronata), Ficus capreifolius, F. sur, F. sycamorus, Trichilia emetica*, *Combretum erythrophyllum, Acacia karroo, A. robusta, Spirostachys africana, Vitellariopsis dispar, Mimusops obovata, Syzygium guineense*, *Maytenus heterophylla*, *Acalypha glabrata*, *Pavetta lanceolata*, *Phoenix reclinata.*

(d) Riverine and streambank woodland

This community type is protected from grazing by its inaccessibility. These communities are dominated by various tree species and Edwards (1967) recognises three basic types which appear to be driven by soil moisture.

- *Ficus sycamorus w*oodland in very moist soils; associated species, *Trichilia emetica*, *Syzyguim guineense*, *Acacia robusta* and *Spirostachys africana.*
- *Combretum erythrophyllum* woodland is intermediate, and usually deciduous due to seasonal moisture. Associated species include *Dias cotinifolia, Celtis africana, Ficus sur, Rhus chirindensis, Schotia brachypetala, Kiggelaria africana, Bridelia micrantha, Chaetachme aristata, Berchemia zeyheri, Hippobromus pauciflorus, Clerodendrum glabrum, Canthium inerme, Ehretia rigida* and *Diospyros lycioides*.
- *Acacia karroo* riverine woodland occurs in the driest riparian vegetation and is usually

associated with dominant stands of *A. karroo* and *A. nilotica*.

Edwards (1967) also lists a number of forest pioneers which are frequently encountered in the riparian zone and these include *Trichilia emetica, Nuxia floribunda, Nuxia congesta, Pittosporum viridiflorum, Rhus legatii (R. chirindensis), Halleria lucida, Burchellia bubalina, Protorhus longifolia, Ficus natalensis* and *Trema orientalis*.

In areas where the alluvial deposits are minimal and bedrock is exposed the incidence of fire decreases dramatically and here tree species enter early in the succession. The equilibrium in this scenario is shifted by the occurrence of overgrazing that dramatically reduces fuel loads and fire intensity. The result is a premature shift to woody species that are no longer damaged by fires. In the riparian vegetation this shift is ameliorated, to some extent, by flood events which damage or remove saplings.

Kemper (1995) provided an overview of riparian vegetation within the Thukela system and highlighted the high degree of disturbance by overutilisation of the riparian vegetation as a grazing resource. This report also indicated that the phreatic zone was being utilised extensively as a source of firewood. Kemper (*l.c.*) utilised tree species as riparian indicators in his assessment of the riparian vegetation. The strength of this approach is that it provides a window into past events due to the resilience of trees to changing environments. However, the resilience of tree species means that they are intrinsically poor indicators of ecological changes in the short-term. Alletson (1995) viewed the climax riparian vegetation as primarily arborescent species and inferred that fire and overgrazing have been primary agents in the degeneration of these communities. This is in contrast to the conclusions of Rutherford and Westfall (1986), who cite fire as instrumental in maintaining the integrity of the savanna biome. Overgrazing and fire are in fact antagonistic processes. Overgrazing drives savanna systems out of equilibrium by reducing the fuel loads and allowing tree saplings to survive the milder fires. This results in the choking of open savanna by tree species and reduces its value as a grazing resource. The arguments of Rutherford and Westfall (*l.c.*) support the conclusions of Edwards (1963, 1964 & 1967), who argues that the climax state of this system should be open savanna dominated by sweetveld grasses. These grass communities should also form part of a heterogenous riparian zone in which riparian trees are dominant only in the rocky reaches.

Free-floating aquatics are rare in the system due to the high flow regimes. However, *Spirogyra* sp.(Chlorophyceae), *Cladophora* sp. (Chlorophyceae), *Nitella* sp. (Charophyceae), *Tristicha trifaria* (Podostemaceae / Anthophyta) and *Largarosiphon* spp. (Hydrocharitaceae) have been recorded within the system. The invasive water hyacinth, *Eichhornia crassipes*, has also been seen above the Lake Jana site (Dickens *et al.*, 1999a).

5 ZONATION IN THE THUKELA RIVER

Consideration of the biota present in different zones of the river is necessary so that their habitat requirements can be better understood. The analysis below has been extracted from the data available. It primarily seeks to reveal those species that are confined to the different reaches below the impoundments, where they would be most impacted by the impoundment development. For ease of interpretation, the Reaches selected by Wadeson (1999) in Figure 3.1 have been clustered into three groups which correlate with the Zones described by Oliff in 1960a, i.e.

(i) Lake Jana to Ngubevu (Reaches 5.3 - 6.3 or lower Zone 6 (Oliff, 1960a));

(ii) Bushman's River from Lake Mielietuin to the confluence with the Thukela (Reaches B1 - B6, or lower Zone 6 (Oliff, 1960a));

(iii) Ngubevu to head of estuary (Reaches 6.3 - 7.9 or Zone 7 (Oliff, 1960a)).

5.1 Lake Jana to Ngubevu (Reaches 5.3 - 6.3, or lower Zone 6 (Oliff, 1960a))

5.1.1 Invertebrates in Reaches 5.3 – 6.3

The invertebrates are addressed below separately from the fish and riparian vegetation as it has not been possible to divide the invertebrate data into the individual reaches as described by Wadeson (Figure 3.1). This was also not done in the original work by Oliff (1960a) from which much of the data has been obtained. In future studies, by accessing the original data, this may be possible. The points below, unless otherwise indicated, apply to the entire Zone 6 below Lake Jana to Ngubevu.

- The most abundant mayflies throughout the system were *Baetis harrisoni* and *Pseudocloeon glaucum.* *Afronurus peringueyi* and *Euthraulus elegans* were also abundant. *Centroptiloides bifasciata* was found at all sites, but in low numbers.
- The most diverse mayfly populations were found just above the confluence of Bushman's River, in the upper section of Reach 6.1, possibly as it contains a mixture of species from the very different zones upstream and downstream.
- Rare species found in both Zones 6 and 7 include *Acanthiops tsitsa, Clypeocaenis umgeni, Crassabwa flava, Potamocloeon macafertiorum, Compsoneuriella bequaerti* and *Prosopistoma crassi*. The latter two were also found above the proposed Lake Jana site and so are not as threatened (see comment that follows).
- Notes on the above species: *Acanthiops tsitsa* is also known from other rivers in the North-eastern Cape and KwaZulu-Natal. It seems to prefer swift flow, and its type locality was bedrock in a rejuvenated zone of the Tsista River in the NE Cape. *Clypeocaenis umgeni* is widespread in other rivers in KwaZulu-Natal. This species

requires shallow water with slow flow over coarse sandy substrate (Provonsha and McCafferty, 1995). *Crassabwa flava* is widespread in Mpumalanga and other rivers in KwaZulu-Natal. They prefer cobbles amongst shallow riffles. *Potamocloeon macafertiorum* is not known from many rivers, although it has been collected in Mpumalanga. However, this species is never found in large numbers. It seems to prefer slower current with silt to sand substrate. Interestingly, although not recorded in Oliff's (1960) report, on going through some of the specimens from the 1953/54 survey, held in the Albany Museum collection, *P. macafertiorum* was identified. This was previously recorded as Cloeon sp.? It was collected from Zone 6. *Compsoneuriella bequaerti* is a relatively rare sprawling mayfly that occurs on stones in riffles and on marginal vegetation. According to Gillies (1984), *Compsoneuriell*a species prefer slow-flowing conditions whereas *Afronurus* species prefer faster flow. *Prosopistoma crassi* has a widespread distribution, occurring in tropical to subtropical rivers. Its preferred biotope is on the underside of boulders and rocks in swift current.

- *Hydropsyche longifurca* was present in Reach 5.3 but not further downstream.
- The dominant species of hydropsychid in Zones 6 and 7 during 1985 and 1999 were the larvae of *Cheumatiopsyche* sp. Type 2.
- *Simulium medusaeforme* was the most widespread species and was found all the way down to the lower Zone 7 (Reach 7.6, Site 17). *S. medusaeforme* is considered to be an adaptable species found under a wide range of flow conditions. It is common in the swift-flowing middle reaches of larger rivers where it dominates the simuliids numerically.
- Found <u>only below</u> the Lake Jana site (to the estuary), or in other words warm water lowland species, were 5 mayfly species, 4 of which are considered rare. There were 12 trichopterans found only below the impoundment site but these are not restricted to this region, although some are new distribution records. There were also three simuliid species, namely *Simulium bovis, S. vorax* and *S. cervicornatum,* found only below the impoundment site.
- Found on this river <u>only in this zone</u>, or in other words, species confined to the middle reaches of the river, was only one mayfly species, *Potamocloeon macafertiorum*, 5 trichopteran species, and one important simuliid species, *S. cervicornatum* which is rare but widely distributed (Palmer and de Moor, 1998). The unique species of note in Zone 6 are the *Ceraclea sp*., *Cheumatopsyche sp*. Type 10.
- Found <u>in this zone and above but not in Zone 7</u>, that is species found only in the middle to upper reaches, were only three species of mayfly, *Cloeon africanum, Pseudocloeon aquacidum* and *Acantiops varium*, and two trichopterans but no

simuliids. *Pseudocloeon aquacidum* has a wide distribution, being known as far north as Kenya (Lugo-Ortiz and McCafferty, 1997). It could be expected to occur in more downstream sites, and may just not have been collected. *Cloeon africanum* occurs in still water such as pools and river backwaters, often on plants, and may not have been collected from sampling concentrated on stones in current. *Acanthiops various* tends to occur in the headwater regions of rivers, where they inhabit swift water, clinging to the underside of stones.

- Found in this river only in the reaches above the Lake Jana inflow were 15 species of mayfly, 13 trichopteran species, and 5 simuliid species. These species should not be affected by the developments.
- Distributed throughout the river, in upper and lower reaches, were 25 species of mayfly, 11 trichopteran species, and 4 simuliids. These species tend to have a wide ecological tolerance to a variety of flow conditions and substrate types.
- A new genus and new species of leptocerid Trichoptera is a very interesting find and will need some in-depth study. It was also found along the lower Bushman's River.
- The *Cheumatopsyche sp.* Type 10 is an interesting find and indeed may be a species threatened by an altered flow regime caused by the impoundment.
- The larvae of *Cheumatopsyche sp*. Type 2 (probably *facifera*) are confined to the lower reaches of the river and they are adapted to large river conditions. A modified flow regime may decrease their abundance. They are important and abundant animals playing a role in maintaining good water quality in the lower reaches of the river and forming a keystone species in the food web in these lower zones of the river.
- The zonation of Trichoptera and Simuliidae would be disrupted by dam construction and some of the lower reach species of filter feeding hydropsychids, such as *Cheumatopsyche* sp. Type 2 and *C.* sp. Type 10, *Simulium bovis* and *S. vorax* could all decrease in numbers with species such as *C. thomasseti* and *S. medusaeforme, S. damnosum* and *S. adersi* becoming more common in downstream reaches. The latter two species could become pests on man and his livestock.

5.1.2 Geomorphology, fish and riparian vegetation from Lake Jana to Ngubevu (Reaches 5.2 - 6.3)

Lake Jana Dam Wall Reach 5.2

This reach was heavily scoured by past flooding events. The alluvial soils on the banks are dominated by sparse *Cynodon dactylon* lawns. The water margin is populated by *Juncus oxycarpus*, *Juncus effusus* and *Cyperus compressus.* Occasional clumps of *Phragmites* *australis* occur along the river edge and on the sand bars, in association with *Arundinella nepalense*. Small patches of *Persicaria lapathifolia* occur along the reach. Riparian trees in this area are sporadic due to the lack of suitable riverbanks but a few specimens of *Ficus sycamorus* and *Combretum erythrophyllum* are present.

Reach 5.3 (Zingela farm & Kaisha farm & upper Thukela Estates)

Geomorphological description (Wadeson, 1999): Single thread, moderately confined, straight, plain-bed morphology. Limited bank erosion and moderate bed aggradation.

Fish:

There are 6 species (Zingela farm) and 8 species (Kaisha farm) recorded for this reach and both sites include collections of the Natal endemic, *Labeo rubromaculatus* (Table 4.1). A mixture of moderately large pools with coarse sand substrate and riffles/rapids over cobbles, boulders and occasional bands of bedrock. Good numbers of young scaly, labeo and the riffle-dependent *Amphilius natalensis* were found in the rapids, indicating the acceptability of the habitat to them. The Kaisha site yielded a goby, *Awaous aeneofuscus*, which had not previously been recorded this far inland. Drought conditions and consequent unusually low flows may have permitted this species to get further inland than they usually do.

Vegetation:

This reach is dominated by rapids. The riparian zone includes hygrophilous grasses, in areas where there is sufficient sediment deposition, and Valley Bushveld tree species in the rocky flanking areas. *Phragmites australis* patches occur sporadically and these are interspersed with *Miscanthus* spp., *Juncus exsertus, Cyperus denudata* and *Arundinella nepalensis* which occupy small bars in the faster flowing parts of the river. *Persicaria lapathifolium* occurs very sporadically on the marginal sediments.

Reach 6.1 (Thukela Estates, Bloukrans to Sundays River)

Geomorphological description (Wadeson, 1999): Single, thread, moderately confined, stable sinuous pool-riffle morphology. Moderate bank erosion, moderate bed degradation in riffles and moderate aggradation in pools.

Fish:

There are 9, and one anticipated, species recorded for this reach, including the Natal endemic, *Labeo rubromaculatus* (Table 4.1). Long, sand bed pools predominate here, separated by fairly short cobble and boulder riffles/rapids. The rocks are thickly coated with algal slime, probably aggravated by the fertiliser-enriched and sometimes high conductivity water of the

Bloukrans River which enters the Thukela at this point. Fish populations were good in the riffle below the Bloukrans confluence, but were more varied amongst the *Potamogeton crispus* beds found just above the confluence.

Vegetation:
Overgrazing has decimated the herbaceous riparian vegetation. The river banks are clothed in closely cropped *Cynodon dactylon* lawns. The alluvial deposits show strong evidence of disturbance with many unpalatable ruderal species viz. *Tagetes minuta*[*2], *Bidens pilosa*[*], *Xanthium spinosum*[*], *Argemone ochroleuca*[*], *Verbena bonariensis*[*], *Conyza floribunda* and *Zinnia peruviana*[*]. The small riverine tree, *Nuxia oppositifolia,* is particularly dominant in this reach, forming large populations on the boulder-strewn floodplain. These trees are unpalatable but show evidence of damage due to recent flood events. In association with these stands are occasional coppicing bushes of *Maytenus heterophylla, Schotia brachypetala* and *Dichrostachys cinerea*, all Valley Bushveld species.

Reach 6.2 (Jolwayo weir & Thukela Ferry)

Geomorphological description (Wadeson, 1999): Single thread, unconfined entrenched channel, stable sinuous. Pool-riffle morphology. Extreme bank erosion, moderate bed degradation on channel margins, extreme bed aggradation in riffles.

Fish:
There are 7 species recorded for this reach, one of which is a Natal endemic, *Labeo rubromaculatus* (Table 4.1). Large sandbed pools were again dominant here, with riffles over large cobbles and boulders between them. Large numbers of fish were found in the riffle, including a few big scaly and labeo specimens, but no eels. There were notably few juvenile fish present.

Vegetation:
Riparian vegetation in this reach is very heavily overgrazed. *Phragmites australis* occurs in small patches but has largely been grazed out of the system and currently these patches are limited to steep, inaccessible banks. The extensive boulder beds are covered by toxic species. Perhaps the most significant of these are the monotypic stands of *Gnidia meisnerianus (G. cuneata)* which are toxic to grazing animals due to their accumulated alkaloids. Other species inhabiting the boulder beds are conspicuously unpalatable or toxic and include *Nicotiana glauca*[*], *Asclepias fruticosa, Sesbania punicea*[*], *Ambrosia artemisiifolia, Ricinus*

[2] [*] Alien weed species

communis[*], *Catharanthus roseus*[*] and *Xanthium spinosum*[*]. Less accessible banks are covered with sparse lawns of *Cynodon dactylon* and, very rarely, clumps of *Hyparrhenia hirta.*

Reach 6.3 (Ngubevu)

Geomorphological description (Wadeson, 1999): Single thread, moderately confined, stable sinuous. Plain bed morphology, extensive bank erosion and extreme bed affradation.

Fish:

There are only 3 species recorded for this reach (Table 4.1). Only large specimens were collected, two eel species and *Barbus natalensis*.

Vegetation:

The riparian vegetation in this reach is restricted to heavily grazed *Phragmites* patches. The river banks are dominated by *Cynodon dactylon* (heavily grazed) and toxic shrubby weeds such as *Sesbania punicea*[*] and *Cassia didymobotrya*[*]. As a grazing resource the riparian vegetation is important to local communities.

5.2 Geomorphology, fish and riparian vegetation on the Bushman's River from Lake Mielietuin to the confluence with the Thukela (Reaches B1 - B6, equates Zone 6 (Oliff, 1960))

Invertebrates:

See Section 4.5 for a description of the invertebrates in the Bushman's River.

Reach B.1 (Weenen Nature Reserve)

Geomorphological description (Wadeson, 1999): Single thread, unconfined, sinuous channel, pool-riffle morphology with cobble bars. Moderate bank erosion, extreme aggradation (embedded cobbles) and bars.

Fish:

There are 6 species recorded for this reach which includes two alien species, *Cyprinus carpio* and *Micropterus punctulatus* (Table 4.1). In the Weenen Nature Reserve gorge and below it the physical habitat is varied, with small, deep pools and an abundance of rocky riffles/rapids with overhanging marginal vegetation, but no sandbanks. An ancient weir in the gorge, feeding an irrigation canal, is large enough to be a barrier to fish migration for much of the year, but would be able to be bypassed at periods of high flow. A dense algal slime coats the rocks. Only a few fish, of a good variety of species, have been collected here, although sampling effort has been limited.

Reach B.2 (Weenen)

Geomorphological description (Wadeson, 1999): Single thread, moderately confined, sinuous channel, gravel bars. Extensive bed erosion and extreme bed aggradation.

Fish:

There are only 2 species recorded for this reach but one is the Natal endemic, *Labeo rubromaculatus* (Table 4.1).

Bushman's River Reaches B1, B2 & B 3

Vegetation:

Current communities are dominated by species reliant on silt deposition. Arborescent species in the phreatic zone and on the riparian fringe are the exotic riverine poplar *(Populus deltoides**), which is sporadically common along consolidated banks, and the black wattle (*Acacia mearnsii**). *Salix mucronata* occurs sporadically and may once have been much more common as a small riparian tree. The riparian zone within the channel is dominated by *Arundinella nepalensis* and *Miscanthus sorghum*. These species are particularly prevalent on the small bars which are common within the main channel. The large bars are consolidated and these are dominated by *Phragmites australis* fringed with *Juncus exsertus.* Along the water margins *Cyperus marginatus* is the prevalent hygrophilous species. It seems likely that *Persicaria* was a dominant component of the riparian fringe but these populations have crashed and are currently represented by sporadic individuals. The current floristic and physiognomic structure classifies this as a Ruderal and Hygrophilous Community.

There are fair numbers of ruderal annual species which are indicative of regular ecological disturbance (*Argemone mexicana**, *Tridax procumbens**, *Melilotus alba**, *Conyza floribunda* *****, *Xanthium spinosum**, *Apium leptophyllum**, *Vicia faba**, *Pseudognaphalium luteo-album** and *Bidens pilosa**.)

Bushman's River Reaches B4, B5, & B6

These reaches were not accessible by road but were observed from the air by helicopter. Ground truthing and specimen collection was possible at B5. The area is dominated by bedrock with small pockets of alluvium.

Vegetation:

Vegetation in the riparian zone is virtually absent due to the limited sedimentation.

Miscanthus clumps are occasional on rocky bars, along with small pockets of *Juncus oxycarpus.* Above the waterfall there are pockets of *Phragmites australis, Equisetum ramosissimum, Typha capensis, Salix mucronata* and *Persicaria lapathifolia*. Along the water's edge small patches of *Matricaria nigaellifolia*, *Rorippa nasturtium-aquaticum*, *Ranunculus multifidus*, *Cyperus latifolius* and *Scirpus paludicola* occur. The ecological significance of the riparian vegetation in these reaches is negligible.

The area is also mildly infested with water-borne seed of agricultural weeds (*Xanthium spinosum**, *Pseudognaphalium luteo-album**, *Argemone mexicana**, *Oenothera rosea** and *Catheranthus rosea**).

Reach B.6 (Darkest Africa & Nkasini Bridge)

Geomorphological description (Wadeson, 1999): Single thread, confined, low sinuosity, pool-rapid morphology. Limited bank erosion and moderate bed degradation.

Fish:

There is only 1 species recorded at Darkest Africa but a further six species, which occur at Nkasini Bridge a little way downstream, should also occur here, but were not collected. There were 8 species at Nkasini Bridge, including the Natal endemic, *Labeo rubromaculatus* (Table 4.1). This is a moderately steep section of river comprising mainly areas of riffle and rapid on a cobble and boulder bed. Marginal vegetation comprises *Scirpus* and *Phragmites* where small areas of sand have accumulated. Again, the rocks are covered with algal slime. Fish are scarce, although a good variety of species have been collected, and *Physa acuta* snails are sometimes abundant.

5.3 Ngubevu to head of estuary (Reaches 6.3 - 7.9. or Zone 7 (Oliff, 1960))

5.3.1 Invertebrates in Reaches 6.3 – 7.9

The invertebrates are addressed below separately from the fish and riparian vegetation as it has not been possible to divide the invertebrate data into the individual reaches as described by Wadeson (Figure 3.1). This was also not done in the original work by Oliff (1960a) from which much of the data has been obtained. In future studies, by accessing the original data, this may be possible. The points below, unless otherwise indicated, apply to the entire Zone 7.

- The most abundant mayflies throughout the system were *Baetis harrisoni* and *Pseudocloeon glaucum.* *Afronurus peringueyi* and *Euthraulus elegans* were also abundant. *Centroptiloides bifasciata* was found at all sites, but in low numbers. These are all well known to be tolerant and successful under various conditions.

- The most diverse mayfly populations were found at Jameson's Drift in Reach 7.2. One would expect a higher diversity at Reach 7.4 where the river becomes more braided, offering a greater diversity of habitats.
- Rare species found in both Zones 6 and 7 include *Acanthiops tsitsa, Clypeocaenis umgeni, Crassabwa flava, Potamocloeon macafertiorum, Compsoneuriella bequaerti* and *Prosopistoma crassi*. The latter two were also found above the proposed Lake Jana impoundment site and so are not as threatened.
- The dominant species of hydropsychid in Zones 6 and 7 during 1985 and 1999 were the larvae of *Cheumatopsyche* sp. Type 2.
- Two species of hydroptilid caddis (*Hydroptila cruciata* and *Orthotrichia barnardi*) were common.
- *Simulium medusaeforme* was the most widespread species and was found all the way down to the lower Zone 7 (Reach 7.6, Site 17). *S. medusaeforme* is considered to be an adaptable species found under a wide range of flow conditions. It is common in the swift-flowing middle reaches of larger rivers where it dominates the simuliids numerically.
- Unique in the Thukela to this zone were three species of mayfly, *Pseudocloeon piscis, Crassabwa flave* and *Acanthiops tsitsa*, and three species of trichopteran. *Pseudocloeon piscis* was described in 1997 by Lugo-Ortiz and McCafferty, and was, therefore, unknown in earlier surveys. On checking some of the 1953/54 survey material, *P. piscis* was found in Zone 4 (Foothill torrent zone upstream of Lake Jana) but this identification was only possible in the light of more recent taxonomic work (Lugo-Ortiz and McCafferty, 1997). This species is widespread in Mpumalanga, KwaZulu-Natal and is recorded from the Eastern Cape. Nothing is recorded about its ecological requirements, but its relatively widespread distribution and occurrence in waterworks filtration plants and near sulphur springs (Lugo-Ortiz and McCafferty, 1997) indicates that it is a tolerant species. *Crassawba flava* and *Acanthiops tsitsa* may well be found in other reaches too, and further collecting needs to be done.
- Confined in the Thukela to the river below the Lake Jana impoundment site (to the estuary) were 5 mayfly species, 4 of which are considered rare. There were 12 trichopterans and three simuliid species, namely *Simulium bovis, S. vorax* and *S. cervicornatum*.
- *Athripsodes corniculans, Dipseudopsis capensis* and *Oxyethira sp*. were recorded only from this zone. All three of these species should be found higher upstream and the two known species have a more widely recorded distribution.

5.3.2 Geomorphology, fish and riparian vegetation from Ngubevu to head of estuary (Reaches 6.3 - 7.9. or Zone 7 (Oliff, 1960))

Reach 7.1 (Thukela at and below Mfongosi)

This is a particularly wild and inaccessible stretch of river, favoured by rafting parties. Bedrock intrusions are common, creating a rough, varied riverbed with fewer pools and more rapids than elsewhere. Observation was from the air only.

Reach 7.2 (Jameson's Drift)

Geomorphological description (Wadeson, 1999): Single thread, moderately confined, moderately sinuous. Pool-riffle morphology, extreme bank erosion, extreme bed aggradation.

Fish:

There are 7 species recorded for this reach (Table 4.1). One of the species is a Natal endemic, *Labeo rubromaculatus.* Moderately long sand bed pools, separated by bedrock or boulder rapids and riffles predominate here. Gill netting the pools in February and September in the mid-1960s yielded fair numbers of catfish, scaly and two species of labeo, but electrofishing in the riffles in October 1999 yielded only one scaly, a few crayfish and two Potamonautes crabs. Higher TDS and conductivities, due to the prevailing low-flow conditions, may have caused the fish to retreat to the deeper pools. Local anglers reported that numbers of large fish were now to be found only at the mouth of a nearby tributary stream.

Vegetation:

Heavy sedimentation is prominent in this reach. Species composition shows some degree of overlap with Thukela Ferry. However, the monotypic stands of *Gnidia meisnerianus* appear to be intolerant of the sandy sedimentation levels and this species is quite rare. The dominant ruderal species in this reach is *Leucas lavenduliifolia*[*] interspersed with toxic herbaceous ruderals such as *Tridax procumbens*[*], *Argemone mexicana*[*], *Asclepias fruticosa* and *Ambrosia artemisiifolia*. A very sparse cover of *Cynodon dactylon* occurs in patches.

There is considerable evidence that the sporadic occurrence of *Cynodon dactylon* is a grazing artifact and that controlling stock numbers in this reach would dramatically improve the grazing resource.

Reach 7.3 (Shu Shu Island)

Geomorphological description (Wadeson, 1999): Anabranching, moderately confined, sinuous channel. Bedrock rib morphology, moderate bank erosion, moderate bed degradation in rapids and aggradation in pools.

Fish:

There are 9 species recorded for this reach (Table 4.1). One of the species is a Natal endemic, *Labeo rubromaculatus*. In comparison to the previous site there are now species such as *Tilapia sparrmanii,* the goby, *Glossogobius callidus*, as well as a small barb, *Barbus viviparus*. The stability of this area may be the reason for the relatively higher species count.

Vegetation:

Very heavily grazed *Cynodon dactylon,* infested with sporadic *Sesbania punicea**, *Leucas lavandulifolia** and *Asclepias fruticosus* occur on the floodplain. In the rocky riparian patches, open woodland occurs with few isolated large trees (*Acacia robusta, A. karroo, Euphorbia tirucalli, Ficus natalensis, F. sycamorus, Sclerocarya birrea, Spirostachys africana* and *Trichilia emetica*). Shrubby species of Open Riparian Woodland and sub-canopy species in this reach include *Croton meynhardtii, Maytenus heterophylla, Strychnos spinosa, Gardenia thunbergii* and *Chaetacme aristata*. The reach has very limited alluvial deposits, which appear to be unstable and are not vegetated. The opposite river bank is dominated by *Phragmites* and *Salix mucronata.* The reach is important as a grazing resource. Some harvesting of *Trichilia emetica*, by the local community, is evident.

The conservation status of this reach is moderate due to the levels of woody biodiversity. Hygrophilous grass communities are, however, heavily impacted by grazing of the riparian fringe.

Reach 7.4 (Middledrift)

Geomorphological description (Wadeson, 1999): Anabranching, moderately confined, stable sinuous. Pool-rapid morphology, moderate bank erosion, moderated bed degradation in rapids and aggradation in pools.

Fish:

There are 8 species recorded for this reach (Table 4.1) but not the Natal endemic, *Labeo rubromaculatus*. A large bedrock intrusion here gives rise to a much-dissected river, with bush-covered islands and marginal beds of *Phragmites*. A wide variety of fish and crayfish species were collected in December 1996, but in October 1999 relatively few scaly, labeo and gobies were collected. Higher conductivities were noted at this time.

Reach: 7.5

Geomorphological description (Wadeson, 1999): No description.

Fish:
No data.

Vegetation:
Very limited riparian vegetation occurs on the river banks, which are heavily grazed. Most riparian vegetation is restricted to inaccessible sand bars. Islands and true riverine vegetation is dominated by pockets of *Phragmites australis* fringed by *Juncus* spp.

Riparian communities on the rocky outcrops are disjunct and floristically equivalent to Open Hygrophilous Woodland (Edwards, 1967). The canopy component in this community includes *Acacia karroo, Ficus sycamorus, Spirostachys africana, Syzygium cordatum* and *Sideroxylon inerme.* Subcanopy and marginal species include *Sesbania sesban, Phoenix reclinata, Ochna serrulata, Acacia ataxacantha, Hippobromus pauciflorus, Solanum giganteum, Boscia albitrunca, Croton meynhardtii, Ficus ingens, Crotalaria natalensis, Clerodendrum glabrum, Pavetta lanceolata* and *Schotia brachypetala.* Some of the smaller woody species occur in short riverine scrub, including *Nuxia oppositifolia, Erythrina humeana, Putterlickia verrucosa, Cissus quadrangularsis, Maytenus heterophyllum, Asparagus suaveolens, Asclepias fruticosus* and *Ceratothecca triloba.*

The number of truly hygrophilous shrubs within the system is low but includes *Ficus capreifolia*, *Ludwigia octovalvis* and *Persicaria lapathifolia*. Hygrophilous herbs, which occur in protected crevices of the rocky outcrops, include *Cyrtanthus breviflorus, Equisetum ramosissimum, Cyperus esculentus, C. difformis.* Small patches of grass persist, despite the grazing pressure, and these are dominated by *Cynodon dactylon,* interspersed sparingly with *Bothriochloa radicans.*

Invasive species include a number of toxic perennials which are dispersed with sediments and these have the potential to become problematic with reduced flooding episodes (*Cassia didymobotrya**, *S. punicea**, *Ricinus communis** and *Caesalpinia decapetala***).* The smaller herbaceous, ruderal species are unlikely to be problematic (*Verbena bonariensis**, *Catharanthus roseus** and *Veronica anagalis-aquatica***).* The sandy banks are colonised sparsely by unpalatable exotics such as *Leucus lavendulifolia**, *Argemone mexicana** and *Nicotoniana glauca**.

This reach is highly accessible and the immediate vicinity is heavily populated. It is, therefore, unlikely that the hygrophilous grasses will recover, due to the high livestock density. This reach is used extensively for domestic purposes (bathing, drinking).

Reach 7.6 & 7.7 (Emabhobhane)

Geomorphological description (Wadeson, 1999): Single thread, moderately confined, stable sinuous. Pool-rapid morphology, moderate bank erosion, moderate bed aggradation in pools.

Fish:

There are 6 fish species recorded for this reach and notably all are large species including the Natal endemic, *Labeo rubromaculatus* (Table 4.1). Long stretches of shallow, braided sand bed channels predominate here, separated by occasional bedrock or boulder riffles. Some rock clusters accumulate small amounts of sand, and some of these are vegetated with dense stands of *Phragmites*. A bedrock intrusion near Emabhobhane Store causes the formation of a side-channel on the right bank which becomes isolated at extreme low flow. The side channel held a few scaly and tilapia in water of moderate conductivity (186µS/cm), but the main river held very few fish, mainly gobies, and an abundance of crayfish and had a conductivity of 412µS/cm (moderately high for a river). A local angler commented that there were ‘no fish’ in the river now.

Vegetation:

Phragmites australis occurs sporadically. *Leucas lavendulifolia*[*] is very common and appears to be avoided by goats. Phreatic tree species are quite common and include predominantly Valley Bushveld species such as *Clerodenrum glabrum* and *Croton meynhartii*. The riparian zone is poorly delimited from the phreatic zone and the riparian trees which occur sporadically are *Ficus sycamorus, Sideroxylon inerme* and clumps of *Phoenix reclinata*. In this reach the alluvial sands and channel banks are heavily overgrazed but the remnants of *Cynodon dactylon* lawns indicate that with the correct management the grazing resource could be vastly improved.

Edwards (1967) reports *Trichelia emetica* and *Combretum erythrophyllum* as important components of the riverine/phreatic zones around Middledrift but these species are sporadic in the current vegetation. *Trichelia emetica* is sought after for medicinal purposes and the species has probably succumbed to over-harvesting of bark.

Reach: 7.7

Geomorphological description (Wadeson, 1999): No data.

Fish:
No data

Vegetation:
The flood plain in this reach is dominated by unstable sands, with isolated rock outcrops. The sandy river banks lead up to rocky cliffs with Valley Bushveld on one side, and up to riverine bush on the other.

Large stands of *Phragmites australis* occur, interspersed with *Solanum incanum* and *Ricinus communis**, which form dense reed swamps. Adjacent to the reed swamp are large stands of riverine forest dominated by *Ficus ingens, F. natalensis* with *F. sycamorus* and *F. capreifolia* in the moister areas. In the alluvial sands of the reach sparse stands of *Asclepias fruticosus, Polypogon monspeliensis**, *Commelina diffusa, Sesbania sesban, Senecio madagascariensis, Nicotianum glauca**, *Persicaria lapathifolia, Justicia flava, Leucus lavendulifolia**, *Chromolena odorata**, *Lantana camara**, *Verbena bonariensis**, *Passiflora foetida**, *Melilotus alba** and *Walafrida densiflora.*

Above the "Fig line" is a dense strip of riverine woodland separating the river from cultivated sugar cane. In rocky areas the riverine woodland is dominated by a melange of mesic and Valley Bushveld species including: *Ochna natalitia, Diospyros lycioides, Nuxia oppositifolia, Brachylaena discolor, Eugenia zeyheri, Maytenus heterophylla, Grewia occidentalis, Dichrostachys cinerea, Euclea schimperi, Combretum apiculatum, Sideroxylon inerme, Cardiospermum* sp.*, *Pavetta lanceolata, Myrica serrata, Mimusops obovata, Cadaba natalensis, Asparagus laricinus, Acacia ataxacantha, Clausena anisata, Euphorbia cooperi, Hibiscus tiliaceus* and *Cussonia spicata.*

The opposite river bank is moderately disturbed and included *Cynodon dactylon* lawns interspersed with clumps of *Melinis repens* and *Erogrostis superba*. The river edge supports sparse clumps of *Phragmites australis*.

This reach is in good condition and its species diversity reflects this. The reach is mostly ungrazed due to sugar farming practices. The river is utilised for irrigation.

Reach 7.8 (Essiena farm & Mandini)

Geomorphological description (Wadeson, 1999): Divided, entrenched, braided channel. Regime morphology, limited band erosion and extreme bed aggradation.

Fish:

There are 6 (Essiena) and 9 (Mandini) species recorded for this reach (Table 4.1). The Natal endemic, *Labeo rubromaculatus,* was collected at Mandini. Shallow, braided channels on a sand bed predominate here, with occasional pieces of bedrock protruding through it. Numbers of gobies were collected here, as well as a few tilapia and a catfish. Large crayfish were abundant, as were *Caridina* shrimps, and several *Varuna litterata* swimming crabs were noted. This was the upstream limit for these crabs in October 1999. Interestingly, the water conductivity was now down to 183µS/cm.

Vegetation:

This is a large, expansive river section, comprising mostly sandy alluvial deposits with very little bedrock. Large exposed, uncolonised sand bars. One riparian zone rising up to rocky slopes with Valley Bushveld, the other levelled onto a grassy bank. The reach is dominated by Reedswamp of *Phragmites australis* flanking a steep rocky slope with *Ficus ingens* separating the river bank from Valley Bushveld. The opposite bank is largely undercut and dominated by a sedge fringe (*Cyperus compressus, Isolepis costata, Juncus effusus* and *J. exsertus*) interspersed with clumps of *Phragmites australis* and *Typha capensis*. The drier areas of the hygrophilous grass community is invaded by small stands of *Cassia didymobotrya**. A number of hygrophilous tree species occur in this reach (*Salix mucronata, Syzygium cordatum, Ficus capreifolia, F. sur, F. sycamorus* and *Maesa lanceolata*). Within the Reedswamp community a number of herbaceous and shrubby hydrophytic species are commonly encountered, including *Equisetum ramosissimum, Lobelia anceps, Scutellaria racemosa**, *Ranunculus multifidis, Persicaria senegalensis, P. serrulata, Amphilopteris prolifera, Pteris vittata, Macrothelypteris torresiana**, *Marchantia* spp., *Rorripa nasturtium-aquatica, Ludwigia octovalvis* and *Stenotaphrum secundatum*.

The small flood plain is heavily grazed *Cynodon dactylon* infested with perennial weeds including *Sesbania punicea**, *Cassia didymobotrya**, *Desmodium incanum**, *Lantana camara**, *Verbena aristigera**, *Leucas lavandulifolia**, *Chromolaena odoratum**, *Catharanthus roseus**, *Oenothera parodiana** and *Psidium guava**. A limited number of unpalatable indigenous herbs were observed on the river banks (*Walafrida densiflora, Solanum incanum, Gomphocarpus fruticosus, Eriosema psoraleoides* and *Lippia javanica*).

The reach is an important grazing resource.

Reach 7.9 (Harold Johnson)

Geomorphological description (Wadeson, 1999): Divided, moderately confined, braided channel. Regime morphology, stable banks and extreme bed aggradation.

Fish:

There are 11 species recorded for this reach with an estuarine/marine influence and two endemic Red Data species, *Taenioides jacksoni* and *Myxus capensis,* as well as the Natal endemic, *Labeo rubromaculatus* (Table 4.1). After leaving the last band of bedrock, where a fairly deep pool occurs, shallow braided channels on a sandy bed are the only instream habitat here, with quantities of semi-aquatic grass and *Phragmites* along the banks. Numbers of scaly, catfish and two labeo species were netted here in the mid-1960s. An angler reported catching carp here some 20 years ago, and reported finding pipefish (species unidentified) sheltering amongst the marginal grass. A little way below the twin bridges the Mandini Mill effluent enters the Thukela altering its quality radically and resulting in a complete absence of fish. This situation ameliorates gradually towards Harold Johnson Nature Reserve, where numbers of three species of goby and a variety of estuarine fish species were collected, and beyond it to the river mouth.

The river bed in this reach is dominated by exposed rock sheets with small isolated sand bars. Limited floodplain is flanked by steep-sided rocky slopes.

Vegetation:

The riparian zone is heavily grazed *Cynodon dactylon* interspersed with *Melinis repens, Stenotaphrum secundatum, Sporobolus pyramidalis, Brachiaria serrata, Sporobolus africanus, Eragrostis curvula, Bothriochloa radicans, Hyparrhenia tamba* and *Enneapogon cenchroides*. Clearly, the diversity of grass species is indicative of a less intense history of overgrazing.

The current intense grazing pressure in the reach is evident by extensive browsing of the hygrophilous fringe which is dominated by *Phragmites*, with small clumps of *Cyperus difformis, C. articulatus, Typha capensis, Persicaria senegalensis, P. serrulata, Equisetum ramosissimum, Cyperus sexangularis, Juncus diffusus, Salix mucronata, Cycnium tubulosum, Ficus sycamorus, F. capreifolia, Salix mucronata* and *Ludwigia octovalvis*. Similarly, the drier riparian shrubs are severely browsed *(Acacia karroo, Crotalaria natalensis, Tetradenia riparia* and *Dichrostachys cinerea).*

A number of aliens are prominent in the riparian vegetation, notably *Chromolaena odorata*[*], *Lantana camara*[*], *Sesbania punicea*[*], *Desmodium incanum*[*], *Catharanthus roseus*[*], *Leucas lavandulifolia*[*], *Passiflora foetida*[*], *Melia azedarach*[*].

On the opposite bank the vegetation is essentially Phreatic Woodland on rocky outcrops. The main canopy species are *Acacia nilotica, A. caffra, Bersama swinnyi, Mimusops obovata, Milletia grandis*, *Cussonia spicata*, *Syzygium cordatum* and *Trema orientalis.* Sub-canopy trees include *Psychotria capensis, Canthium inerme*, *Strelitzia nicolai*, *Brachylena discolor, Solanum panduriforme, Maytenus peduncularis, Pavetta lanceolata, Tricalysia lanceolata.* Occasional lianas occur on the Woodland margins *(Jasminium multipartitum, Dalbergia obovata).*

6 DESCRIPTION OF THE PHYSICAL AND CHEMICAL CHANGES LIKELY TO TAKE PLACE IN THE RIVER ENVIRONMENT AS A RESULT OF THE TWP

Anticipated changes to the river geomorphology and hydrology are presented in other reports in this series (Birkhead and Wadeson, 2000 and Jewitt, 2000). Little of this information was available at the time of drafting this report, so no summary is presented. The only information that was available from Roy Wadeson has been summarised for each reach in the previous and following chapters.

Details of the anticipated water quality for the two proposed impoundments are presented in Dickens *et al.,* 1999a. It is not the intention to repeat all of this information in this report. What follows is a summary of the issues that relate to the downstream water releases. What has been easy to estimate is the approximate quality of the water that will be released from the scour or by spilling from the dams. What is not known, is the contribution of water that will come from spill, variable abstractions, and scour releases. The combination will obviously affect the final river water quality. What has also been difficult to estimate, is how far below the dams the effects of negative water quality issues will be experienced. Clearly, instream river processes and dilution by water ingress will ameliorate this water quality. An indication of the quantity of water likely to be in the river are be contained in the IFR recommendations (Muller, 1997). If it is accepted that implementation of the IFR will be an essential part of the mitigation of the project, then these flows are likely to occur.

It is important that in the next phase of the project, the design of the abstraction tower and the operating rules for the two dams are used to add clarity to the sections below.

6.1 Releases from the dams

At the time of writing this report, the design of the two dam walls had not been finalised although some basic features were available. It is likely that both of the dams will have a multiple level abstraction tower discharging to the downstream river. Designs of this type have become the norm as the beneficial affects on the downstream river are appreciated.

Also unavailable at the time of writing was detail describing the tailponds at the base of, particularly, Jana Dam. It is anticipated that this tailpond will have a wall approximately 35m high, so will form a substantial structure in its own right. Nevertheless, the volume of the tailpond will be fairly small, as will the retention time, although one suggestion was that the pond would often be empty and would only come into operation during high flows. The tailpond could have a number of positive impacts as described below:

- It could be designed to act as a buffer to minimise the sudden changes in flow resulting from the test operation of the dam valves, thus protecting the downstream river from these impacts.
- Mixing of scour and surface water discharged from the lake will be accomplished in the tailpond. This will ameliorate several negative water quality impacts as described above.
- If kept full, the stilling pond will help to ameliorate the poor water quality from scour discharges, i.e. temperatures and oxygen will rise, and some metals will be oxidised before release to the river.
- Water spilled over a high crest can become supersaturated with gases, in particular nitrogen, which can be problematic to fauna downstream. A tailpond would allow these gases to dissipate.

6.2 Quantity and quality impacts downstream of the dams

6.2.1 During construction

- Significant impacts could be experienced during the construction phase of both dams. This would relate mainly to impacts due to excessive turbidity from earth/rock works and oil from machinery. Leaching from concrete works could also have an impact on pH and water quality.

6.2.2 Quantity of water

- Depanding on the operating rules for the dams, the volume of water flowing down the river will be reduced and the pattern of its flow will be altered for the lifespan of the dams. Immediately below the dams the frequency of all types of floods, other than the large flood events, sufficient to cause the dams to spill, will be reduced. This will have potentially disastrous consequences for those fish species which rely on flow-related cues for gonad maturation and spawning runs in the early summer. In the relatively flat valley at Weenen, the river channel may change considerably, due to the reduction of inflowing silt and the unnatural flow regime. The vegetation of the riparian zone in both rivers is likely to be modified, although the impact of grazing and fire is likely to mask changes due to modified flows. Many of the anticipated impacts of flow regulation are contained in the various Instream Flow Requirements studies, reported in Section 8.3.1 below and in the relevant reports (Muller, 1997 and Louw, 1999).

- In the dry season it will be necessary to release water downstream to Middledrift for transfer to the Mhlatuze River. If this water has to be released from Lakes Jana or Mielietuin it may result in dry season flows greater than those that occur naturally. In the Vaal and Orange Rivers the dry season is when pestilential numbers of the blackfly, *Simulium chutteri*, occur. Increased dry season flows provide more habitat for the blackfly larvae, so populations increase to aggravate the problem. It is unlikely that *S. chutteri* will appear and be a problem in the Thukela River, as it is not known from KwaZulu-Natal. Nevertheless, increasing dry season flows is a step into the unknown and might result in the appearance of a different blackfly species able to seize the opportunity. It is recommended that the dry season releases between Lakes Albert Falls and Nagle be investigated as a neighbouring test case. Preliminary information is that there is no noticeable insect problem (Dickens, *pers com.)*.

6.2.3 Phytoplankton

- Simpson (Dickens *et al.*, 1999a) considers that there is likely to be sufficient phosphorus in the lakes to produce a fairly abundant phytoplankton. In any event, the ever-increasing human population of the Estcourt, Colenso and Ladysmith areas will ensure an ongoing trend of increasing phosphate concentrations and of increasing phytoplankton populations. Impoundments serve as nutrient sinks and the phosphate levels in the Bushman's and Thukela Rivers downstream of the impoundments should decrease, but phytoplankton in the release water may increase.
- Depending on the depth at which water is released and the time of the year, large quantities of plankton will occur in the water released from the impoundment. This will result in large populations of filter-feeding invertebrates in the river near the impoundment, which will affect the rest of the food chain. The plankton will be rapidly removed, and the increased filter-feeding populations of invertebrates will disappear within a small distance of the impoundment. It is considered unlikely that the filter-feeding invertebrates will include nuisance species of Simuliidae. However, the adults of filter-feeding caddis flies (Trichoptera) are attracted to light and could occur in such numbers as to be a real nuisance near the dam wall, particularly to tourist infrastructure.

6.2.4 *E. coli* (measure of faecal contamination*)*

- The data evaluated suggest that there will be a great improvement in the bacterial water quality in the rivers by orders of magnitude, resulting from the upstream impoundment. Data for Lake Inanda showed that at the 90th percentile, lake surface counts of *E. coli* were just over 10 cells/100ml while river inflow was over

1000 cells/100ml (Dickens *et al.*, 1999a). The data also show that when bottom water releases are made there will be little difference in concentrations.

6.2.5 Turbidity and sediments

- The impoundment surface water turbidities will be far lower than normal river turbidities due to sedimentation of the silt particles. Consequently, water releases downstream will be less turbid than is natural, thus encouraging abundant algal growth and altering the instream river habitat. On the other hand, indications from Lake Spioenkop are that the water released from Lake Jana may be slightly turbid even in the dry season.
- The impoundment will retain most of the silt in the inflowing waters. This will alter the sediment dynamics of the river channel below the impoundment. The river channel will lose fine particulate material immediately downstream of the impoundment by downstream transport and the riverbed will become armoured. The downstream extent of armouring will be limited by the inflow of silt from the catchment and the reduced capacity of the river to transport sediment due to the lower total flow. However, the low gradient river channel in the Weenen irrigation area is expected to become unstable. Below Weenen the gradient of the river increases again and there is unlikely to be marked accumulation of silt in the river channel upstream of the Thukela confluence. Biologically the changes in the amount of sediment in the river channel will change the areas of various biotope types relative to one another, although it is doubted that any biotope types will be completely lost to the system. In particular, the areas of un-embedded (by fine particulate material) stones in the current may be increased. This is important and beneficial for many invertebrates and some fish which require un-embedded stones for their survival, as they seek cover under and between the stones. Sediment brought into the river by tributaries may limit the extent of armouring.
- Consideration of sediment dynamics must include the availability of water to transport the sediment. On a study area-wide basis there will be less sediment in the river downstream of the impoundment, but at the same time less water to transport sediment. In the new sediment/water equilibrium of the river as a whole, it is expected that the further down the river, the greater will be the accumulation of sediment of local origin in the river channel. Wadeson (1999) has alluded to the probable accumulation of sediment at the confluences of tributaries leading to localised changes in the course of the river channel. Pool habitat is likely to be reduced in the lower river.

- The monthly sudden short-term flush of water in the river may have unexpected impacts on the distribution of particulate matter on the riverbed, to the detriment of the biota. (The sudden release of a flow of 280m^3/s will be a hazard for humans and their livestock, which might be in or on the banks of the river when the water is released.)

6.2.6 Iron and manganese

- Iron and manganese concentrations will fluctuate, from deficient in surface water releases, to potentially toxic in scour water releases. Dissolved manganese, in particular, is likely to have negative consequences on the downstream environment, as it is not oxidised rapidly.
- The lake water surface iron and manganese concentrations will be lower than those naturally occurring in the rivers by a factor of about 2, and consequently when surface water is discharged the rivers will be deprived of these constituents. This will be more than compensated by bottom water releases.
- When bottom anoxic water is released, high concentrations of reduced dissolved iron and manganese will be introduced into the ecosystem with potentially harmful effects as aquatic guideline criteria will be exceeded. The data evaluated suggest that dissolved iron concentrations, which should not vary by more than 10% of the background value, will be orders of magnitude higher. For dissolved manganese, the data suggest that the target guideline concentration will be exceeded by the 30th percentile (70% of the time), the chronic effect value at the 50th percentile (50% of the time) and the acute effect value at the 95th percentile (5% of the time). The discharge of bottom water will result in drastic changes in the concentrations of iron and manganese in the rivers, which could prove toxic to many species of plant and animal.
- The only mitigatory step that can be taken would be to ensure that dilution and oxidation of the iron takes place in the tailponds of the impoundments before overflow to the rivers. Unlike iron, which is relatively easily oxidised, there will not be rapid oxidation and precipitation of manganese as the process is extremely slow. This will mean that the problem will persist down river.

6.2.7 pH

- The pH values of the surface water (to approximately 10m depth) are unlikely to be very different to those of the natural regime for the rivers and, therefore, surface release of water from the lakes will not change the natural regime.

- Bottom water, which will be anoxic, is likely to have lower pH values than the natural by between 0.5 and 1 pH unit due to anaerobic processes taking place. Release of bottom water is potentially harmful to the ecosystem as the aquatic guideline limit of a maximum change of 0.5 pH units will be exceeded, especially when there are rapid changes from surface spill to scour or *vice versa*.
- The only mitigatory step to raise the pH is blending with the surface or tailpond water, but it would take more high pH water than low pH water to effectively raise pH as it is a logarithmic value. As an example, it would take 3 times as much pH 8 water mixed with one volume of pH 7 water to raise the pH to 7.5.

6.2.8 Ammonia

- Free ammonia is the form of ammonium species that is toxic to aquatic life. The percent of free ammonia relative to the total concentration present is dependent on an equilibrium controlled by pH and temperature. High ammonium concentrations are usually produced in the anoxic zones in lakes and, therefore, release of bottom water is potentially toxic to aquatic life.
- It is likely that there were much higher total ammonia concentrations in the bottom water than in the surface water or natural river water.
- When the total ammonium species concentrations were used to calculate free ammonia concentrations at a pH of 8.0 and temperature of 25^{o}C (possible temperature of downstream river), the bottom water exceeded the target aquatic guideline concentration at the 55th percentile and the chronic effect value at about the 75th percentile. This means that 45% of releases would be harmful and 25% very harmful to the ecosystem.
- The only mitigatory step that could be taken would be to ensure the release of as much surface water as possible, together with the monthly bottom water releases.

6.2.9 Temperature

- Comparing impoundment inflow temperatures to those at different levels in the impoundment showed that in summer, surface and 6m depth temperatures could be warmer than the river by up to 5^{o}C, while bottom temperatures could be up to 13^{o}C colder. Consequently, the natural temperature regimes for the rivers will be greatly disturbed by impoundment discharges. If only surface waters are released, in winter or summer, the impoundment water will be warmer than the river water. Bottom waters will be colder in summer but variable in winter. Modification of the temperature regime can have major consequences for ecosystem function, including changes in the composition of the biota. The guidelines for aquatic life state that sudden temperature changes should not exceed 2^{o}C. In mitigation, the depth of discharge from the lakes could be selected to most closely match the natural temperature of the river. Valves at the bottom of the Lake Jana dam wall will be tested by the release of 280m^{3}/s of water (full impoundment) for a five minute period at monthly intervals. In summer the cold water released may be expected to have a deleterious impact on the river ecosystem immediately below the impoundment due to the very low temperature of the water, its expected anaerobic condition and the sudden increase in flow almost immediately followed by a major decrease. The severity of the temperature shock is expected to be rapidly attenuated as the cold water warms through contact with the air, the heat of the sun and mixing with water already in the river. The impact of the cold water is related not only to the extent of the temperature change but also to the rate of temperature change. The greater the temperature difference and the greater the rate of change, the greater the biological impact.

6.2.10 Oxygen

- There is little doubt that the bottom releases for the Lakes Jana and Mielietuin will be completely anoxic and potentially detrimental to the ecosystem. For mitigation of the releases of anoxic bottom water, the release mechanism should be such that the water is rapidly re-oxygenated which spraying the water into the tailponds below the impoundments can bring about.

6.3 Distance of downstream water quality changes

Extensive literature exists showing the downstream effects of dams and the recovery distance required to return the water quality in the river to a "normal" condition. O'Keeffe *et al.* (1990) published a report on the situation in several Cape rivers, unfortunately small in comparision to the planned Thukela dams. Nevertheless, they recorded recovery distances of up to 30km and reported recovery distances of 86km on the Great Fish River.

In order to estimate the length of river downstream of the impoundments that will be affected by the scour releases from the impoundments, data for the Lake Albert Falls release to river, which is usually scour water, and the inflow to Lake Nagle 24km distance further down river were examined for temperature, pH, iron, manganese and ammonia concentrations. Limitations of using this data to make such estimates are that the water sampled below Lake Albert Falls was not just scour water as there was overflow from the dam at times, and the inflow to Lake Nagle also contained inflow from four tributaries, which may have affected variable concentrations either by dilution or concentration. Further, the volume of scour release from Lake Albert Falls (about 5m^{3}/s) is far smaller than those proposed for the

Thukela impoundments and, therefore, factors such as different downstream river depths and water surface-area resulting in different contact with the atmosphere for temperature equilibrium and oxidation reactions to occur would also be very different, and in this comparison not in favour of the Thukela impoundments. Nevertheless, the indications are as follows:

- Temperature differences between the cold scour release water and the warmer inflow to Lake Nagle during the summer months ranged between 2 and 14^{o}C (actual 18 up to 32^{o}C), while in the winter there were little or no differences as the impoundment had turned. These sharp temperature rises indicate that equilibrium with environmental temperatures had been reached in this river stretch of 24km.
- Similarly, pH increases of 0.5 units between the impoundments (to pH's of about 8.0, which is normal for this river) can be seen in the data, indicating equilibrium had been reached.
- Large decreases in total iron and manganese concentrations between the impoundments can be seen in the data, particularly for the summer months. This could be due to oxidation and precipitation of the reduced forms of the metals, but as analyses for the soluble forms were not conducted, it is uncertain what concentrations of these forms, which are potentially toxic to aquatic life, remained in the inflow to Lake Nagle. It is probable that most of the iron was oxidised but this is unlikely to be the case for manganese, which is slower to oxidise.
- There is an indication of a small ammonia loss from the river between the impoundments (average 0.08 to 0.06mg/l) and, viewed together with the nitrate data, which generally shows a slight increase (average 0.27 to 0.31mg/l), some oxidation of ammonia to nitrate is indicated. This process will reduce the equilibrium concentration and, therefore, toxicity of free ammonia but the change indicated here, 25%, is not great and in the case of the Thukela impoundments many more river kilometers may be required to reduce potential ammonia toxicity.

It will be necessary in the next EIA phase of the project to more accurately determine the water quality changes that will take place due to the impoundment of upstream waters, and the distance downstream that the changes will persist.

6.4 Recommendations from the Instream Flow Requirements Assessment (Muller, 1997)

Following are some of the recommendations emanating from the IFR process. These summarise the flows identified that will protect the river environment, with some of the reasons for each recommendation. They also give an idea of the conditions that could prevail once water releases from the dams are managed in accordance with the recommendations of the IFR assessment. Details need to be extracted from the reports by Muller (1997) and Cooke (1997). The position of the sites can be seen on Figure 3.1.

IFR Site 2 – below Jana Dam. An important consideration was to maintain the macro channel at this site. During winter maintenance months, a flow of $2m^3.s^{-1}$ was considered adequate to maintain sufficient habitat for insects and fish such as *Amphillius* which live in fast moving water, even if only in the middle channel of the river. It was also seen as necessary to keep riparian vegetation amongst the rocks on the river bank alive, as these are important habitats for other fauna. During this time, other fish would be restricted to pools. During the summer a flow of $9m^3.s^{-1}$ was considered adequate to keep the secondary channel active as a refuge for fish fry and to keep terrestrial plants out. A summer flood of $200m^3.s^{-1}$ was considered necessary to maintain the geomorphology and riparian vegetation structure. It would also scour the pools and lateral channels and a slow recession of the floods would allow for deposition of sediments. Drought flows are naturally much lower than those given above and provide a survival flow in order to maintain the existence of, primarily, the invertebrates and fish. Drought conditions are natural, but cannot be imposed on the system too frequently without a danger of severe ecological damage.

IFR Site 5 – at Thukela Ferry above the confluence with the Mooi River. According to a report by Louw in Cooke (1997), winter maintenance flows of $6m^3.s^{-1}$ were designed to maintain pool depth for fish and flowing water over roots and pebbles to maintain sufficient habitat for invertebrates. Flows of $20m^3.s^{-1}$ are necessary to maintain habitat variability. Important flows for fish were in September and October. Large floods of $300m^3.s^{-1}$ were considered necessary for geomorphological considerations and to prevent the middle section from silting up.

IFR Site 3A - on the Bushman’s River at Weenen Nature Reserve (Site 3B was not pursued). It was decided to maintain only the main channel, as secondary channels appeared to be temporary. Winter maintenance flows of $0,7m^3.s^{-1}$ were anticipated to provide a varied habitat to support the diversity and population size of invertebrates and to wet the roots of riparian grasses and reeds. A summer flow of $3m^3.s^{-1}$ was designed mainly for the fish as it provides adequate depth for juvenile fish and eels in the riffles. Adult fish would be found mostly in the pools. A large summer flood of $60m^3.s^{-1}$ would maintain the channel and the riparian vegetation.

7 POSSIBLE IMPACTS ON THE RIVER ECOLOGY RESULTING FROM THE TWP

For a better assessment of the changes to the river ecology, it would have been useful to have had both detailed descriptions of the geomorphological changes likely to take place in the river (cross sectional changes, substrates, etc.), as well as to have some idea of the flows that could be expected once the dam walls are in place. Unfortunately, little of this information was available at the time of writing this report. The only information was a draft report on the geomorphological changes likely to take place as supplied by Roy Wadeson. Unfortunately, his assessment was in turn limited by the unavailability of hydrological data. The data available at the time of writing this report were very general and suggest two somewhat antagonistic processes. Firstly, the reduction of flooding because of the impoundments is likely to lead to increased fine sediments accumulating in the main and secondary channels. Secondly, increased base flows are likely to scour a new channel. The scant information provided at this stage was limited to a brief verbal description of the changes that could take place in each reach, in response to both reduced flood levels and elevated low flows. The reader is referred to Birkhead and Wadeson (2000) and Jewitt (2000), which will have been released post-script. The likely quantity of water in the river was also proposed, as a potential mitigation for the project, in the IFR process (Muller, 1997). In the future it will be useful to combine this information into a better assessment of the conditions that the biota are likely to experience in the river. At the stage of writing this report it was impossible to link ecological changes to flow with any confidence.

7.1 General impacts on biota in the Thukela and Bushman's Rivers below the proposed impoundment sites

Note: More detailed impacts that may occur in the different reaches are discussed in Section 7.2.

7.1.1 Invertebrate populations

The downstream zonation observed in the Ephemeroptera, Simuliidae and hydropsychid Trichoptera will be disrupted and it is likely that ubiquitous species such as *Simulium nigritarse, S. adersi, S. medusaeforme,* and to an extent *S. damnosum* s.l., will become more abundant. Species such as *Simulium vorax* will become rarer. It is not possible to accurately predict what species assemblages will develop. There will be definite changes in functional communities of species.

A modification of the thermal regime with much colder water being discharged from the bottom of the impoundments at regular intervals will have a devastating effect on the macroinvertebrate biota. The gradual natural seasonal decrease in autumn through winter, followed by a gradual increase of water temperatures in spring, will be completely disrupted. Irregular temperature fluctuations will upset the biological rhythms of many species, and aquatic insects will fail to pupate, metamorphose or emerge. Certain adaptable species could become abundant and pose pest problems that would be costly to control.

Reduced sediment loads in swift-flowing water immediately downstream of the impoundment will lead to increased erosion capacity and this will lead to exposure of bedrock (armouring) in these reaches. Species community structure will be disrupted with no detritus for detrital feeding species. Such conditions will favour bedrock-dwelling species, e.g. certain species of Simuliidae.

The Thukela and Bushman's Rivers currently have a mixture of suspension filter feeders and detritus feeders with low numbers of grazers. Reduced input of detritus and particulate matter in the river downstream of the impoundment sites will influence macroinvertebrate community structure. Rather than a total elimination of certain species, there will be subtle changes in species dominance and a gradual change in the functional ecological role of species found. Such changes will favour more generalist species and lead to a reduction in more narrowly specialised species. These changes could be associated with feeding, cryptic behaviour, and breeding and seasonal emergence patterns.

Less sediment in the water will lead to a greater clarity of water leading to greater penetration of light and more algal and plant growth on substrates downstream of the impoundment. This will cause a shift in those species able to utilise this as a habitat. Greater clarity of the water will make species more vulnerable to predators dependent on vision and again this will lead to subtle changes in species composition. Clear water in the impoundments could lead to algal blooms with plants getting into the river downstream of the impoundment. This will favour certain filter-feeding species such as simuliids and certain Hydropsychidae. Growths of algae on the stones downstream of the impoundments will also be encouraged by the low turbidly of the water.

In the lower reaches of the river, lower flows will lead to increased sedimentation of riffles and a loss of braided sections of riverbed in wide riffle-bar reaches. This will lead to a reduction in the heterogeneity of substrata and aquatic biotopes which will lead to a concomitant reduction in species diversity. This could have dire effects on the river ecology as there will then be a few dominant species which could periodically develop into population sizes of pest proportion.

The above paragraphs describe how the presence of the impoundments is likely to affect downstream invertebrate populations. In principle, all of the changes must be negative, as they are changes away from the natural order for that catchment. The overall size of the invertebrate populations will decrease as the river becomes smaller, and at the same time, the diversity of organisms will change to accommodate the changes in the physical and chemical environment. Some species may disappear (it has not been possible to say which) and the balance of abundance will shift. Implementation of the IFR will partially mitigate for these changes.

7.1.2 Fish populations

An impoundment at Jana would eliminate a substantial length of the Thukela River which will be inundated, but fish would not naturally move beyond the region of the headwaters due to the cascade found below the Ezakheni abstraction weir. However, this would be only a small portion of the total spawning region available to them downstream of the impoundment. The wall may prove a problem to breeding migrations as the fish may accumulate below the dam wall in circumstances unfavourable to them. The barrier effect on the Thukela thus cannot be considered severe.

The presence of a major waterfall in the Bushman's River near its confluence with the Thukela already prevents fish migrations, except those of eels, beyond that point. Given that this waterfall already isolates the scaly population of the Bushman's River from that of the Thukela, further fragmentation caused by an impoundment at Mielietuin would only fragment the populations of fish occurring in the Bushman's River above the waterfall. It would be possible to mitigate this by the occasional transporting of fish by road from below to above the impoundment.

More significant would be the possible disruption of eel migrations by both dam walls and their possible disappearance from the upper reaches of the Thukela and Bushman's Rivers. It is thought that Lake Pongolapoort, being impassable to eels, has already caused their disappearance from the Pongolo River above that impoundment. This would be a serious impact as the loss of this major predator from the upstream catchments must have a negative effect on the ecology.

The release of deoxygenated hypolimnetic water could kill or discourage fish from several kilometres of riverbed below both impoundments. This effect would partially lessen with distance as cascading causes re-oxygenation of the water, although factors such as ammonia and manganese could remain a problem. Cold shock from hypolimnetic water would also interrupt or delay fish spawning activities if such releases were made during the breeding season in October-February. The impact of impoundment water releases on fish spawning, for the species found in this system, should be investigated.

The impoundment could result in the removal of excessive nutrients from the water. This could create improved water quality and instream fish habitat conditions in the downstream river.

Scouring and consequent armouring of the riverbeds for several kilometres immediately below the impoundments will create deeper pools but will reduce the availability of interstices in which freshly spawned fish eggs could be protected or in which juvenile fish could hide from predation. Reduced flows will also lead to increased silting, especially of cobble beds, in the middle and lower river reaches. Similarly, there will be a loss of spawning habitat and a decrease in pool depths in the lower reaches, thus affecting both breeding and overwintering habitat of the larger fish species.

Less variable baseflows and reduced incidence of spate or flood flows could lead to an increase in carp populations in the main rivers. The loss of other fish eggs to these predators would increase and pool habitats could become significantly muddied, especially during low flow periods. Both influences would impact adversely on all indigenous fish species.

The above paragraphs suggest that the major impact on fish populations will be on the downstream habitat and that the barrier to migration is less significant. Habitat changes will result in a change in the populations of fish, with different species taking over dominance. IFR flows would be essential to minimise the changes to the physical habitat, but they will not prevent large shifts in population structure. This means a change in biodiversity. Every effort must be made to ensure that this does not become a loss.

7.1.3 Riparian vegetation

Increased channel sedimentation may result in an increase in the *Phragmites* populations in many reaches. This species is controlled by grazing, fire and flooding. The impact of grazing will clearly continue to prohibit the growth of *Phragmites* in some of the reaches but in ungrazed sections of river an increase in reedbed communities may occur due to the reduced impact of flooding.

Seeds of many of the weed species are dispersed in the river. This includes *Sesbania punicea**, *Desmodium incanum**, *Catharanthus roseus**, *Leucas lavandulifolia**, *Oenothera parodiana**, *Verbena aristigera**, *Argemone mexicana**, *Cardiospermum* spp., *Cassia didymobotrya**, *Melilotus albus**, *Nicotianum glauca**, *Ricinus communis**, *Xanthium strumarium, Zinnia peruviana**, *Tagetes minuta**, *Acacia mearnsii** and *A. dealbata**. It is likely that these species are well represented in the alluvial seed banks. Under the present conditions, saplings of weedy species are susceptible to flooding which may drown or dislodge them. If flooding is reduced then the recruitment of the weedy perennials could become problematic. This is especially important in the case of arborescent and climbing species which smother or displace riparian vegetation and disrupt the riverine ecology (*Caesalpinia decapetala*, *Cardiospermum* spp. *Cassia didymobotrya**, *Acacia mearnsii** and *A. dealbata**).

Scouring of the new channel may reduce the occurrence of smaller hygrophilous grasses and sedges (Juncaceae, Cyperaceae, *Miscanthus* spp. and *Arundinella nepalensis)* in the main channel. These may be important spawning sites for fish.

Cynodon dactylon appears to be of cardinal importance as a grazing grass on the Thukela floodplains. The species is adapted to survive occasional flooding. It is unclear how the new flow regimes may affect this important resource. One scenario is that, under reduced flooding, an increase in tree species in the present riparian zone will reduce the areas occupied by *Cynodon dactylon*, which is intolerant of shading. This may have important sociological impacts. A second scenario is that the species is protected, to some extent, from grazing and desiccation by periodic burial in flood sediments. The reduced occurrence of floods may increase the vulnerability of *Cynodon dactylon* to the above-mentioned stresses.

Vitellariopsis dispar, which has a harvestable fruit for local communities, has a fairly narrow distribution largely restricted to the Thukela catchment. The species has been collected from Waterval Farm below Colenso, the lower Mooi River (Ngubevu), the Thukela near Mashunka Mt., Weenen Nature Reserve, Middledrift, Muden and at the Buffalo confluence. Clearly, the impact on this endemic species warrants careful consideration with respect to flow regimes.

Increased base flows may reduce habitat variability and favour large competitive vegetation at the expense of species adapted to cope with higher water velocities.

The above paragraphs suggest that substantial riparian vegetation changes are likely to take place, many having a negative impact on the resources used by the people living in the catchment. Continued high flow events will be one way of minimising these changes, which may be met by the IFRs. It is recognised that although the vegetation is already in a very poor condition, judicious management of the impoundments should prevent further deterioration.

7.2 Anticipated impacts on the biota in the different zones of the Thukela and Bushman's Rivers

7.2.1 Lake Jana to Ngubevu (Reaches 5.3 - 6.3)

Dominating this reach will be an artificial flow regime with reduced floods, which will cause embedding of cobbles and thus reduced fish spawning habitat, especially for *Barbus* and *Labeo* species. It will also result in the loss of cover for fish eggs and fry, and a loss of habitat for *Amphilius natalensis.* It may also lead to the constriction of the river channel and an invasion of woody trees, in particular wattle, but also of reeds. Grazing and collecting by the people in the area would work against this trend. There would probably be a loss of the *Cynodon dactylon* grazing areas.

In a contradictory way, also contributing to impacts would be the elevated low flows in the rivers. This would have the effect of scouring fine sediments from some areas, thus improving spawning habitat and habitat for *Amphilius* and also providing improved habitat for several species of invertebrates.

Invertebrates:

Six rare species of mayfly may be impacted. These have a range of flow requirements from fast to slow. Superficially, it appears that all the habitats required by these species will be provided below the impoundments, but not enough is known about them to be able to conclude this with any confidence. Similarly, one rare species of blackfly occurs only in this reach, but also on other rivers.

A new species and a new genus of caddisfly occur in this reach. These are important finds but, as little is known about them, it will not be possible to manage the river to cater for them. A precautionary approach of mimicking natural flow variability is the only option open.

The species of caddisfly and blackfly currently in the river are an important part of this reach. They are likely to decrease and to be taken over by a new compliment. Some blackflies, such as *S. damnosum* and *S. adersi* may become a pest to man and beast.

Most species are widely distributed along the Thukela River, thus having a broad habitat requirement but a few are very specific. Changes to the river may negatively affect them.

Impact on Reach 5.3 (Zingela farm & Kaisha farm & Thukela Estates)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- cobbles become embedded. Increased low flows:- bank and bar erosion, armouring.

Fish:

This is a stable fixed boulder reach composed of embedded boulders and cobbles and as such might be an important spawning site for the larger species. The boulders and cobbles would also provide good feeding substrate for the *Labeo* species. Reduced floods would probably result in habitat loss as cobbles become embedded. This would result in a loss of spawning habitat, as well as feeding habitat for some species and loss of cover and hiding areas for the smaller fish. Increased low flows would probably lead to removal of fines thus possibly improving spawning habitat. The impact on backwater nursery areas would have to be monitored.

Vegetation:

An increase in peripheral sedimentation may result in an increase in the size of the *Phragmites* populations. These might become particularly prominent on the deltas and bars which develop in the tributary zone. It is unclear whether the increased low flows will scour sufficiently to affect *Miscanthus* spp. and *Arundinella nepalensis* within the channel.

Impacts on Reach 6.1 (Bloukrans to the Sundays River)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- cobbles become embedded in sand. Increased low flows:- bank and bar erosion, armouring, reduced habitat diversity.

Fish:

This is an unstable pool-riffle reach. Reduced floods and scouring may reduce channel width and thus result in habitat loss, as well as loss of important interstitial spaces for embryonic development (i.e. spawning area), and habitat loss for the one questionable species, *Amphilius natalensis*, which may occur there. Increased low flows will probably reduce habitat diversity but increase habitat area for species such as *Amphilius natalensis* if they occur there and feeding habitat for the *Labeo* species. Nursery areas for larval fish would have to be monitored to assess the impact on these critical habitats that are essential for good recruitment.

Vegetation:

Reduced flooding and increased sedimentation are unlikely to affect the large stands of *Nuxia oppositifolia* unless seed banks of *Acacia mearnsii** and *A. dealbata** are deposited. It is unlikely that the effect of changing flow regimes will outweigh the dramatic effects of overgrazing in the reach. Potentially, a hygrophilous reedswamp community could invade the river flanks but the susceptibility of *Phragmites* to grazing makes this unlikely.

The sparse *Cynodon dactylon* lawns of the reach are an important grazing resource for local herdsmen. It is unclear how reduced flooding and reduced silt deposition on the floodplain will affect this species.

Impacts on Reach 6.2 (Jolwayo weir & Thukela Ferry)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- cobbles become embedded in sand. Increased low flows:- bank and bar erosion, armouring, reduced habitat diversity, increased habitat area.

Fish:

Geomorphological data indicate that this reach is characterised by an unstable pool-riffle nature dominated by embedded cobbles, and there is extensive erosion. Reduced floods are likely to smother substrate resulting in loss of habitat, especially for *Amphilius natalensis*, and suitable spawning sites for the large *Barbus* and *Labeo* species (Table 4.1). The loss of interstitial spaces may mean that *Amphilius natalensis* will be lost from this reach and that main channel spawners will not be successful or there will be reduced recruitment. Increased low flows may change and negatively impact on the food resource and species composition for all fish species. Geomorphological data also suggest that increased flows will result in reduced habitat diversity that may impact on nursery areas for larval stages of most species.

Vegetation:

Reduced flooding and increased sedimentation may allow recruitment of unpalatable tree species on the expansive floodplains adjacent to the river. It is unclear whether the absence of *Acacia mearnsii*[*] and *A. dealbata*[*] is the result of local harvesting, in which case changing flow regimes will not affect the occurrence of woody vegetation.

The absence of hygrophilous grass communities is a result of overgrazing and hypothetical predictions of potential vegetation shifts are, therefore, esoteric. The value of the reach as a grazing resource to the local communities is insignificant due to its gross mismanagement. Most of the livestock appear to browse the adjacent Valley Bushveld vegetation.

Impacts on Reach 6.3 (Ngubevu)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- fines cover the bed, bars grow. Increased low flows:- bank erosion, armouring, more cobbles.

Fish:

Geomorphological data indicate that this is a stable pool-rapid, plain bed reach with severely embedded boulders. Reduced floods will probably cause loss of habitat and area as fines would cover the bed reducing spawning success and altering the food resources for the fish. The eel species may prefer the pool areas for hiding and feeding in but pools are likely to be reduced with reduced floods that would have scoured the pools, as well as the spawning beds for species such as *Barbus natalensis*. Increased low flows may result in improved habitat as more cobbles are inundated. This may lead to more crabs, an important food source for the eel species. It would also provide more spawning sites, although nursery sites would have to be monitored as food resources may not develop sufficiently for the larval fish.

Vegetation:

Changing flow regimes are likely to reflect changes in Reach 6.2.

7.2.2 Lake Mielietuin to confluence with Thukela (Reaches B1 - B6)

Dominating this reach will be an artificial flow regime with reduced floods, which will cause embedding of cobbles and thus reduced fish spawning habitat, especially for *Barbus* and *Labeo* species. It will also result in the loss of cover for fish eggs and fry. It may also lead to the constriction of the river channel and an invasion of woody trees, in particular wattle, but also of reeds. There would probably be a reduction of annual plant species on the river banks being replaced by perennials.

In a contradictory way, also contributing to impacts would be the elevated low flows in the rivers. This would have the effect of scouring fine sediments from some areas, thus improving fish spawning habitat and also providing improved habitat for several species of invertebrates. Reduced food resources and habitat diversity would reduce diversity of biota. There would also be reduction of fish nursary areas.

Invertebrates:

The diversity in this river is not as good as the Thukela. Of note were the sponges with associated Sisyridae larvae, the only ones recorded in this river. They are found in other river systems. There appears to have been some loss of mayfly and caddisfly diversity over the past 40 years but overall the changes are few. The wide diversity of blackflies suggests that habitats are also diverse in this river.

Impacts on Reach B.1 (Weenen Nature Reserve)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- bed and bank aggradation and bar development. Deposition of fine sediments. Increased low flows:- bar erosion, widening, armouring.

Fish:

This reach is characterised by being unstable and comprised of riffle-pool morphology with large sand bars. Reduced floods will possibly result in loss of important interstitial spaces which would impact on spawning success, as well as loss of habitat due to channel contraction. This may adversely impact on the small barbs and the juveniles of the large *Barbus* species due to lack of cover, considering that there is an alien bass predator in this reach. With silt deposition and carp present this will add to the turbidity of the site as the carp stir up bottom sediments. Increased low flows would probably result in clean gravels and reduced habitat diversity. This may on the one hand improve the spawning beds but on the other reduce the food resources in the quiet backwater nursery areas for larval fish and thereby impact negatively on recruitment.

Impacts on Reach B.2 (Weenen)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- bed aggradation. Bar develpmemt, deposition of fine sediments - change to a sand bed river. Increased low flows:- bar erosion, armouring, clean gravel.

Fish:

This is an unstable reach of an alluvial regime type which is dominated by a uniform gravel/sand bed. Reduced floods will cause channel contraction and thus potential habitat loss for juveniles. Increased low flows will possibly result in clean armoured gravels which may improve or even create new spawning beds for two species present but the nursery areas may be constantly flushed not allowing for good larval growth and recruitment.

Impacts on Reaches B1, B2 and B3

Vegetation:

According to the geomorphology report, the future state of this reach is likely to change considerably with scouring of the silts and reduction of channels to a well-defined solitary channel.

The alluvial deposits within the primary and secondary channels contain large seed banks of the wattle, *Acacia mearnsii** and *A. dealbata** (as is evidenced by the recruitment of saplings). Currently the infestation by these species is minimised by flood events that remove saplings. Without these events the area is likely to become heavily infested with wattle, leading to the exclusion of natural riparian species. It is important to minimise the impact of this infestation because streambanks dominated by the alien species are likely to be heavily eroded and the seed production will infect the lower reaches.

If the wattle is controlled the alluvial deposits might become colonised by *Phragmites* which presently dominates the bars. *Salix mucronata* is likely to maintain its position as a small riverine tree within the system. The loss of small bars within the main channel may lead to a decline in *Arundinella nepalensis* and *Miscanthus* species.

The increased low flow and reduction of flood events will stabilise the system with respect to the vegetation ecology and the ruderal, annual elements are likely to decrease within the reach.

Impacts on Reach B.6 (Darkest Africa & Nkasini Bridge)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- sedimentation and bar development, some loss of habitat as cobbles embedded. Increased low flows:- armouring, bar erosion, loss of diversity as fines scoured out.

Fish:

This is a stable pool-rapid reach within a gorge with large boulders and cobbles. It may be an important spawning site for *Barbus natalensis, Labeo molybdinus* and *Labeo rubromaculatus* and this should be assessed. Reduced floods may possibly result in loss of spawning and feeding habitat as cobbles become embedded. Increased low flows will scour fines and may alter the food resources for some of the species and flush important nursery backwaters. There is a need to monitor what happens in the nursery areas.

Impacts on Reaches B4, B5 & B6

Vegetation:

Due to the bedrock and lack of deposition in this reach, the riparian vegetation is poorly developed. The small pockets of ruderal vegetation are not ecologically significant and changing flow regimes are unlikely to affect riparian vegetation to any great degree.

7.2.3 Ngubevu to head of estuary (Reaches 6.3 - 7.9)

Reduced floods and increased low flows will have less impact this far down the river, and most of the changes will relate to sedimentation of the substrate. Associated with this is a reduction of important habitat for fish breeding, as well as for invertebrates. The reduction in flooding will mean a reduction in marginal habitats for fish fry but increased low flows will provide good habitat, especially for the small barbs. In the center of the rapids, flows should maintain some habitat diversity with scoured rocks but this will be less in quantity than before impoundment. In the coastal zone, the alluvial riverbeds will not change much and will continue to be dominated by sand. If any erosion does take place, this will create greater habitat diversity to the benefit of the ecosystem. A particular caution is the impact on the Red Data fish that occur in the upper estuary. These populations will need to be monitored.

Woody and weed species may encroach onto the river banks, pushing out the *Cynodon* lawns. Major floods will reverse this trend but will cause damage in the process.

Invertebrates:

Six rare species of mayfly may be impacted. These have a range of flow requirements from fast to slow. Superficially, it appears that all the habitats required by these species will be provided below the impoundments, but not enough is known about them to be able to conclude this with any confidence. Three species of mayfly and three caddisfly, which are confined to this reach of the river, were found.

Impacts on Reach 7.2 (Jameson's Drift)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- cobbles become embedded in sand. Increased low flows:- bank and bar erosion, armouring of riffles.

Fish:

Geomorphological data indicate that this is an unstable pool-riffle reach, characterised by extreme erosion, severely embedded boulders and lateral sand bars. It is suggested that reduced floods will smother substrate resulting in loss of habitat. The fines covering the cobbles may reduce or eliminate suitable spawning sites in this reach. Even if the fish spawn, their embryos may be smothered by the fines. Increased low flows may provide better spawning beds. However, backwater nursery areas may be reduced in quantity and quality and this requires monitoring.

Vegetation:

It is unclear whether the reduced incidence of floods will have a negative impact on the *Cynodon dactylon* lawns. One possible scenario is that the flood sediments provide *Cynodon* rhizomes with protection from desiccation and excessive grazing. A loss of this sedimentation may lead to a rapid degradation of this resource.

Impacts on Reach 7.3 (Shu Shu Island)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- reduction in marginal habitat as cobbles become embedded. Increased low flows:- bank and bar erosion, armouring, gain of marginal habitat area, increased flow diversity through bedrock.

Fish:

Geomorphological data for Reach 7.3 indicates that this area is stable and dominated by a bedrock rib. Reduced floods may result in some loss of marginal habitat which would impact on nursery areas and larval and juvenile habitat for the larger species and all life histories stages of some of the smaller species such as the barbs. Increased low flows may result in a gain of marginal habitat area which would favour habitat for the smaller barbs and juveniles of larger species, as well as nursery areas for most species, depending on rate of replacement of backwaters. The increased flow diversity through the bedrock may be beneficial to spawning beds for the mid-channel spawners.

Vegetation:

See below.

Impacts on Reach 7.4 (Middledrift)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- no change in rapid habitat. Increased low flows:- bank erosion, erosion of fines, change to a single thread channel, loss of substrate diversity.

Fish:

This is characterised by a stable pool-rapid reach with aggradation in pools and degradation in the rapids. It is suggested that reduced floods would smother coarse substrate, especially in pools which may affect the feeding of *Labeo molybdinus*. It is suggested that there will be no change in rapid habitat which may be favourable for spawning. Increased low flows will remove fines in rapid habitat but result in a loss of substrate diversity. This will lead to a change to a single thread channel, which may impact on the smaller barbs and reduce larval fish habitat and hiding areas for juveniles of large species and juveniles and adults of small species.

Vegetation:

See below.

Impacts on Reach 7.6 & 7.7 (Emabhobhane)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- cobbles become embedded. Increased low flows:- bank erosion, armouring, increased flow diversity through bedrock.

Fish:

The reach is characterised by a stable pool-rapid reach with moderate erosion. Reduced floods may result in the smothering of coarse substrate which would mean a deterioration in spawning bed quality and loss of marginal habitat which may impact on nursery areas and juvenile fish habitat. Increased low flows may result in a gain in marginal habitat, favouring smaller species and juveniles of larger species.

Vegetation:

See below.

Impacts on Reach 7.8 (Essiena farm & Mandini)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- bar development, deposition of fines, side bench development but little change in in-stream habitat i.e. remains a sand bed channel. Increased low flows:- bank and bar erosion, armouring of bed to gravel adds diversity, change to a single thread.

Fish:

This reach is characterised by unstable alluvial deposits with extreme aggradation. Reduced floods will result in very little habitat change as it will continue to be a sand bed channel and therefore little impact on the fish species. Increased low flows will change to a single thread channel that may offer less protection from predation to smaller species and juveniles of larger species.

Vegetation:

See below.

Impacts on Reach 7.9 (Harold Johnson)

Changes in geomorphology (Wadeson, 1999): Reduced floods:- bar development, deposition of fines, change to single thread channel, little change in in-stream habitat, i.e. remains a sand bed channel. Increased low flows:- bank and bar erosion, deeper and narrower, armouring of bed to gravel adds diversity, change to a single thread channel.

Fish:

This reach is characterised by unstable alluvial deposits with extreme aggradation. With reduced floods there will probably be little change in fish habitat as there will be a sand bed channel. With increased low flows, the probable change to a single thread channel and change to a gravel bed may influence species composition as the armouring of the sand bed will create some habitat diversity. The impact on the Red Data species, *Taenioides jacksoni*, would need to be closely monitored.

Impact on vegetation in Reaches 7.3 - 7.9

In all the lower reaches there will be fairly uniform changes. The woody vegetation is likely to be relatively unaffected by the changing flow regimes. This is due to their stable rocky substrates and their ability to tap into ground water. The larger hygrophilous species, such as *Ficus capreifolius* and *F. sycamorus,* would be affected, especially at the sapling stage and these species may drop in prominence along the present watercourse. Fortunately, the fruits are endozoochorous and thus are easily moved around in the system by birds.

With respect to the hygrophilous grasses and sedges and the *Cynodon* lawns, two scenarios are apparent. Where grazing is heavy, the suppression of other species already occurs and the primary concerns revolve around maintaining the condition of the grazing resource. Water-borne seed is common in the alluvial deposits and if saplings are allowed to establish, due to the loss of flood events, then the grazing could degenerate significantly, which may increase the pressure on the hygrophilous fringes. Careful weed control programmes should mitigate against this problem.

Overall, changing flow regimes in the coastal strip will be far less critical due to the increased occurrence of rainfall but this may increase the severity of weed problems. The changing flow regimes will, in the short-term, provide open sites of alluvial soil for pioneers (weeds). If these peripheral areas are invaded by *Cynodon* and allied grasses, the grazing resource could increase substantially in size. If the sites are not managed carefully and exotic weeds cut off the existing *Cynodon* banks from the future river channel, then the resource could collapse in the lower reaches.

Table 7.1: Impacts associated with the TWP on the downstream river environment

It is important to appreciate that the table below contains only general impacts. Specific detail is available in the above section.

Effects on the instream habitat and structure

Generic Impact	Effect	Cause	Magnitude / Intensity	Extent / Spatial Scale	Duration	Sign	Certainty	Significance	Mitigation possible Y/N
Reduced biodiversity and consequent dominance by generalist species	Reduced variability of habitats for all organisms	Reduced variability of flow regime	High	Local	Long term	Negative	Probable	Medium	Y
Loss of productivity and diversity, therefore less sustainable use of resource	Reduced size of river and reduced quantity of habitat and productivity	Reduced volumes	High	Local	Long-term	Negative	Probable	Medium	Y
Reduced biodiversity and loss of natural stress period during winter	Unnatural conditions possibly favouring species such as blackfly	Increased dry season baseflows	Moderate	Local	Long term	Negative	Improbable	Medium	Y
Change to populations favouring some species at the expense of others. Destabilisation of riverbanks.	Increased armouring of river and creation of new habitats and loss of old. Erosion of riverbanks. Increased "clean" surfaces on stones favour some fish and invertebrates.	Reduced sediment input from impoundment discharges. Scouring effect increased in low flows due to eroding capacity of low turbidity water.	High	Local	Long term	Negative & positive	Definite	Medium	N

Generic Impact	Effect	Cause	Magnitude / Intensity	Extent / Spatial Scale	Duration	Sign	Certainty	Significance	Mitigation possible Y/N
Reduction of population size of many species of fish and invertebrates. Reeds encroach.	Sedimentation of river bed. Gravel beds and interstices filled with sediment - loss of habitat for fish eggs and fry. Confinement of unsedimented habitat to middle of river in high flow areas. Reduction in size and depth of pools. Invasion by reeds.	Reduced floods	High	Local	Long term	Negative	Probable	Medium	Y

Effects on riparian vegetation

Spread of alien weeds, especially wattle, and invasion by reeds	Successful dispersal of alien tree seeds. Invasion by *Phragmites.*	Reduced variability of flows	High	Local	Long term	Negative	Probable	Medium	Y
Threat to Thukela River endemic species	Modified biota (e.g. possible threat to *Vitellariopsis* populations	Modified flow and flooding regimes	High	International	Long term	Negative	Improbable	Medium	Y
Riparian vegetation becomes more woody	Riparian plant communities dominated by large, competitive vegetation	Elevated low flows	High	Local	Long term	Negative	Possible	high	Y
Loss of plant numbers and habitat for fish and invertebrates	Scouring of sediment reduced habitat for hygrophilous grasses and sedges	Elevated low flows	Moderate	Local	Long term	Negative	Probable	Medium	Y
Loss of important grazing species for local herbivores	*Cynodon* grass lawns lost to woody species	Reduced flooding	Moderate	Local	Long term	Negative	Probable	Medium	Y

Effects on instream biology

Generic Impact	Effect	Cause	Magnitude / Intensity	Extent / Spatial Scale	Duration	Sign	Certainty	Significance	Mitigation possible Y/N
Ecosystem modification. Lower productivity of river with changes to all levels of the food chain	Lowered productivity of river ecosystem	Impoundments trap nutrients and “purify” the river water. Low nutrients in impoundment discharges to river.	Low	Local	Long term	Positive & negative	Definite	low	Y
Only tolerant organisms survive (e.g. Chironomids)	Elimination of susceptible fauna.	Anoxic hypolimnetic scour water releases. Lack of oxygen in water.	Moderate	Local	Long term	Negative	Improbable	low	Y
Toxicity eliminates some species and alters population balance	Elimination of susceptible fauna	Anoxic hypolimnetic scour water releases. pH, ammonia and managanese all at potentially harmful levels. Concentrations may exceed DWAF guidelines.	High	Local	Long term	Negative	Probable	Medium	Y
Toxicity eliminates some species and alters population balance	Elimination of susceptible fauna through toxic effects. Silting up of interstities between stones and covering of stones out of current with fine sediment.	Construction activities at dam walls. Oil, fine sediments and cement contaminate water.	Low	Local	Short term	Negative	Probable	Medium	Y
Elimination of sensitive species and threat to Red Data fish species	Concentration of pollutants (Mandini effluent) on lower Thukela	Reduced river flows in lower river	Moderate	Local	Long term	Negative	Probable	Medium	Y

Generic Impact	Effect	Cause	Magnitude / Intensity	Extent / Spatial Scale	Duration	Sign	Certainty	Significance	Mitigation possible Y/N
Change to populations favouring those that feed on algae and predators that feed by sight. Shift in population structure.	Clear water encourages unusual algal growth on rocks, and alters predator – prey relationships	Increased water clarity, especially in summer months	High	Local	Long term	Negative	Definite	Medium	N
Large populations of plankton feeding organisms develop, e.g. some caddisflies and blackflies may become pests	Plankton provide food not normally found in these rivers	Clear, plankton-rich water released from impoundments	Moderate	Local	Long term	Negative	Definite	low	N
Change in species dominance and change in functional role of species found	Loss of food source for some invertebrate populations	Clear water discharges and reduced availability of detritus and particulate matter in water	Moderate	Local	Long term	Negative	Probable	Medium	N
Impact on those species sensitive to these changes, and increase of those able to tolerate them. Overall disturbance and lessening of productivity.	Unnatual flows create havoc on many species – incorrect cues, drowning of eggs, stranding of invertebrates, etc.	Modified flow regime - pulsing flows (valve testing)	High	Local	Long term	Negative	Probable	Medium	Y
Elimination of those species dependent on temperature for parts of their life-cycle, e.g. loss of predation on blackflies and development of pest problems	Incorrect cues for several biological processes, e.g. loss of synchronisation between blackfly and caddisfly emergences, failure of pupation and metamorphosis	Modified and irregular hydrothermal regime	Moderate	Local	Long term	Negative	Definite	Medium	Y

Generic Impact	Effect	Cause	Magnitude / Intensity	Extent / Spatial Scale	Duration	Sign	Certainty	Significance	Mitigation possible Y/N
Nuisance / pest levels of adult aquatic invertebrates	Trichoptera and other insect adults increase around impoundment lights and tourist infrastructure	Regulated river flows and phytoplankton in the water released from impoundments	Low	Local	Long term	Negative	Improbable	low	Y
Reduced breeding success of some species, e.g. *Barbus natalensis*	Obstruction of breeding migrations	Dam walls a barrier to fish movement	Moderate	Local	Long term	Negative	Probable	Medium	Y
Exotic carp disrupt natural fauna in downstream river	Increased carp numbers in river habitats (especially middle and lower Thukela): positive (angling) and negative impacts (local fish species)	Reduction in flow variability	Low	Local	Long term	Negative/ positive	Probable	low	Y
Development of two isolated fish populations	Genetic isolation of fish populations on Bushman's River	Dam walls a barrier to fish movement	Low	Local	Long term	Negative	Improbable	low	Y
Loss of major river predator in upper reaches	Eels disappear from above impoundments	Dam walls a barrier to eel migration	High	Local	Long term	Negative	Probable	Medium	Y

8 SUGGESTED MITIGATORY ACTIONS

It is important to appreciate that the suggestions below have a low confidence but are in keeping with the feasibility stage of the project. Mitigations that are more detailed will need to be suggested during the following phase of the project.

Mitigation of the changes that are likely to occur in the river will be possible to a large degree by a proper implementation of the outcome of a full IFR investigation that should be done as part of a comprehensive determination of the environmental reserve. Some information has been provided by the IFR studies done to date (summarised by Louw, 1999). Unfortunately, current knowledge of the existing Thukela River ecosystem is insufficient to be able state, with more confidence, the conditions that must be created in the river and whether the IFR can meet these. Nevertheless, at this stage there does not seem to be any serious objection to the proposed impoundments and the impacts they will have BUT this needs to be further investigated during the EIA phase of the project. Even more important, is that investigations must continue AFTER construction, to monitor and continually refine the IFR releases to ensure and optimise their efficiency.

The provision of a multiple depth discharge strucuture as part of each dam wall is an essential part of the design in order to mitigate many of the downstream impacts. Although detailed information on this was not available at the time of writing this report, the project team were informed that provision of this discharge tower was likely. The details of its design are not relevant to this report; all that is important is that water can be discharged from a variety of depths to the river.

Structuring water flows from the impoundments to satisfy the downstream ecology will be a complex issue that has been partially defined in the previous IFR studies (summarised by Louw, 1999). It is important to appreciate that this IFR process did not adequately focus on the lower reaches of the Thukela River. Altough the 1995 IFR workshop did include sites as low as the confluence with the Buffalo River (approximately half way between Jana Dam and the sea), these lower sites were considered to be of minimal value as the hydraulics at the time of the survey were not adequately measured (Louw, 1999). It is recommended that further investigation be done to fill this gap and that the range of sites be extended to the lowest reaches of the river.

Confidence in the IFR recommendations is reduced as sufficient information on the flow requirements of all of the species present in these rivers does not exist. The only solution is to take a precautionary approach and to mimic the natural flow regime (albeit with less water) on which the natural biota is structured, but using whatever specific information is available. Some of these factors are mentioned below (recommendations from the IFR process are summarised in Section 6.4)

8.1 Mitigation of construction activities

Proper control and prevention of ingress of fine sediments into the river during earth and rock moving will need to be done. Proper site management can control prevention of oil spills from machinery.

8.2 Mitigation of impacts on instream habitat and structure

Regulation of flow is the cornerstone for mitigating the impacts resulting from the impoundment of rivers and is the driving philosophy behind the IFR process. Flows that will negatively affect instream habitat and structure include a lack of variability in flow, reduced flooding, and elevated base flows especially during the dry season. The IFR process strives to redress these issues and so to mitigate the impacts by re-introducing flow variability and flooding.

The reduction of sediment movement in the river due to removal by the upstream dams, cannot be mitigated, especially in the reaches immediately below the dams. Fortunately, sediment is supplied to the river from tributaries downstream of the dams but not in the quantities that would have been in the main channel (the virgin river may have had substantially less sediment than at present, which would mean that the impacts could be to reduce excessive sediments currently in the river). There will also be increased scouring of the sediments due to the discharge of clean water from the dam, but this cannot be effectively mitigated. Sediment released during scouring of the dam is of the finest particle size and will not make up for the loss of coarser sediments in the riverbed. An accumulation of sediments will occur in places, due to the reduction of flood events. This can be mitigated by the proper control of floods, with periodic high flow events as recommended in the IFR reports (Muller, 1977).

Thus, the management of the river channel can be achieved through manipulation of the flow, in particular the so-called channel-maintaining floods built into IFR estimates and by managing landuse in the catchment and riparian zone. The effectiveness of channel-maintaining floods in achieving their goal is untested and might be problematic in the Weenen area, due to the proximity of the impoundment and the unstable nature of the riverbed. Silt-free floods might possibly induce unwanted changes in the position of the river. Unfortunately, the poverty of the people and the steep terrain in much of the Thukela River valley, will work against any attempt to reduce silt loads through catchment management.

The present proposal to release a monthly flow of up to 280m^3/s is singularly ill advised from an ecological and social viewpoint. This could be ameliorated through the provision of several valves so that the increase in river flow at any one time would be less than 280m^3/s. Alternately, the pool at the base of the Lake Jana dam wall could be designed to hold the entire test release for gradual draining into the downstream river.

8.3 Mitigation of impacts related to water quality

The anticipated mesotrophic/eutrophic status of the impoundments, and all of the negative affects which that has, could be improved by reducing the pollutant load to the impoundments. This would mean applying stringent effluent discharge standards to all wastewater discharge points in the upstream catchment (currently not in place - pers. com. Mr Kobus Rothman, DWAF). This would have positive effects on the quality of water in both impoundments, which in turn will have an effect, albeit lesser, on the downstream river. Large lakes such as these act as massive “maturation ponds” and have a substantial purifying effect on the water by the time it is released to the downstream river. The inclusion of multi-level discharge valves from the dams will allow the optimal quality of water to be released to the river. A simple scour release, as practised in many dams in the past, is possibly the most damaging to the river, so every effort should be made to mitigate these impacts. Some suggestions are made below.

Most of the water quality impacts related to the discharge of hypolimnetic water from the scours of both impoundments could be either fully or partially mitigated by releasing a combination of scour and epilimnetic or surface water. Unfortunately, different combinations would favour different mitigations so a model to achieve the optimum combination would have to be developed.

- Those impacts that would be mitigated by having a mixture of hypo- and epilimnetic water would be: algae, turbidity, and temperature.
- Those impacts that would be lessened by using pure surface water releases would be: pH, iron, manganese, ammonia, oxygen, and H_2S.
- Those impacts that would be lessened by using 100% scour water releases would be: turbidity and algae.

Of the above, H_2S, oxygen and iron problems would be eliminated by fully aerating the discharge water through a spray or plunge pool turbulence. Unfortunately, managanese and ammonia are less rapidly removed from the system, so their effects will be felt for some distance downstream. Likewise, temperature effects will be felt for a considerable distance downstream but are relatively simple to mitigate as described above. Plankton from the impoundments will have a very localised impact on the river ecosystem just downstream of the dams, and there would be minimal advantage in attempting to prevent their occurrence.

8.4 Mitigation of impacts on riparian vegetation

As riparian vegetation is only partially influenced by flows in the river, only those aspects that are affected can be managed as part of the dams operation. Other aspects such as overutilisation and overgrazing of the riparian vegetation cannot be influenced by flows in the river and thus are beyond the ambit of this project. Nevertheless, impoundment releases in the river will either assist or further degrade this resource.

- A lack of flooding could lead to the invasion of woody species (especially wattle and *Sesbania*) at the expense of creeping grasses currently used for grazing. This would ultimately lead to the destabilisation of the riverbanks and large-scale damage during large flood events. Regular floods of sufficient magnitude (as difined in the IFR) should serve to eliminate these invasives.
- It is not known what flow requirements are needed to protect the rare *Vitellariopsis*. These need to be defined, but a semi-natural flow regime as described in the IFR should go a long way to protecting this plant from destruction and being outcompeted by aliens.
- Flow variability and flooding is necessary to control the encroachment of reeds into the river channel.
- Scouring of the river channel will reduce the habitat for hygrophilous sedges and grasses. As described above, a loss of sediment from the system is difficult to mitigate, but flow variability and careful redistribution of sediments by flood releases could maintain sufficient sediments in the system for these plants.

8.5 Mitigation of impacts on fish

- Mitigation of habitat and water quality impacts on fish are included in Sections 8.2 and 8.3 above.
- Artificial water releases to encourage spawning below the dam walls are part of the IFR recommendation. This also suggests flows that allow for proper development and recruitment of the fish species. If successful then there will be fewer mortalities at the

base of the dam walls as migrating fish will find suitable spawning beds before they reach the dam walls.

- Movement of sediment, which can either clog up substrate intersticies and thus reduce spawning sites, or scour out rivers and pools and improve habitat, can all be regulated by flows. These are contained within the IFR recommendations.
- For reasons given before, fishways for migrating fish species do not appear to be necessary. The impact on the genetic make-up of the fish populations above the falls on the Bushman's River, which would be fragmented by Lake Mielietuin dam wall, would most easily be mitigated by the occasional (every 5 years?) capture and transport of live fish around the wall.
- An eelway should be considered for each impoundment (if eels are found in the Bushman's River - to-date they have not been). Unless an eelway is installed on the dam wall, eels will disappear from the impoundment, as well as upstream of the impoundment as the dam wall will seriously impact their juvenile (elver) upstream distributional migration. It is, therefore, important to construct eelways to enable elvers to overcome the dam walls or to design the wall in a way that can be overcome by the elvers. However, once the eels mature they need to be able to safely negotiate all barriers as they return to the sea to spawn. This downstream migration needs to also be considered. Designs for eelways must be suggested in the following phase of the project.

8.6 Mitigation of impacts on aquatic macroinvertebrates

(More detail will be found in Appendix 1).

Very little information is available on the habitat requirements of the invertebrates that are to be found in the Thukela River. The information below is an attempt to gather some information about those requirements that are known that could be influenced by management of the river. It will be noticed that there are a wide range of requirements, sometimes apparently conflicting. Yet, in any river, a wide range of habitats do exist simultaneously with, for example, fast flows in the centre of riffles, and slower flows on the edges. In order to cater for the diversity of requirements, it is thus appropriate to adopt a "landscape" approach, and to maintain a diversity of habitats within the river, and by so doing ensure that every species is catered for.

Ephemeroptera

Oligoneuriidae:

These mayflies are filter feeders in the nymphal stages and live in swift-flowing waters. They rely on the flowing water to carry food to them and they collect the food by means of filtering hairs on the front legs. Highly modified mouthparts are used to scrape filtered material off the filtering hairs. The oligoneuriid, *Elassoneuria trimeniana*, recorded from Zones 5-7 in 1953/54, is a species requiring a strong flow of water. This species was not recorded in the 1985 or in the 1999 survey but were collected by Mr Conor Cahill in April 1999. Perennial flow also seems to be a requirement for maintaining populations of this species, although species of the genus *Elassoneuria* are found at lower altitudes and warmer waters than *Oligoneuriopsis* and hence may not need such abundant flows to maintain cool temperatures as required by the latter genus.

Baetidae:

These include the species such as *Centroptiloides bifasciata*, a large predatory species found only in the swiftest flowing water on large boulders and stones (it soon dies when left in stationary water) and *Pseudopannota maculosa* (which was not recorded during the extremely low flow conditions when the survey was conducted in 1999). Both these species would not prosper under prolonged reduced-flow conditions.

Prosopistoma crassi (Prosopistomatidae) is widespread in tropical waters. Flow requirements for this species appear to be associated with conditions creating substrates predominantly composed of large cobbles to boulders, i.e. flows exceeding $0.8ms^{-1}$ (Hynes, 1970).

Tricorythus discolor and *T. reticulatus* were found in eroding biotopes in the river. Oliff (1964) found that silt deposits restricted the distribution of these species. They are, however, tolerant of moderate pollution and a moderate to swift flow regime.

Maintaining proper flows (e.g. the IFR) from the impoundments would largely provide for the above species.

Trichoptera

Hydropsychidae:

The filter feeding hydropsychids, *Cheumatopsyche thomasseti* and *C. afra*, are widespread and tolerant species. The ecological requirements of *Hydropsyche longifurca* are less well understood but this species is often found in association with the above two species and is larger than any of the *Cheumatopsyche* species found in the Thukela River. The several other species of hydropsychid found are less well known as regards their ecological requirements. It would seem that the larvae of *Cheumatopsyche* sp. 2, the most abundant of hydropsychid species encountered during the 1999 survey, are those of *C. falcifera*, and that flow velocity and substrate type and depth requirements for this species are similar to those of

C. thomasseti. All the above-mentioned species need a strong flow of water over riffles or rapids to keep stone surfaces cleared of sediment and to support their silken collecting nets with which they capture organic matter (including other insects and algae on which they feed). They are all multivoltine, going through several generations a year. Synchronisation of spring emergences plays an important part in controlling pest blackfly population levels in medium to large rivers (flows of over 5 cumecs) (de Moor, 1992). Temperatures of downstream releases could have the greatest impact on this synchronisation and will thus need careful assessment.

Maintaining proper flows (e.g. the IFR) from the impoundments would largely provide for the above species.

Simuliidae

Simulium damnosum s.l. The species from the Thukela and Bushman's Rivers was found in swift-flowing sections of the river in riffles and on marginal vegetation all the way down to the coast.

Simulium adersi was found in Zones 6 and 7. This species is a widespread pollution- and saline-tolerant species, usually found in slow-flowing, medium-sized rivers with a stable flow regime. *Simulium adersi* has been recorded biting man in the Eastern Cape.

Species in the subgenus *Simulium (Metomphallus*) require swift-flowing conditions (ranging from 0.8 - 1.5ms^{-1}), with clear bedrock or large boulders and stones in larger streams and rivers. They form the dominant component of swift-flowing African rivers.

The larvae of species belonging to the subgenus *Simulium (Pomeroyellum*) which included *Simulium mcmahoni, S. rotundum* and *S. cervicornutum* are found in slow- to moderately swift-flowing water 0.2 - 1.0ms^{-1} attached sparsely either to stones, dead leaves or vegetation. These three species are often found in shallow, flowing, warmer water under sub-tropical conditions.

9 BASELINE AND FUTURE MONITORING

The intensity of monitoring of the Thukela River system will ultimately be determined by the need to satisfy management goals. These goals will be determined by the reserve process, where the management class of the river will be established. It would also be useful to make use of the guidance provided by Rogers and Bestbier (1997) in the setting of objectives for the management of these rivers. Until this is done, the suggestions for monitoring given below can only be treated as suggestions. Details such as exact methods and frequency of monitoring should be described during the next phase of the project.

9.1 Baseline monitoring

- Baseline monitoring should attempt to better establish the characteristics and condition of the river before construction of the impoundment starts.
- It is suggested that water quality data, measurements of transects across the river and the sediment characteristicsof the riverbed should be collected from several sites down the length of the two rivers.
    - Quantitative or quasi-quantitative data on representative components of the instream and riparian biota should be gathered at intervals appropriate to the rapidity of change within each ecosystem component concerned. Factors that should be considerd include a measure of biodiversity, the functional groups of organisms, and the presence of species of special interest. These will need to be linked to a measurement of habitat availability. Biota that should be monitored include:
    - Benthic invertebrate diversity and abundance, including rare or endangered species as well as potential pest species. In conjunction with this, a general biotic index such as SASS (Chutter, 1998) with which to monitor river condition, should be used.
    - Fish diversity and distribution. Included in this should be information about spawning patterns of certain species, especially *Barbus natalensis*, *Labeo molybdinus* and *Labeo rubromaculatus*. This understanding will aid later decisions on instream flows. It is also important to understand their migration patterns and triggers which may be negatively impacted by an altered flow regime. There is a need to assess the times of year when densities of elvers are highest as this will need to equate with the time of operation of an eelway. It will also be necessary to assess the time of year when adult eels are migrating to the sea.

- Riparian vegetation should be monitored, with a minimum requirement being an index of riparian vegetation condition, such as that proposed by the National River Health Programme (DWAF). The riparian vegetation mapped at the IFR sites should be monitored for change.

9.2 Future monitoring and research needs

- Future monitoring is concerned with what comes out of the impoundment and what happens to the river structure and environment as a result.
- Volumes of water discharged on a daily basis, discharge point (spill, depth of abstraction, valves), water temperature (daily), and quality of water released from the impoundment should be measured.
- The components of the Baseline Study should continue to be measured at the sampling points and at the sampling intervals used in the Baseline Study.
- Maintenance of sediment-free substrata and prevention of clogging of interstices in riffles needs to be managed and thus shoud be monitored.
- A regular biological monitoring programme should be developed to ensure that the objectives of the mitigation programme are being met. This programme should be designed to ensure that changes in the functioning of the river ecosystem are noted so that corrective action can be taken. This should include:
  - Monitoring of species diversity.
  - Determination of the relative abundance of selected species.
- Specific areas that need to be monitored and researched include:
  - Monitoring of the response of *Cynodon* lawns and associated woody vegetation to changing flow regimes may circumvent massive degradation of this grazing resource.
  - Since the habitat for *Amphilius natalensis* will be lost under the impoundments, it is important to ascertain their instream flow requirements below the dam walls so that a healthy population will be encouraged.
  - It would be useful to assess what flows would benefit or be detrimental to alien species of fish such as carp.
  - It would be useful to monitor the population shifts in *Phragmites* within the system over the next 5-10 years to generate an understanding of the autecology of the species. The information generated will provide a better predictive capability regarding the species and its responses to changing flow regimes.
  - A study of the occurrence and autecology of *Vittelariopsis dispar* within the system should be initiated. This study should focus on (i) the impact of

changing flow regimes on the species, (ii) the current recruitment of seedlings within populations and, (iii) the value of fruits to local communities.

- Increasing dry season flows is a step into the unknown and might result in the appearance of a blackfly species able to seize the opportunity. It is recommended that the dry season releases between Albert Falls and Nagle Dams be investigated as a neighbouring test case.
- Further work to survey the diversity of species of invertebrate, many of which will be new discoveries to science, is strongly recommended.

9.3 Data management, interpretation and river management

- Baseline and future monitoring will waste money unless they are backed up by a determination to use the data gathered to manage the river towards a clear set of objectives.
- This means that there must be a dedicated, defined system to manage the data (including quality assurance and quality control), to interpret the data and to implement the findings. There must also be a clear delegation of responsibility to do this.

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Mr Mark Graham, Umgeni Water, for help with drafting this report.

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A river ecologist who has undertaken a reconnaissance study of the Thukela/Mhlatuze transfer scheme and was study leader for the biophysical aspects of the Vaal Augmentation Planning Study (VAPS), Thukela option in its reconnaissance and pre-feasibility phases.

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Thirty-five years experience of fish distribution patterns and ecology in KwaZulu-Natal, particularly in the Thukela Basin.

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APPENDICES

APPENDIX 1: AN EXPLORATORY SURVEY AND SYNTHESIS OF PREVIOUS SURVEYS CONDUCTED ALONG THE TUGELA (THUKELA) AND BUSHMAN'S RIVERS TO ADVISE ON INSTREAM FLOW REQUIREMENTS OF THE AQUATIC MACROINVERTEBRATES

APPENDIX 2: RIVERINE PLANT SPECIES ON THE THUKELA RIVER SYSTEM

APPENDIX 1

AN EXPLORATORY SURVEY AND SYNTHESIS OF PREVIOUS SURVEYS CONDUCTED ALONG THE TUGELA (THUKELA) AND BUSHMAN'S RIVERS TO ADVISE ON INSTREAM FLOW REQUIREMENTS OF THE AQUATIC MACROINVERTEBRATES

Appendix 1.

An exploratory survey and synthesis of previous surveys conducted along the Tugela (Thukela) and Bushman's Rivers to advise on instream flow requirements of the aquatic macroinvertebrates.

by

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EXECUTIVE SUMMARY AND CONCLUSIONS

The Department of Water Affairs are planning further interbasin transfers of water from the Thukela and Bushman's Rivers to supplement the evergrowing demand for water in Gauteng. Before planning of an interbasin tranfer of water it is important to consider sociopolitical and biological factors that may be detrimentally effected. The biological integrity of a river system must be cared for and an increase or decrease in flow can have deleterious influences on the riverine biota and impinge on the natural ecological functioning of the river. From a biological viewpoint it is important to consider whether there may be any transfer of undesirable biota from one catchment to another. Also will the modified flow regime lead to an increase in pest species in either the donor or recipient river system? Will any rare or endangered species be threatened by a modified regulated flow regime?

Between 1953 and 1955 Dr W D Oliff surveyed the Tugela (Thukela) River and between 1956 and 1957 the Bushman's River (Oliff 1960a, 1960b). Brand et al (1967) conducted further surveys in 1965 and produced a synthesis on previous surveys. In 1984 and 1985 Mr B K Fowles resurveyed many of the sites studied during the 1950's and 1960's in order to obtain some measure of changes that might have occurred in the intervening 30 year period. Unfortunately there was insufficient funding to analyse and report on all the rivers surveyed and only a preliminary assessment of selected samples from the Buffalo River was conducted (Fowles 1986). All these papers and reports analysed the status and abundance of the aquatic macroinvertebrates relating primarily to water quality.

An assessment of the instream flow requirements IFR of the macroinvertebrates of the Thukela River at selected sites was reported on by Chutter in Heinsohn (1995). In this report a number of indirect impacts on macroinvertebrates resulting from flow regulation by means of dams were listed. The importance of maintaining permanent flow and ensuring correct seasonal distribution of high and low flow regimes was emphasised. The shortage of detailed information on the flow requirements of most freswater biota was noted. It was therfore suggested that the modified flow regime should be managed in order to maintain existing biotope diversity. This could of course be reflected by measuring the diversity of selected aquatic macroinvertebrates especially species with narrow or stenoptopic requirements. From this viewpoint the assessment of species presently found and an assessment of overal species diversity, being assessed in this study, will serve to provide a baseline measure of what is there and what needs to have special care to be conserved. Because of previous surveys it was possible to assess, to a degree, what changes had occurred in these river system since the 1950's. Only a monitoring system able to assess the continued presence of selected species over the long-term can help prevent flow regulation practices detrimental to species earmarked for conservation.

In August 1999 a helicopter survey and a visit to some sites by motorvehicle enabled preliminary assessment of the diversity of aquatic biotopes along the Thukela and the Bushman's rivers, downstream of the proposed Jana and Mielietuin dam sites. Some collection of macroinvertebrates from selected biotopes along the Bushman's and Thukela Rivers was also undertaken. A one-week follow up survey in early October conducted further collections and although the samples collected could not be fully analysed, identification of selected material was carried out.

During the second survey sites which were considered important for determining the species composition under prevailing flows and for assessing flow requirements of the instream biota were selected for further survey purposes and study. SASS collecting techniques were used with the following modification; as many biotopes as possible were sampled at each site, a fine mesh size net (280 micrometre pore size) was used at most sites and material collected from each biotope was preserved separately. In addition to the SASS methods, other specialised collecting techniques to sample as wide a diversity of macroinvertebrates as possible were also used.

The brief given for this project was to assess changes in species diversity that might occur following construction of dams upstream. Information on the flow requirements needed to maintain the present diversity of biota in the donor river systems were also considered. In order to assess the flow requirements of these rivers it is considered important to determine the water quality and quantity requirements of the biota. As previous surveys were conducted around 45 and 15 years ago it was deemed necessary to determine changes that may have occured in the present river systems. A resurvey of selected sites and a study of the previous surveys conducted along the Thukela and Bushman’s Rivers was made. All this information was synthesised to determine if there were any rare or endangered species or possibly species with special environmental requirements that should be taken into account. Ideally river flows should be managed to ensure the survival of the extant communities along the river. If this is done, good quality water for downstream users (biota and man) can be ensured.

Because of the time limitations for conducting the study (approximately two months from the inception of the project) a detailed survey of the riverine biota was not possible. Complete analysis of the limited data collected was also not feasible and the level of identification of many of the invertebrate groups could not be carried down to species level. Data on the 1999 survey were collected during extreme low-flows and would therefore not reflect the greatest annual diversity of the river systems studied.

Even with the limited data available it was possible to note that no further serious deterioration of water quality has occurred in the lower reaches of the Bushman’s River since the 1960's. A rich diversity of hydropneustic aquatic insects in both the Thukela and Bushman’s Rivers suggested that the water was of a relatively good quality especialy at the lowermost site in the Bushman’s River.

Regarding species composition of known taxa, the fauna has not changed markedly over a 45 year period. Ephemeroptera and Trichoptera are still diverse and dominant taxonomic groups. The early surveys showed clearly that the upper reaches of the Thukela River identified as the mountain and foothill torrent zones in Oliff's 1960a paper had a distinctive fauna. The present survey did not take these regions into account and discussion of the unique fauna are left only as a mention in tables 4-8.

Impacts on the river ecology resulting from the construction of the impoundments are:

* The downstream zonation of aquatic macroinvertebrates observed in the Thukela River will be disrupted and will be influenced with changes in species and the relative abundance of various species occurring.

* Colder water discharged from the bottom of the dams at regular intervals will have a devastating effect on the macroinvertebrate biota. Natural seasonal water temperatures will be

disrupted. Irregular temperature fluctuations will upset the biological rhythms of many species and aquatic insects will fail to pupate, metamorphose or emerge. Certain adaptable species will become abundant and become pests which will be costly to control.

* Bottom releases of anoxic water will be toxic to riverine biota.

* Reduced sediment loads in swift flowing water immediately downstream of the dam will lead to increased erosion capacity and this will lead to exposure of bedrock (armouring) in these reaches. Species community structure will be disrupted with no detritus for detrital feeding species. Such conditions will favour bedrock dwelling species i.e. certain species of Simuliidae and hydropsychid Trichoptera.

* The Thukela and Bushman's Rivers have a mixture of suspension filter feeders and detritus feeders with low numbers of grazers. Reduced input of detritus and particulate matter in the river downstream of the dam sites will influence macroinvertebrate community structure. Subtle changes in species dominance and a gradual change in the functional ecological role of species will occur.

* Less sediment in the water will lead to a greater clarity of water with more algal and plant growth on substrates downstream of the impoundments. Greater clarity of the water will make species more vulnerable to predators dependant on vision. This will lead to subtle changes in species composition.

* Clear water in dams could enhance algal blooms. Phyto and zooplankton will increase and be released into the river downstream. This will favour filter feeding simuliids and hydropsychids.

* Much further downstream of the Dams lower flows will lead to increased sedimenting up of riffles and a loss of braided sections of river. This will lead to a reduction in the heterogeneity of substrata and reduction in species diversity. This will modify the river ecology leaving fewer but dominant species which will periodically develop into pest proportional population sizes.

RECOMMENDATIONS

* Ecological requirements of the biota are strongly governed by the flow and thermal regime of the river and modification of sediment deposition or erosion and seasonally unaturally low or high temperatures as well as rapid fluctuations in temperature will lead
to species eradication and functional community structural changes.

* To assess in greater detail whether there are rare or endangered species as well as concentrations of potential problem or pest species along the course of the rivers, a two year in-depth survey of the benthic macroinvertebrates in the late winter and late summer as well as light trap and adult insect collecting in summer should be undertaken.

* As a management proposal for the Thukela River it is reccommended that efforts should be made, at least to maintain and if possible try to improve conditions that will enhance the diversity of filter feeding species in the riffle and running water biotopes.

* The regulated flow regime should be simulated to model as closely as possible the natural seasonal flow regime. Unseasonal releases of water should be prevented at all times.

*   Maintenance of sediment free substrata and prevention of clogging of interstices in riffles should be managed.

*   The lower sandbed reaches in zone 7 have braided channels with riffles, cascades and rapids as well as islands of macrophytes. These biotopes should be accounted for in designing a flow regime. The maintenance of a diversity of biotopes in these lower sandbed reaches will ensure that no single group of animals will dominate the fauna of the river. Maintenance of species diversity will ensure that pest species such as certain -Simulium- spp. and bilharzia vector snails do not become abundant, a problem which would have to be further managed.

*   The presence of a mixed community of filter-feeding and gatherer-collector species characterised the Thukela and Bushman's Rivers for all sites surveyed. There are many species that require a regular input of detritus and sediment for continued survival. Careful management of the thermal regime should also be considered in the river management programme.

A regular monitoring programme should be developed to ensure that the recommendations are met. A late winter/dry season survey of benthic macroinvertebrates should be undertaken annually. In addition, a late summer survey with light traps (to collect adults) should be implemented. The monitoring programme should cover the following:

* An in-depth two year survey to develop a base-line data set for determining the species diversity and relative abundance of key taxa
* Annual monitoring of species diversity
* Annual determination of the relative abundance of selected species

SUMMARY

Between 1953 and 1955 Dr W D Oliff surveyed the Tugela (Thukela) River and between 1956 and 1957 the Bushman's River (Oliff 1960a, 1960b). Brand *et al* (1967) carried out further surveys in 1965 and produced a synthesis on previous surveys. In 1984 and 1985 Mr B K Fowles re-surveyed many of the sites studied during the 1950's and 1960's in order to obtain some measure of changes that might have occurred in the intervening 30-year period. Unfortunately there was insufficient funding to analyse and report on all the rivers surveyed and only a preliminary assessment of selected samples from the Buffalo River, mostly from the stones-in-current (SIC) biotope, was conducted (Fowles 1986). These papers and reports analysed the status and abundance of the aquatic macroinvertebrates relating primarily to water quality.

An assessment of the instream flow requirements (IFR) of the macroinvertebrates of the Thukela River at selected sites was given by Chutter in Heinsohn (1995). In this report a number of indirect impacts on macroinvertebrates resulting from flow regulation by means of dams were listed. The importance of maintaining permanent flow and ensuring the correct seasonal distribution of high and low flow regimes was emphasised. The shortage of detailed information on the flow requirements of not only aquatic macroinvertebrates, but most freshwater biota was noted. It was therefore suggested that the modified flow regime should be managed in order to maintain existing biotope diversity. This could of course be reflected by measuring the diversity of selected aquatic macroinvertebrates especially species with stenotopic requirements. From

this viewpoint the assessment of species presently found and an assessment of overall species diversity (being assessed in this study) will serve to provide a baseline measure of the present community of aquatic macroinvertebrates as well as to identify any biota which require special attention in order to maintain their conservation status. As a result of work done in previous surveys it is possible to make some assessments of the changes that have occurred in these river system since the 1950's. A long-term monitoring system which assesses the presence of selected species is necessary in order to make recommendations on flow regulations. This will help to prevent flow regulation practices which are detrimental to species which are earmarked for conservation.

In August 1999 a helicopter-survey and a visit to some sites by motor vehicle enabled a preliminary assessment of the diversity of aquatic biotopes along the Thukela and the Bushman's rivers, downstream of the proposed Jana and Mielietuin dam sites. Some collection of macroinvertebrates from selected biotopes along the Bushman's and Thukela Rivers was also undertaken. A one-week follow-up survey in early October allowed further collection, and although the samples collected could not be fully analysed, identification of selected material was carried out.

During the second survey, sites which were considered important for determining the species composition under prevailing flows and for assessing flow requirements of the instream biota, were selected for further survey purposes and study: SASS collecting techniques were used with the following modifications: as many biotopes as possible were sampled at each site, a fine mesh net (280 micrometre pore size) was used at most sites, and material collected from each biotope was preserved separately. In addition to the SASS methods, other specialised collecting techniques were also used in order to sample as wide a diversity of macroinvertebrates as possible.

The 1999 survey revealed that the diversity of species in the Thukela and Bushman's rivers was different from those recorded in the 1950's. Because there was still a rich diversity of hydropneustic species it was, however, concluded that no significant changes in water quality or aquatic biotopes had occurred in the intervening 45 years. Construction of dams on the Thukela and Bushman's rivers would lead to significant modifications in the flow regime, thermal characteristics of downstream water and substratum composition. These would all have to be carefully monitored and managed so as to minimise the impact they would have on macroinvertebrate communities.

INTRODUCTION

The Department of Water Affairs are planning additional interbasin transfers of water from the Thukela and Bushman's Rivers to supplement the ever-growing demand for water in Gauteng. Before undertaking such a water transfer scheme it is important to consider the socio-political and biological factors that may be detrimentally effected by this development. The biological integrity of a river system must be cared for and an increase or decrease in flow can have deleterious influences on the riverine biota and impinge on the natural ecological functioning of the river. From a biological viewpoint it is important to consider whether there may be any transfer of undesirable biota from one catchment to another. The possible increase in pest species (in the donor or the recipient river systems) due to modified flow regimes, should also be considered.

A measure of the abundance and diversity of aquatic macroinvertebrates in a river provides information on the status or "environmental health" of that system. Because different species of invertebrates have a range of tolerances to various types of pollution and have varying aquatic life-cycle durations, the community structure of aquatic invertebrates can provide a time-integrated measure of the prevailing conditions. Such studies can, through the absence or presence of certain species, enable an assessment of the time of the disturbance and (in certain instances) what the form of the disturbance was (e.g. specific kinds of chemical or organic pollution or alterations in flow regimes). This is something which water chemistry samples, which give an instantaneous record of prevailing conditions, can not tell us. Because of their small size and relative sedentary nature, aquatic macroinvertebrates are vulnerable to ecological disturbances which can result in the elimination of certain biota from a section of river for some time. Unlike fish, macroinvertebrate species are not able to swim away from inhospitable conditions, and also need time to recolonise sections of river. Various macroinvertebrate species do this at differential rates.

Aquatic macroinvertebrates are important processors of organic matter. They serve a vital function in purifying the water in a river and also provide a valuable food resource for larger animals within and even outside the system. In order to continue functioning optimally, the component species in a river system require regular inputs of nutrients, sediments and water flow. Each specific river system is characterised by its own particular assemblage of species forming functional communities within reaches. These communities are optimally adapted to the prevailing flow conditions which control temperature, sediment transport and nutrient flows. A reduction or increase in flow, sediment transport or nutrient loads will lead to changes in community structure through loss of certain species and increases in others, as well as providing conditions for new- or otherwise-scarce species to flourish.

The brief given for this project was to assess changes in species diversity that might occur following construction of dams on the Thukela and Bushman's rivers. Information on the flow requirements needed to maintain the present diversity of biota in the donor river systems was also considered. In order to assess the flow requirements of these rivers it is considered important to determine the water quality and quantity requirements of the biota. As previous surveys were conducted around 45 and 15 years ago it was deemed necessary to determine what changes may have occured in the present river systems. Besides a re-survey of selected sites and a study of the previous surveys conducted, other published information on the aquatic biota of the Thukela and Bushman's Rivers was also consulted. All this information was synthesised to determine if there were any rare or endangered species, or possibly species with special environmental requirements that should be taken into account. Ideally the flows should be managed to ensure the survival of the extant communities along the river. Only if this is done, can good quality water be maintained for downstream users (biota and man). It is with this concept in mind that the structure of the invertebrate communities was examined.

To quantify the needs of the aquatic macroinvertebrates as regards physical water-flow requirements, an approach known as "Hydraulic Stream Ecology" has been developed (Statzner, Gore and Resh 1988). Habitat requirements of individual species are used to characterise requirements of the communities in specified biotopes. Factors such as current speed, depth and substrate characteristics are the major components considered. In South Africa, studies on instream flow requirements to accurately determine flow requirements of selected species have only been undertaken recently in selected rivers (King and Tharme 1994, Skorozewski and de Moor 1999). Extrapolation of requirements of particular species in

one catchment to other species or even the same species in other catchments, have serious shortcomings. As one moves from rivers in a more temperate region to those in a more tropical realm, a reduction in flow and water volume will result in a concomitantly larger increase in water temperature. This will directly influence the dissolved oxygen levels in the water which are a controlling factor in enabling certain species to exist in a river. The height of the proposed Jana and Mielietuin Dams with proposed regular bottom-releases of water,
would however lead to reduced temperatures of the river water downstream of the dam sites. This will negatively impact on life-cycle patterns of numerous species. With decreased temperatures in spring and summer, the insect pupae may not receive the right cues to
enable completion of metamorphosis and emergence of adults. Bottom-released water will also be anoxic or low in oxygen and this too will decimate the species downstream of the water outlet.

Because of the time limitations for conducting the study (approximately two months from the inception of the project) a detailed survey of the riverine biota was not possible, and
complete analysis of the limited data collected was not feasible. Data were also collected during extreme low-flows and would not reflect the greatest annual diversity of the river systems studied. A detailed survey would require sampling at all seasons, over a period of at least two years.

STUDY AREA AND METHODS

Figures 1-3 illustrate the sampling stations used during Oliff's (1960a, 1960b) repectively, Brand *et al* (1967) and Fowles' (1986) surveys. The additional sites surveyed during the helicopter and road surveys reported on here, are presented in Figure 4 and Table 1. Table 2 lists the samples from sites selected from B K Fowles survey in 1985 which had to be sorted and synthesised for the purpose of this study. Information on the topography, geology, rainfall and vegetation in the catchment is described in detail elsewhere (Oliff 1960a, 1960b; Brand *et al* 1967).

Between 1953-1961 Mr W D Oliff and colleagues undertook hydrobiological surveys of Natal rivers which included the Thukela and Bushman's Rivers (Oliff 1960a, 1960b; Brand *et al* 1967). Mr B K Fowles commenced a re-survey of Oliff's sites in 1984-1985 and, although the survey was completed, there was insufficient time to analyse the samples (Fowles 1986). Collecting techniques employed in these surveys were the same as those used by Oliff (1960a, 1960b) i.e. surber square foot bottom samplers, 62 mm diameter core sediment-samplers and hand nets. The nets used to sample aquatic biotopes for macroinvertebrates for the original survey of the main Thukela River had a pore size of around 1000 mm and in all subsequent surveys nets with a pore size of around 280 mm were used. Owing to time constraints only brief surveys were undertaken: a one-day helicopter survery and a one-day motor vehicle survey in August 1999 as well as a six-day follow-up collecting trip in October 1999.

During the Fowles 1985 survey 17 samples from the Thukela and 8 samples from the Bushman's River were collected.

During the late winter - spring survey of 1999, four sites along the Bushman's and 14 sites along the Thukela River were surveyed (Figure 4, Table 1). River flow at this time of the year is normally low, prior to the high summer flows. This allows easy access to the main river channel. This season is characterised by increasing water temperatures and the emergence of the adult stages of many aquatic insects. It is therefore a favourable time for collecting adult macroinvertebrates by means of light traps.

Photographic records were made of the general aquatic environment at each sampling site. This represents a visual record of aquatic biotopes present and also gives a general idea of the prevailing conditions at the time of sampling. Aquatic invertebrates were sampled using various water- and aerial hand nets ranging in net mesh size from 80 micrometres (0.08 mm) to 1000 micrometres (1 mm). Sampling of aquatic stages was done using a standard SASS net (mesh size 1000 mm); a hand-net (mesh size 280mm); a small D hand-net (mesh size 80mm) for sampling bedrock in swift-flowing reaches and the hygropetric splash zones of waterfalls. A large coral or kraal net (mesh size 1000 mm) was also used to sample riffles and sandy river beds thus ensuring the capture of rapid-swimming invertebrates which might escape from smaller nets. General hand-picking of stones, lodged branches and removable substrates was also carried out. As many aquatic biotopes as possible were sampled at each site (Table 1). Light traps, to collect the adult stages of many aquatic insects important for species identification, were set up at several sites. Where time permitted, general collecting of flying adult insects was also carried out.

The biotopes sampled included stones in and out of current, marginal vegetation and root stocks, floating and submerged aquatic macrophytes, filamentous and encrusted algae, sediments on substrata, the surface of water bodies, adult flying insects with aquatic nymphal and larval stages, and insects attracted to light traps. A light trap using a super-actinic light source over a white tray was used where conditions were suitable. Sheet light traps, which allow selective collecting and rearing of mayfly sub-imagoes to the adult stage (needed for species identification) were also used. Biotopes were sampled in a number of ways: Invertebrates associated with aquatic plants were collected by running a net through aquatic macrophytes and marginal vegetation. Aquatic macrophytes were also collected and examined and, where stony substrata were present, stones were lifted and brushed by hand or washed into a collecting net. Aquatic animals were also picked off these stones with a fine pair of forceps or by hand. Sediments were stirred up and either a coarse- or fine-meshed net was run through disturbed sediments and substrates. Where running water was found, stones in the flowing current were dislodged and kicked and invertebrates were carried by the current into a net suspended below the disturbed substrates. A synopsis of all biotopes sampled at each site is given in Table 3.

Unsorted samples from both the 1985 and 1999 surveys, as well as selected animals collected, were given a catalogue number for each site, date and biotope. Samples were labelled and preserved in either 80% ethanol or 4% formaldehyde. Selected samples were sorted in the laboratory by first picking out large animals and then passing each sample through a series of nets of different mesh-sizes to separate large and small invertebrates. A final check of each sample with a dissecting microscope was carried out to remove any smaller animals that could be missed in the coarse sorting.

Identification of selected animals were carried out using museum-voucher material for comparison, and where specimens of particular species were not available, the library of taxonomic papers held by the Albany Museum was used. Certain groups will be sent away to specialists for more detailed identification and the remainder of samples which could not be identified in the present survey, will be stored for sorting and identification at a later date. All material collected will be stored and curated in the Albany Museum, Grahamstown. Material will be stored under the Thukela River catalogue (TUG) or the Bushman's River catalogue BUS). The collection contributed 58 separate TUG and 22 separate BUS catalogue entries. Samples have been sorted and given individual species identification labels under the specific river catalogues.

The collection contributed about 800 separate catalogue entries and about 15000 specimens.

RESULTS

Tables 4 and 5 present the recorded taxa collected along the Thukela and Bushman's Rivers. In addition to information gathered during the surveys, taxa collected and reported on in other literature as well as that held in the National Collection of Freshwater Invertebrates at the Albany Museum are also included. Papers consulted for this include (Barnard 1932, 1934, 1937, 1940, Crass 1947, Demoulin 1970, McCafferty 1971, McCafferty and Gillies 1979, Scott 1983, de Moor 1993).

The surveys conducted by W D Oliff and colleagues produced an extensive list of species (Tables 4 and 5). This was compiled over a number of years comprising numerous visits to various regions along the river systems and included extensive summer time collecting with hand nets and other techniques. Analysis of selected taxa gathered during the present survey is presented in these two tables. With the limited time available for collecting and the requirements of other specialists to assist with the identification of many of the taxa, it was not possible to present an exhaustive review of the taxa that were found along these rivers. More intensive sampling would be needed in the summer and preferably extending over several years, to ensure coverage of species found during different seasons and during average and wet or dry years. Odonata in particular would require specialist collecting techniques to allow proper assessment of the species present.

A COMPARISON OF THE MACROINVERTEBRATE FAUNA BETWEEN 1953 AND 1999

The main purpose of the 1985 survey carried out by B K Fowles was to compare the community or assemblage of macroinvertebrates with the surveys carried out in the 1950's. The techniques used were thus carefully selected to be similar, although the mesh sizes of nets used in surber samplers for the Thukela River were smaller for the 1985 (c. 280 micrometres) than for the 1953 (c. 1000 micrometres) survey.

A major problem with comparing the faunal composition of species from the 1950,s and 1985 with the more recently-collected samples, is that different techniques and net pore sizes were used. In the 1950's and 1985 Surber samples were used to sample stones-in-current biotopes whereas in 1999 SASS nets, 280 mm mesh hand nets, coral nets and kicking of substrates were used. All these techniques would inadvertently pick up a percentage of organic drift. The SASS net technique would under-collect sesile organisms such as Simuliidae and, because a courser mesh size (1000 mm as opposed to 280 mm) is used, smaller animals such as certain species of entomostracan Crustacea, Chironomidae and oligochaete worms belonging to the genus *Nais,* would be under-represented and this would give a skewed representation as regards the dominance of different species. Oliff (1960a) reported that a reduction in the pore size of sampling nets from 1000 mm to 280 mm resulted in a two-fold increase in the abundance of animals collected. This would naturally influence the dominance and representation of species in community analysis. The sites selected for the 1999 survey are also not the same as sites used during earlier surveys and, although the locality of certain sites was close to those of earlier surveys, this discrepancy adds to the level of uncertainty in comparisons. The purpose of the

1999 survey was to obtain a maximum estimate of species diversity rather than to carry out an extensive quantitative analyses of species abundances in different biotopes.

Because of time constraints the level of identification of many of the invertebrate groups could not be carried down to species level in this study. Ostracoda, Cladocera and Copepoda as well as certain families of Diptera, Coleoptera and Hemiptera, were not identified to the highest possible level but will be further identified with more time and specialist identification services. By the same token the Ephemeroptera, Trichoptera and Diptera (Simuliidae) were identified with far greater resolution in 1999 than in the earlier studies as a result of the improved knowledge and understanding of the systematics of these biota. For this reason a far greater heuristic value can be attached to identifications carried out with a modern phylogenetic approach, and better predictions can be made with regards to the expected presence or absence of different clades (groups of related species). Where material from the earlier surveys was preserved as voucher specimens, it was possible to go back to these old collections and check previous identifications.

THE THUKELA RIVER

Table 4 shows that the detail of species identification varies. For many taxa (Turbellaria, Nematoda, Annelida, Crustacea, Odonata, Hemiptera, Dytiscidae, Chironomidae) identifications to species-level were conducted on most of the material in the 1950's, and this could not be done for the present survey. All the major groups are present and await further identification. For other groups more effort has been spent on ensuring accurate identification and, using more modern phylogenetic classification of groups like the Ephemeroptera, Trichoptera and Simuliidae, a considerable improvement on what was known in the 1950's and 60's has been made. Many name-changes have been taken into account and in Tables 4 and 5 the most recent taxonomic names have been used and have also been applied to the material from the 1950's and 60's. Mollusca too have been more accurately identified and more species are recorded for both the 1999 and synthesis of the 1985 survey.

Planorbid snails, including the vector of urinary bilharzia *(Bulinus tropicus),* were found at several sites during the 1985 and 1999 surveys (Table 4). These were not recorded in the 1953/54 survey. Increasingly lower flows in the river will favour these snails and will lead to a concomitant increase in bilharzia.

It was noted that no freshwater crabs (Potamonautidae) were collected during 1985 and 1999 surveys. Atyiid shrimps *Caridina* spp. were common in marginal vegetation in the lower reaches of the Thukela River in the Valley Sand Bed (Zone 7) and freshwater prawns *Macrobrachium vollenhoveni* were found in riffles and stoney runs at station 8 (corner of Khaisha Farm, about 10 km downstream of the proposed Jana Dam site). This species becames progressively more abundant at all sites in riffles further downstream.

The dragon and damselflies (Odonata) represent the best-studied aquatic order of insects in South Africa and are represented in this region by 162 species (Pinhey 1984, 1985). All nymphal stages and the adults are carnivorous and feed mostly on other insects. Identifying Odonata to species level requires the collection of adults which can only be effectively collected with hand nets in the day-time during the hot summer months of the year. Several days of dedicated collecting at each site would ensure a good representative selection of species. Unfortunately, the time and manpower did not allow for this type of collecting and only nymphal Odonata collected are incorporated in Table 4.

A nymph of *Paragomphus* was found at most sites surveyed in 1985 and 1999. A number of species of Libellulidae were commonly found. *Zygonyx* sp. usually associated with stoney substrates in swift-flowing water were found at most sites in the Thukela River.

During 1953/55, 1985 and 1999 respectively 41, 21 and 30 species of Ephemeroptera were recorded along the main Thukela River. Only zones 4-7 were surveyed during 1985 and 1999 and this therefore reflects a better understanding of this order of insects for the latter survey. Unfortunately specimens collected in the 1950's were not always retained as voucher material and many eroneous identifications or refinement of identifications could thus not be checked.

Two species of burrowing mayflies were collected in the 1953 survey (Table 4, Table 6). No species were found during the 1985 and 1999 surveys. These species require a sand/clay substrate in which they make U-shaped burrows, using their feathery gills to create a water current through their burrows, thus bringing food particles to these nymphs. These species are very dependent on flow type. Changes in the flow regime can alter the nature of the substrate and hence their preferred biotope. This eventually affects their survival in a river. It is likely that these species would be found in the foothill sandbed region (Zone 5) which was not extensively surveyed during 1985 or 1999.

The number of Baetidae species recorded during the earlier 1953/54 survey was considerably higher than in the two more recent surveys (23 species as opposed to 12 and 15 respectively for 1985 and 1999). This was mostly because the data presented in the 1953/1954 survey reflected a much longer collecting period, and also covered the upper reaches of the river in greater detail. Little information on the flow requirements of the Baetidae has been recorded. Generally, species such as *Baetis harrisoni*, *Pseudocloeon glaucum*, *P. vinosum*, *Cheleocloeon excisum* and *Afroptilum sudafricanum* are widespread and able to survive under a variety of conditions, whereas the *Demoreptus* species tend to be more specific in their flow requirements, needing fairly rapid flow and clean water. *Potamocloeon macafertiorum* has long slender claws typical of psammophilous species, and occurs in reaches where the flow is slower and the substrate sandy.

The Caenidae are a family still needing major taxomomic revision, although several distinct species can be recognised. The most interesting is *Clypeocaenis umgeni*, which has filtering hairs on its legs and mouthparts. This species inhabits faster flowing water compared to many of the other members of the Caenidae which generally live in slower flowing regions or out of the current, where in silt deposition occurs. The taxonomic knowledge in the 1960's was inadequate to recognise the diversity of species.

In the family Leptophlebiidae, only the tolerant *Euthraulus elegans* was collected in the 1999 surveys. It was also the only leptophlebiid species recorded below zone 4 in the earlier surveys.

The flat-headed sprawling Heptageniidae cling to stones in moderate to fast-flowing current, and their distribution and abundance may also be affected by changes in flow conditions in a river. They were recorded lower downstream in 1985 and 1999 than in the 1950's.

The presence of Sisyridae, *Ceraclea (Pseudoleptocerus*) sp. and *Xenochironomus* sp. (all associated with freshwater sponges) which were not recorded previously, is also noteworthy. It is unlikely that freshwater sponges and their associated fauna are a recent introduction in the river, but an increase in the abundance of these species would indicate changes in the general river ecology. A greater abundance of fine filter-feeding organisms such as freshwater sponges and Simuliidae would indicate an increase in detritus and associated bacteria in the system.

During 1953/55, 1985 and 1999 respectively 23, 11 and 18 species of Trichoptera were recorded along the main Thukela River (Table 7). Only seven species were found during both 1953/54 and 1999. This is partially due to more detailed surveys of the upper reaches of the river in 1953/54 and also because rare taxa were taken into account and could easily be missed in a one-off survey. Some confusion exists with the identification of two species *Hydropsyche ulmeri* and *Cheumatopsyche thomasseti* from larval material. These associations seem uncertain and need further resolution. There may thus be a double recording of some species in the present report. Further examination of adult Hydropsychidae collected could reveal more species for the 1999 survey.

All the aquatic moths collected belong to the family Pyralidae. Rock-dwelling species feed on diatoms and algae, other species feed on aquatic and submerged plants. One and three different species were respectively collected in the 1985 and 1999 surveys.

During 1953/55, 1985 and 1999 respectively 7, 7 and 8 species of Simuliidae were recorded along the main Thukela River (Table 8). Only three species were found during both 1953/54 and 1999. This is partially due to more accurate identification of simuliid larvae during the 1985 and 1999 surveys, and this is borne out by the fact that all except one species was recorded during both of these surveys (Table 8). The presence of *Simulium dentulosum* and *S. debegene* in zone 5 during the 1953/54 survey is indicative of strong torrential flows and would indicate that this was in the upper reaches of zone 5 in the Thukela River.

THE BUSHMAN’S RIVER

The macroinvertebrate faunal diversity in the Bushman’s River was not as rich as that of the Thukela River (Table 5). During the 1985 and 1999 surveys respectively, 4 sites and 8 biotopes and 4 sites and 10 biotopes were surveyed in the Little Bushman’s and Bushman’s Rivers (Tables 1 and 2). Not all samples have been analysed and the data presented reflect only a preliminary assessment of what was found.

Freshwater sponges and associated Sisyridae larvae were also recorded for the first time in this river system. As for the Thukela River, freshwater crabs Potamonautidae were also not collected in either the 1985 nor 1999 surveys. Atyidae and Palaemonidae were recorded in 1999.

Only five species of Baetidae were identified from the Bushman's river sites from the 1999 survey, as opposed to 13 species reported by Oliff (1960) (Table 5). However, a few interesting species not reported by Oliff include *Cloeodes inzingae*, *Demoulinia crassi* and *Pseudocloen aquacidium*. Much change has taken place in recent years in the taxonomy of the African Baetidae, and it is possible that certain species may have been overlooked or mis-identified in the earlier collection. *Demoulinia crassi* is known to occur in still deep stretches of river, and like the *Potamocloeon* species (not recorded from the Bushman's River), it dwells on the surface of sandy substrates where it collects detritus upon which it feeds.

No burrowing mayfly species (Oligoneuriidae) were recorded from this river. They had possibly already been excluded by the effects of pollution already in the 1950's.

Perlidae stoneflies were recorded for the first time in 1999. This may indicate some improvement in water quality, but may also reflect the fact that this species, although it may have been present was not recorded previously.

The reports written between 1960 and 1967 recorded 11 species of Trichoptera. In the 1985 and 1999 surveys respectively 4 and 10 species of Trichoptera were recorded. Light-trap collecting produced 5 of these records. Of the ten species recorded in 1999 only four were also recorded prior to 1967. This either indicates a significant change in species composition or it reflects differences due to the use of different sampling techniques.

The number of simuliid species recorded for 1960, 1967, 1985 and 1999 were 5, 0, 1 and 10 respectively. This reflects a more intensive survey for these species and also a greater level of identification during the most recent survey. It is to be expected that the simuliid species diversity would be greater than that recorded during 1967 and 1985. The sites surveyed during 1985 were mostly near Estcourt where pollution from factory and sewage effluent was high and would have lead to reduced species diversity. The 1967 report included only the MVIC biotope, hence reflecting a limited substratum for simuliid colonization. This was also seen in the Trichoptera. Of particular note was the rich diversity of *Simulium (Metomphallus*) species. *S. medusaeforme, S. hargreavesi, S. vorax* and *S. wellmani* were all represented. As discussed below these species are indicators of swift flowing water and their species diversity reflects heterogenious substrate types and a diversity of flow conditions. Species in the subgenus *Simulium (Pomeroyellum*) were also represented by three species. Their affinities and flow requirements are discussed below. The most interesting find was a single larva of *Simulium lumbwanum* (found at site 4 on the Bushman's River) a species which is phoretic on Heptageniidae mayflies. Further research is needed to investigate this discovery.

Even with the limited data available, it is possible to conclude that no further serious deterioration of water quality has occurred in the lower reaches of the Bushman's River since the 1960's. A rich diversity of hydropneustic aquatic insects indicates that the water was of a relatively good quality especialy at the lowermost site in the Bushman's River.

ZONATION IN THE THUKELA RIVER

Oliff 1960a proposed a zonation for the Thukela River (Figures 6 and 7) and a more detailed examination of the distribution of Ephemeroptera, Trichoptera and Diptera (Simuliidae) along this zonation is undertaken (Tables 6-8).

Ephemeroptera

Oliff (1960) identified eight hydrological zones within the main Thukela River. These are: (1) the source zone, (2) the waterfall zone, (3) the mountain torrent zone, (4) the foothill torrent zone, (5) the foothill sandbed zone, (6) the rejuvenated river zone, (7) the valley sandbded zone, and (8) the estuarine zone. In early October 1999, a survey of the main Thukela River was conducted to assess the diversity of its mayfly fauna. Emphasis was given to Oliff's (1960) zones 6 and 7. Upstream and downstream differences in the composition of the mayfly fauna within these zones are discussed below. Numbered sites mentioned correspond to numbered sites in Table 2, Fig. 4.

Sites 8, 9, 10, 11, and 12 are within Oliff's (1960) zone 6. Site 8 is upstream and site 12 is downstream. Site 8 is relatively poor in its composition, with only five mayfly species found. These species are, in descending order of abundance: *Baetis harrisoni, Pseudocloeon glaucum, Afronurus peringueyi*, *Centroptiloides bifasciata*, and *Clypeocaenis umgeni.* Site 9 is the most diverse, with 14 species. These species are, in descending order of abundance: *Pseudocloeon glaucum, Baetis harrisoni, Euthraulus elegans, Caenis* sp. 6, *Afronurus peringueyi, Pseudocloeon vinosum, Centroptiloides bifasciata, Caenis* sp. 3, *Cheleocloeon excisum, Potamocloeon macafertiorum, Cloeon africanum, Caenis* sp. 2, and *Compsoneuriella bequaerti.* Only four species were collected from site 10. In descending order of abundance, these species are: *Pseudocloeon glaucum*, *Afronurus peringueyi*, *Baetis harrisoni*, and *Caenis* sp. 5. Only two species were found in equal numbers in site 11. These species are *Baetis harrisoni* and *Caenis* sp. 3. No data is available from site 12.

Sites 13, 14, 15, 17, and 18 are within Oliff's (1960) zone 7. Five species were collected from Site 13. In descending order of abundance, these species are: *Euthraulus elegans, Afronurus peringueyi, Pseudocloeon glaucum, Clypeocaenis umgeni,* and *Centroptiloides bifasciata.* Nine species were collected from site 14. These species are, in descending order of abundance: *Pseudocloeon glaucum, Baetis harrisoni, Afronurus peringueyi, Tricorythus discolor, Euthraulus elegans, Acanthiops tsitsa, Crassabwa flava, Prosopistoma crassi,* and *Centroptiloides bifasciata.* Nine species were also collected from site 15. These species are, in descending order of abundance: *Pseudocloeon glaucum, Baetis harrisoni, Centroptiloides bifasciata*, *Euthraulus elegans, Tricorythus discolor, Clypeocaenis umgeni*, *Caenis* sp., and *Pseudocloeon vinosum.* No data is available on site 17. Four species were collected from site 18. These species are, in descending order of abundance: *Pseudocloeon piscis, P. vinosum, Cheleocloeon excisum,* and *Caenis* sp.

In both zones, the most abundant species are *Baetis harrisoni* and *Pseudocloeon glaucum. Afronurus peringueyi* and *Euthraulus elegans* are also abundant. *Centroptiloides bifasciata* tends to be found at all sites, but in low numbers. The middle reaches within each zone (site 9 for zone 6 and sites 14 and 15 for zone 7) are the most diverse (see above). Zone 6, with 16 species, has a slightly more diverse mayfly fauna than zone 7, with 14 species. Rare species found in both zones include *Acanthiops tsitsa, Clypeocaenis umgeni, Crassabwa flava, Prosopistoma crassi, Potamocloeon macafertiorum,* and *Compsoneuriella bequaerti.*

Trichoptera

The highest diversity of Trichoptera species (Table 7) was found in zone 4 in the 1953/54 survey with 14 recorded species. Ten and 11 species were collected in the rejuvenated River (zone 6) during 1953/54 and 1999. Surveying of reaches with riffle bars in the Sand Bed River (zone 7) indicated the presence of 10 species in 1999, whereas only 5 were recorded in 1953/54. A downstream zonation of hydropsychid species was evident from the limited data analysed. The dominant hydropsychid during 1999 in zone 4 was *Cheumatopsyche* sp. 5. During 1985 the dominant species in the upper reaches of zone 5 were *Cheumatopsyche thomasseti* and *Amphipsyche scottae*. During 1999 *Hydropsyche longifurca* was present in zones 4 and 5 and the uppermost site of zone 6 (Station 8) in the Thukela River. This species was not found further downstream during the 1985 or 1999 surveys. The dominant species of hydropsychid in zones 6 and 7 during 1985 and 1999 were the larvae of *Cheumatiopsyche* sp. 2. *Cheumatiopsyche* sp. 9. was found in lower numbers, but was also present at sites higher upstream.

Two species of hydroptilid caddis (*Hydroptila cruciata* and *Orthotrichia barnardi*) were common in zone 7 of the Thukela River during 1985 and 1999. Leptocerid caddisflies were represented by 6 species but were never abundant. Light-trap sampling enabled the collection of several species not recorded from benthic sampling. It was notable that Ecnomidae were rare in light trap samples which were dominated by hydropsychid Trichoptera at all sites surveyed.

Simuliidae

A zonation of *Simulium* species was discernible from the upper reaches down to the coast. *Simulium dentulosum* and *S. debegene* were recorded in the uppermost zones in 1953/54 and are the most commonly-occurring simuliids in the upper mountain torrent regions.
There were several species within the sub-genus *(Metomphallus*) collected in this survey and *Simulium medusaeforme* was the most widespread species and was found all the way down to the lower zone 7 (site 17). *S. medusaeforme* is considered to be an adaptable species found under a wide range of flow conditions. It is common in the swift-flowing middle reaches of larger rivers where it dominates the simuliids numerically. *Simulium wellmani* was another species which was found in the middle reaches. Its distribution was more restricted to the upper-middle reaches (Zones 4 and 5) than *S. medusaeforme*. *Simulium vorax* (recorded in zones 6 and 7) is often found together with *S. medusaeforme* but it is usually the dominant species in larger rivers with a greater flow volume and velocity. Owing to the very low flow conditions during the 1985 and 1999 surveys, this species was rare. *Simulium bovis* was only found in the two lowermost zones 6 and 7, and appears to be restricted to the lower river reaches where turbidity is high and flows may fluctate considerably.

GENERAL CONCLUSION AS TO THE CHANGE OF SPECIES RECORDED OVER 45 YEARS

Regarding species composition of known taxa, the fauna has not changed very much over a 45 year period for both the Thukela and Bushman's Rivers. Ephemeroptera and Trichoptera are still diverse and represent two of the dominant taxonomic groups.

The early surveys showed clearly that the upper reaches of the Thukela River (identified as the mountain and foothill torrent zones in Oliff's 1960a paper) had a distinctive fauna. The present survey did not take these regions into account, and discussion of the unique fauna remains only as a mention in tables 4-8.

FLOW REQUIREMENTS OF SELECTED AQUATIC MACROINVERTEBRATES

Ephemeroptera
Oligoneuriidae

These mayflies are filter feeders in the nymphal stages and live in swift-flowing waters. They rely on the flowing water to carry food to them and they collect the food by means of filtering hairs on the front legs. Highly modified mouthparts are used to scrape filtered material off the filtering hairs. *Oligoneuriopsis lawrencei* is restricted to the upper reaches of the river (Zone 3) and large perennial streams at altitudes over 1100 m asl. The flow requirements for this species, from previous collecting experience, are swift to torrential flows with large boulders or cobbles forming suitable substrates. Agnew (1973, 1980) provides compelling evidence to confirm that this species, as expected for all Oligoneuriidae, is univoltine and needs perennially-flowing water. Overwintering diapause eggs are evidently laid. These remain dormant for about six months before nymphs hatch in the ensuing spring and develop through to adults during late summer to autumn. It is also noted that *Oligoneuriopsis* species are "cold adapted" species and need cool, well oxygenated water throughout the summer period to complete development.

The oligoneuriid *Elassoneuria trimeniana* recorded from zones 5-7 in 1953/54 is also a species requiring a strong flow of water. This species was not recorded in the 1985 or in the 1999 survey. As this species is also univoltine, it may have been present as small larvae and would not have been detected during the late winter and spring seasons when the surveys in 1985 and 1999 were conducted. Adult *E. trimeniana* were found in a light trap sample collected by Mr Conor Cahill in April 1999, indicating that this species is still found on the Thukela River. Perennial flow also seems to be a requirement for maintaining populations of this species, although species of the genus *Elassoneuria* are found at lower altitudes and warmer waters than *Oligoneuriopsis* and hence may not need such abundant flows to maintain cool temperatures as required by the latter genus.

Baetidae

These include the species such as *Centroptiloides bifasciata* a large predatory species found only in the swiftest flowing water on large boulders and stones (it soon dies when left in stationary water) and *Pseudopannota maculosa* (which was not recorded during the extremely low-flow conditions when the survey was conducted in 1999). Both these species would not prosper under prolonged reduced-flow conditions.

Prosopistoma crassi (Prosopistomatidae) is widespread in tropical waters. Flow requirements for this species appear to be associated with conditions creating substrates predominantly composed of large cobbles to boulders i.e. flows exceeding 0.8 ms^{-1} (Hynes 1970).

Tricorythus discolor and *T. reticulatus* were found in eroding biotopes in the river. Oliff (1964) found that silt deposits restricted the distribution of these species. They are, however, tolerant of moderate pollution and a moderate to swift flow regime.

Trichoptera

Hydropsychidae

The filter feeding hydropsychids *Cheumatopsyche thomasseti* and *C. afra* are widespread and tolerant species. The ecological requirements of *Hydropsyche longifurca* are less well understood but this species is often found in association with the above two species and is larger than any of the *Cheumatopsyche* species found in the Thukela River. The several other species of hydropsychid found are less well known as regards their ecological requirements. It would seem that the larvae of *Cheumatopsyche* sp. 2, the most abundant of hydropsychid species encountered during the 1999 survey, are those of *C. falcifera*, and that flow velocity and substrate type and depth requirements for this species are similar to those of *C. thomasseti*. All the above-mentioned species need a strong flow of water over riffles or rapids to keep stone surfaces cleared of sediment and to support their silken collecting nets with which they capture organic matter (including other insects and algae on which they feed). They are all multivoltine going through several generations a year. Synchronisation of spring emergences plays an important part in controlling pest blackfly population levels in medium to large rivers (flows of over 5 cumecs) (de Moor 1992).

Simuliidae

Simulium damnosum s.l. is recognised as a species complex with more than 40 described Afrotropical species, most of which are distinguishable only on cytological and behavioural characteristics. The species from the Thukela and Bushman's Rivers was found in swift flowing sections of the river in riffles and on marginal vegetation all the way down to the coast.

Simulium adersi was found in Zones 6 and 7. This species is a widespread pollution- and saline-tolerant species, usually found in slow-flowing, medium-sized rivers with a stable flow regime. *Simulium adersi* has been recorded biting man in the eastern Cape.

Species in the subgenus *Simulium (Metomphallus*) (see above for a list of species found) require swift flowing conditions (ranging from 0.8- 1.5 ms^{-1}), with clear bedrock or large boulders and stones in larger streams and rivers. They form the dominant component of swift-flowing African Rivers.

The larvae of species belonging to the subgenus *Simulium(Pomeroyellum*) which included *Simulium mcmahoni, S. rotundum* and *S. cervicornutum* are found in slow- to moderately swift-flowing water 0.2-1.0 ms^{-1} attached sparsely either to stones, dead leaves or vegetation. These three species are often found in shallow flowing warmer water under sub-tropical conditions.

DISCUSSION

The Thukela and Bushman's rivers show a rich diversity of Ephemeroptera (Tables 4, 5 and 6). All except one of the South African families, the Teloganodidae, are found in these rivers. The Trichoptera are not as diverse, being represented by eight of the 18 families recorded in South Africa. Sampling for species in specialised biotopes would undoubtedly reveal more species, but this was outside the scope of the preliminary survey.

A characteristic of the Thukela River is that it arises on an escarpment, drops almost vertically 850 metres via waterfalls to a mountain torrent zone, and then rapidly grades into a foothill torrent zone. The river then flows over a gentle gradient through a foothill sandbed zone for about 40 km up to the town of Colenso. Pool-like conditions and meandering stretches of the river prevail here. There is then an increase in the gradient, creating many rapids and riffles within a swift-flowing river (designated as a rejuvenated zone by Oliff, 1960a). This extends down to the confluence with the Buffalo River. From there the river widens into a Valley Sand Bed zone where deposition of sand predominates the channel. In these lower reaches there are still sections of river where granite and gneiss riffle bars extrude into the sandbed creating short reaches of cascades, riffles and rapids interspersed with longer reaches of sandbed river. The river then flows into a broad estuary.

The above range of conditions has allowed for the observed diversity of macroinvertebrates found in this river (Table 4).

IMPACTS ON THE RIVER ECOLOGY RESULTING FROM THE TWP

The proposed construction of the Jana and Mielietuin Dams will defininitely affect the fauna in a number of ways:

The downstream zonation observed in the Ephemeroptera, Simuliidae and hydropsychid Trichoptera will be disrupted and it is likely that ubiquitous species such as *Simulium nigritarse, S. adersi*, *S. medusaeforme* and to an extent *S. damnosum* s.l. will become more abundant. Species such as *Simulium vorax* will become rarer. It is not possible to accurately predict what species assemblages will develop. There will be definite changes in functional communities of species.

A modification of the thermal regime with much colder water being discharged from the bottom of the dams at regular intervals will have a devastating effect on the macroinvertebrate biota. The gradual natural seasonal decrease in autumn through winter followed by a gradual increase of water temperatures in spring will be completely disrupted. Irregular temperature fluctuations will upset the biological rhythms of many species, and aquatic insects will fail to pupate, metamorphose or emerge. Certain adaptable species will become abundant and pose pest problems which will be costly to control.

Besides a change in the thermal regime, resulting from bottom releases of water, toxic reduced ammonia and hydrogen sulphide will be released and can cause a kill-off of all life downstream of the dam if not carefully managed.

Reduced sediment loads in swift-flowing water immediately downstream of the dam will lead to increased erosion capacity and this will lead to exposure of bedrock (armouring) in these reaches. Species community structure will be disrupted with no detritus for detrital feeding species. Such conditions will favour bedrock-dwelling species i.e. certain species of Simuliidae.

The Thukela and Bushman's Rivers have a mixture of suspension filter feeders and detritus feeders with low numbers of grazers. Reduced input of detritus and particulate matter in the river downstream of the dam sites will influence macroinvertebrate community structure. Rather than a total elimination of certain species there will be subtle changes in species dominance and a gradual change in the functional ecological role of species found. Such changes will favour more generalist species and lead to a reduction in more narrowly-specialised species. These changes could be associated with feeding, cryptic behaviour, breeding and seasonal emergence patterns.

Less sediment in the water will lead to a greater clarity of water leading to greater penetratration of light and more algal and plant growth on substrates downstream of the impoundment. Greater clarity of the water will make species more vulnerable to predators dependant on vision and again this will lead to subtle changes in species composition.

Clear water in the dams could lead to algal blooms with plants getting into the river dowstream of the dam. This will favour certain filter-feeding species such as simuliids and certain Hydropsychidae.

Much further downstream of the Dams, lower flows will lead to increased sedimentation of riffles and a loss of braided sections of riverbed in wide riffle-bar reaches. This will lead to a reduction in the heterogeneity of substrata and aquatic biotopes which will lead to a concomitent reduction in species diversity. This could have dire effects on the river ecology as there will then be a few dominant species which will periodically develop into pest proportional population sizes.

RECOMMENDATIONS

Ecological requirements of the biota are strongly governed by the flow and thermal regime of the river and modification of sediment deposition or erosion, and seasonally-unnatural low or high temperatures, as well as rapid fluctuations in temperature, will lead to species eradication and functional community structural changes.

To assess in greater detail whether there are rare or endangered species as well as concentrations of potential problem or pest species along the course of the rivers, a two-year, in-depth survey of benthic macroinvertebrates in the late winter and late summer as well as light trap and adult insect collecting in summer should be conducted.

As a management proposal for the Thukela River it is reccommended that efforts should be made, at least to maintain and if possible try to improve, conditions that will enhance the diversity of filter feeding species in the riffle- and running water biotopes. Maintenance of sediment-free substrata and prevention of clogging of interstices in riffles should be managed. The lower sandbed reaches in zone 7 have braided channels with riffles, cascades and rapids as well as islands of macrophytes. These biotopes should be accounted for in designing a new flow regime. The maintenance of a diversity of biotopes in these lower sandbed reaches will ensure that no single group of animals will dominate the fauna of the river. Maintenance of species diversity will ensure that pest species, such as certain *Simulium* spp. and bilharzia-vector snails, do not become abundant, a problem which would have to be further managed.

The presence of a mixed community of filter-feeding and gatherer-collector species characterised the Thukela and Bushman's Rivers for all sites surveyed. There are many species that require a regular input of detritus and sediment for continued survival. Careful management of the thermal regime should also be considered in the river management programme.

A regular monitoring programme should be developed to ensure that the recommendations are met. A late winter/dry season survey of benthic macroinvertebrates should be undertaken annually. In addition, a late summer survey with light traps (to collect adults) should be implemented. The monitoring programme should cover the following:

* An in-depth two year survey to develop a base-line data set for determining the species diversity and relative abundance of key taxa
* Annual monitoring of species diversity
* Annual determination of the relative abundance of selected species

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List of Tables used in Macroinvertebrates Report

Table 1: Sampling stations and biotopes surveyed along the Bushman's and Thukela Rivers during 1999

Site & Date	Description of site	Coordinates	Biotopes sampled
1. 4.X.99	Bushman's River at Riversdale	285540S 295843E	SIC, BRIC, MVIC, LIGHT
2. 17.VIII.99	Bushman's River above Weenen	285200S 300450E	SIC
3. 17.VIII.99	Bushman's River above Waterfall	284900S 301010E	SIC, POOL
4. 4.VIII.99	Bushman's River at Nkasini Bridge	284605S 300959E	SIC, MVIC, SAM
5. 3.X.99	Mahai River in RNNP	284118S 285638E	SOC, SIC, MVOC, LIGHT
6. 2.X.99	Thukela River at junction of Ingezungu River	284101S 285911E	SIC, ALGAE, FNW
7. 3.X.99	Thukela River below Rugged Glen Stables	284102S 290034E	SIC
8. 5.X.99	Thukela River at Khaisha farm corner	284419S 300836E	SIC, SOP
9. 18.VIII.99	Thukela River at Tugela Estates	284550S 300940E	SIC, MVIC, LIGHT
10. 17.VIII.99	Thukela River rapids	284430S 301350S	SIC, SOC, SED
11. 17.VIII.99	Thukela River upstream of Tugela Ferry	wrongly marked on map	SIC, BRIC
12. 5.X.99	Thukela River at Mbono downstream of Tugela Ferry	284531S 303224E	SIC, BRIC, LIGHT
13. 17.VIII.99	Thukela River at end of reach 7.2	284610S 305330E	SED, SOC, SIC
14. 6.X.99	Thukela River upstream of Jamesons Drift	284612S 305348E	SIC
15. 18.VIII.99 6.X.99	Thukela River at Mabula Trust farm downstream of Mamba River	285555S 310147E	SIC, MVIC, MVOC, SOC, LIGHT
16. 7.X.99	Mati River, tributary of Thukela River, at Mbulwini	290637S 310817E	SIC
17. 7.X.99	Thukela River at Emabhobhane Drift	290534S 311218E	SIC, BRIC, MVIC, MVOC
18. 7.X.99	Thukela River at Essiena Farm, Sunbury Estate near Mandini	290941S 312010E	SAND, MVIC, LIGHT

Table 2: Sampling stations and biotopes surveyed along the Bushman's and Thukela Rivers during 1985 by Mr B. K. Fowles

Site & date	**Description of site**	**coordinates**	**Biotopes sampled**
36. 7.VIII.1985	Little Bushman's River Stn B1 Sementdrif..	290103S 294705E	SED, MVIC
38. 7.VIII.1985	Little Busmans River Stn B10 below Nestle Factory	284500S 294500E	SED, MVIC
39. 7.VIII.1985	Bushman's River Stn B12 near Municipal Water works	290102S 295307E	MVIC, SED
40. 8.VIII.1985	Bushman's River Stn B16 downstream of sewage works	290042S 295439E	SED, MVIC
32. 31.VII.1985	Thukela River Stn 11at Cavern Road	283000S 294500E	MVIC, SIC
33. 31.VII.1985 2.VIII.1985	Thukela River Stn 10 at Hely Hutchinson Bridge	284353S 292147E	MVIC, MVIC, SED
35. 2.VIII.1985	Thukela River Stn 10A at Harts Hill	284202S 294950E	SIC, MVIC
41. 9.VIII.1985	Thukela River Stn 7 below Bushman's River	284430S 301330E	MVIC
45. 9.VIII.1985	Thukela River Stn 3A at Tugela Ferry	284459S 302634E	MVIC, SIC
47. 5.IX.1985	Thukela River Stn 2 at Nthsongweni	284342S 303913E	SED, SIC, SIC
48. 4.IX.1985	Thukela River Stn 1A at Middledrift	285600S 310154E	SED, MVIC
49. 4.IX.1985	Thukela River Stn1 at Mandini	291015S 312336E	SED, MVIC

Table 3: Aquatic biotopes sampled during the 1985 and 1999 surveys

Biotope	Description
SED	Sediment sample
MVOC	Marginal vegetation out of current
MVIC	Marginal vegetation in current
SIC	Stones in the current
SOC	Stones out of the current
SAND	Sandy substratum
FNW	Flying near water
LIGHT	Light trap collecting at night
BRIC	Bedrock or boulders in current
POOL	Backwater pool or standing body of water
SAM	Submerged aquatic macrophytes
SOP	Surface of water in pool in river

Table 4. List of macroinvertebrate species obtained during various surveys of theThukela River catchment

TAXA	Date of Survey		
	1953/ 1954	1985	1999
PORIFERA			
Fam. Gen. Sp. Indet.			*
TURBELLARIA			
Planariidae			
Dugesia sp.	*		
Planaria sp.		*	*
Dendrocoelidae			
***Sorocelis* sp.**	*		
Microstomidae			
Microstomium sp.	*		
NEMERTEA			
Tertastemmatidae			
Prostoma sp.	*	*	*
NEMATODA			
Dorylaimidae			
Nygolaimus sp.	*		
Diplogasteridae			
Diplogaster sp. 1	*		
Diplogaster sp. 2	*		
Mermithidae			
Gen. sp. indet.	*	*	*
NEMATOMORPHA			
Parachordodidae			
Paragordius sp.			*
ANNELIDA			
HIRUDINEA			
Glossiphoniidae			
Glossiphonia sp.?	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Salifa ?perspicax		*	
Helobdella sp.	*		
Gen. sp. indet.		*	*
OLIGOCHAETA			
Aeolosomatidae			
Aelosoma beddardi?	*		
Naididae			
Chaetogaster sp.	*		
Nais spp.	*	*	*
Stylaria sp.	*		
Slavina sp.	*		
Dero limosa?	*		
Aulophorus furcatus?	*		
Naidium sp.	*		
Pristina sp.	*		
Gen. sp. Indet.		*	
Lumbriculidae			
Gen. sp. indet.	*		*
Tubificidae			
Tubifex sp.	*	*	
Branchiura sowerbyi	*	*	
Limnodrilus sp.	*		
Gen. Sp. Indet.		*	*
MOLLUSCA			
GASTROPODA			
Planorbidae			
Bulinus tropicus			*
Bulinus natalensis		*	
Bulinus spp.		*	*
Gyraulus sp.		*	
Biomphalaria pfeifferi		*	

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Biomphalaria sp.			*
Physidae			
Physa acuta		*	*
Lymnaeidae			
Gen. sp. Indet.		*	
Ancylidae			
Burnupia spp.		*	*
PELECYPODA			
Sphaeriidae			
Pisidium spp.		*	*
Corbiculidae			
Corbicula sp.		*	*
Corbicula fluminalis			*
CRUSTACEA			
CLADOCERA			
Daphniidae			
Daphnia pulex	*		
Daphnia spp.	*	*	
Simocephalus capensis	*		
Simocephalus vetuloides	*		
Simocephalus sp.	*		
Ceriodaphnia quadrangula	*		
Ceriodaphnia cf. pulchella	*		
Moina propinqua?	*		
Bosminidae			
Bosmina longirostris?	*		
Macrothricidae			
Macrothrix propinqua	*		
Ilyocryptus sordidus	*		
Ilyocryptus sp.		*	
Chydoridae			
Leydigia cf. microps	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Leydigia cf. quadrangularis	*		
Alona cf. affinis	*		
Alona cambouei	*		
Alona cf. gutatta	*		
Alona striolata	*		
Alona rectangula	*		
Chydorus gibsoni	*		
Chydorus sphaericus	*		
Chydorus sp.		*	
Gen. sp. indet.		*	*
COPEPODA			
Diapotomidae			
Tropodiaptomus spectabilis	*		
Paradiaptomus lammelatus	*		
Cyclopidae			
Cyclops sp.		*	
Macrocyclops albidus	*		
Tropocyclops confinis	*		
Ectocyclops hirsutus	*		
Eucyclops eucanthus	*		
Eucyclops cf. gibsoni	*		
Eucyclops cf. sublaevis	*		
Eucyclops cf. speratus	*		
Paracyclops cf. affinis	*		
Paracyclops fimbriatus	*		
Paracyclops poppei	*		
Mesocyclops leuckarti	*		
Mesocyclops cf. hyalinus	*		
Thermocyclops schuurmanae	*		
Canthocamptidae		*	*
Elaphoidella bidens	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Harpactiocus sp.	*		
Fam. Gen. sp. Indet.		*	*
OSTRACODA			
Cyprididae			
Ilyocypris australiensis	*		
Isocypris priomena	*		
Isocypris sp.	*		
Cypria capensis	*		
Eucypris sp.	*		
Herpetocypris chevreuxi	*		
Cypridopsis gregaria	*		
Cypridopsis hirsuta	*		
Cypridopsis glabrata	*		
Cypridopsis reniformis	*		
Cypretta arcuata	*		
Cypretta minna	*		
Typhalocypris sp.	*		
Eucypris sp	*		
Zonocypris cordata?	*		
Zonocypris tuberae?	*		
Limnothricidae			
Gomphocythere sp.?		*	
Fam. Gen. spp. indet.		*	*
MALOCOSTRACA			
Mysidacea			
Gastrosaccus brevifissura	*		
Tanaidae			
Tanais annectens	*		
Tanais philetaerus	*		
ISOPODA			
Jaeridae			
Protojarina perbrincki	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Eurydicidae			
Pontogeloides latipes	*		
AMPHIPODA			
Gammaridae			
Crangonyx robertsii	*		
Talitridae			
Talorchestia sp.	*		
Orchestia sp.	*		
Corophilidae			
Corophium triaenonyx?	*		
Aoridae			
Grandidierella cf. bonnieri	*		
DECAPODA			
Grapsidae			
Serarma catenta	*		
Serarma eulimene	*		
Potamonidae			
Potamonautes sidneyi	*		
Potamonautes dubius	*		
Potamonautes warreni	*		
Potamonautes perlatus	*		
Upogebiidae			
Upogebia africana	*		
Penaeidae			
Penaeus monodon	*		
Penaeus japonicus	*		
Metapenaeus monoceros	*		
Atyidae			
Caridina africana		*	
Caridina typus	*		
Caridina nilotica var. natalensis	*		*

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Palaemonidae			
Macrobrachium cf. idella	*		
Macrobrachium equidens	*		
Macrobrachium lepidactylus	*		
Macrobrachium vollenhoveni?			*
Palaemon pacificus	*		
COLLEMBOLA			
Poduridae			
Gen. spp. indet.		*	*
ARACHNIDA			
ARANAEIDA			
Fam. Gen. sp. indet.			*
Tetragnathidae			
Tetragnatha sp.		*	*
Lycosidae			
Gen. sp. Indet.		*	
HYDRACARINA			
Fam. Gen. spp. indet.		*	*
INSECTA			
EPHEMEROPTERA			
Baetidae			
Acanthiops varius	*		
Acanthiops tsitsa			*
Afroptilum sudafricanum	*	*	*
Afroptilum parvum	*		
?Afroptilum spp.	*		
Baetis cataractae	*		
Baetis harrisoni	*	*	*
Baetis lawrencei	*		
Baetis parvulus?	*		
Baetis sp. 1.	*		
Baetis sp. 2	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Centroptiloides bifasciata	*	*	*
Cloeon africanum	*		*
Cloeon virgiliae	*		
Cloeon sp.		*	*
Cloeodes inzingae	*		
Crassabwa flava			*
Cheleocloeon excisum	*	*	*
Dabulamainzia helenae		*	
Dabulamanzia indusii	*		
Dabulamanzia media	*		
Demoreptus capensis			*
Demoreptus natalensis	*		*
Demoreptus monticola	*		
Potamocloeon macafertiorum			*
Pseudocloeon aquacidus		*	
Pseudocloeon bellum	*		
Pseudocloeon glaucum	*	*	*
Pseudocloeon piscis		*	*
Pseudocloeon vinosum	*	*	*
Pseudocloeon sp.nov?		*	*
Pseudopannota maculosa	*	*	
Caenidae			
Caenis capensis	*		
Caenis sp. 2			*
Caenis sp. 3		*	*
Caenis sp. 5		*	*
Caenis sp. 6			*
Caenis spp. indet.	*	*	*
Clypeocaenis umgeni		*	*
Heptageniidae			
Afronurus harrisoni	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Afronurus peringueyi	*	*	*
Afronurus sp.	*		*
Compsoneuriella bequaerti			*
Leptophlebiidae			
Aprionyx tricuspidatus	*		
Adenophlebia auriculata	*		
Adenophlebia sylvatica	*		
Castanophlebia calida	*		
Euthraulus elegans	*	*	*
Tricorythidae			
Tricorythus discolor	*		*
Tricorythus reticulatus	*	*	*
Tricorythus "lowveld"		*	
Polymitarcyidae			
Ephoron savignyi	*		*
Ephemeridae			
Eatonica schoutedini	*		
Oligoneuriidae			
Elassoneuria trimeniana	*		*
Oligoneuropsis lawrencei	*		
Prosopistomatidae			
Prosopistoma crassi	*	*	*
Prosopistoma sp.	*		
PLECOPTERA			
Perlidae			
Neoperla spio	*	*	*
ODONATA			
Chlorolestidae			
Chlorolestes fasciata	*		
Chlorolestes tesselatus	*		
Chlorolestes longicauda	*		
Lestidae			

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Lestes plagiatus	*		
Calopterygidae			
Phaon iridipennis	*		
Chlorocyphidae			
Platycypha caligata	*		
Chlorocypha fitzsimonsi	*		
Chlorocypha spp.			
Platycnemididae			
Allocnemis leucosticta	*		
Coenagrionidae			
Ceriagrion glabrum	*		
Ceriagrion sp.		*	
Pseudagrion acaciae	*		
Pseudagrion citricola	*		
Pseudagrion glaucescens	*		
Pseudagrion kersteni	*		
Pseudagrion makabusiensis	*		
Pseudagrion natalense	*		
Pseudagrion pseudomassaicum	*		
Pseudagrion salisburyense	*		
Pseudagrion sjostedti	*		
Pseudagrion spp.		*	*
Enallagma elongatum			
Enallagma glaucum	*		
Agriocnemis exilis	*		
Gomphidae			
Notogomphus praetorius	*		
Notogomphus sp.		*	
Paragomphus cognatus	*		
Paragomphus hageni	*		
Paragomphus spp.	*	*	*

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Ceratogomphus pictus			
Corduliidae			
Macromia sp.			*
Syncordulia sp.?		*	*
Libellulidae			
Tetrathemis polleni	*		
Orthetrum brachiale	*		
Orthetrum caffrum	*		
Orthetrum crysostigma	*		
Orthetrum farinosum	*		
Orthetrum stemmale	*		
Palpopleura juncunda	*		
Palpopleura lucida	*		
Hemistigmata albipuncta	*		
Diplacodes lefebvrei	*		
Crocothemis erythraea	*		
Crocothemis sanguinolenta	*		
Brachythemis leucosticta	*		
Philonomon luminans	*		
Sympetrum fonscolombei	*		
Trithemis annulata	*		
Trithemis arteriosa	*		
Trithemis dorsalis	*		
Trithemis kerbyi	*		
Trithemis risi	*		
Trithemis stricta	*		
Trithemis sp.		*	*
Zygonyz natalensis	*		
Zygonyx torrida	*		
Zygonyx sp.		*	*

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Rhyothemis semihyalina	*		
Pantala flavescens	*		
Aeshnidae			
Aeshna subpupilata			*
Aeshna miniscula	*		*
Aeshna sp.		*	
Anaciaeschna triangulfiera	*		
Anax speratus	*		
HEMIPTERA			
Belostomatidae			
Sphaerodema nepoides	*		
Gerridae			
Gerris hypoleuca	*		
Gerris swakopensis	*		
Gerris sp.			
Gen. sp. indet.			
Nepidae			
Nepa cf. cinerea	*		
Ranatra cf. linearis	*		
Ranatra sp.		*	*
Veliidae			
Rhagovelia nigricans	*		
Rhagovelia sp.		*	*
Microvelia major	*		
Microvelia sp.?			*
Gen. sp. indet.			*
Hydrometridae			
Hydrometra stagnorum	*		
Mesoveliidae			
Mesovelia sp.		*	*
Pleidae			
Plea pullula	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Plea picanina	*		*
Naucoridae			
Aphelocheirus schoutedeni	*		
Macrocoris flavicollis	*		
Laccocoris limnigenus	*		
Laccocoris sp.		*	*
Gen. sp. indet.			*
Notonectidae			
Enithares ?chinai	*		
Enithares sobria	*		
Enithares sp.	*		
Enithares v. flavum	*		
Anisops cf. aglaia	*		
Anisops debilis	*		
Anisops gracilis	*		
Anisops gracilliodes	*		
Nychia limpida limpida	*		
Gen. sp. indet.			*
Corixidae			
Micronecta hessi	*		
Micronecta scutellaris	*		
Micronecta piccanin	*		
Micronecta spp.		*	*
Sigara sjostedti	*		
Sigara sp.			
Aphididae			
Gen. sp. indet.		*	*
Helotrephidae			
Naboandelus sp.	*		
Ochterus marginitus	*		
NEUROPTERA			

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Sisyridae			
Sisyra sp.			*
TRICHOPTERA			
Leptoceridae			
Adicella sp.	*		
Leptocerus sp.	*		
Athripsodes corniculans		*	*
Athripsodes harrisoni	*		
Athripsodes fissus	*		
Oecetis modesta	*		
Oecetis sp.			*
Leptocerina sp.	*		
Ceraclea (Pseudoleptocerus) sp.			*
Trianodes sp.			*
Trichosetodes anysa			*
New genus			*
Hydropsychidae			
Cheumatopsyche afra	*	*	*
Cheumatopsyche thomasseti	*	*	
Cheumatopsyche falcifera	*		*
Cheumatopsyche triangularis	*		
Cheumatopsyche maculata	*		
Cheumatopsyche “type 10"		*	
Cheumatopsyche “type 9"		*	*
Cheumatopsyche “type 5"			*
Cheumatopsyche “type 2"		*	*
Amphipsyche scottae		*	
Hydropsyche ulmeri	*		
Hydropsyche longifurca	*	*	*
Polymorphanisus bipunctatus	*		
Polycentropodidae			
Polyplectropus sp.	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Pseudoneurecilpsis sp	*		
Ecnomidae			
Ecnomus thomasseti	*		*
Ecnomus natalensis	*		
Ecnomus spp.	*		*
Psychomyidae			
Lype sp.	*		
Pauduniella sp.	*		
Philopotamidae			
Chimarra sp.	*		
Hydroptilidae			
Hydroptila cruciata	*	*	*
Oxyethira sp.			*
Orthotrichia barnardi		*	*
Dipseudopsidae			
Dipseudopsis capensis			*
LEPIDOPTERA			
Pyralidae			
Nymphula sp.			*
Petrophila sp.			*
?Paraponyx sp.		*	
Gen. Sp. Indet			*
COLEOPTERA			
Dytiscidae			
Amarodytes peringueyi	*		
Bidessus sharpi	*		
Canthydrus nigerrimus	*		
Canthydrus quadrivittatus	*		
Canthydrus sedilloyi	*		
Clypeodytes coaarcticallis	*		
Clypeodytes meridionalis	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Copelatus polystrigus	*		
Guignotus harrisoni	*		
Hydaticus servillianus	*		
Hydrovatus validicornis	*		
Hydroporus sp.		*	
Hyphydrus aethiopicus	*		
Hyphydrus? caffer	*		
Laccophilus adspersus	*		
Laccophilus amphlicatus	*		
Laccophilus congener	*		
Laccophilus continentalis	*		
Laccophilus cyclopis	*		
Laccophilus lineatus	*		
Laccophilus olsoneffi	*		
Laccophilus pilitaris	*		
Laccophilus sp.	*		
Philaccolus lineatoguttatus	*		
Neptosternus ornatus	*		
Potamonectes vagrans	*		
Yola natalenisi	*		
Yola subopaca	*		
Yola tuberculata	*		
Gen. indet. sp.1			*
Gen. indet. sp.2			*
Gyrinidae			
Aulonogyrus abdominalis	*		
Aulonogyrus amoenulus	*		
Aulonogyrus alternatus	*		*
Aulonogyrus sesotho	*		
Aulonogyrus spp.		*	*
Dinutes aerus	*		
Gyrinus natalensis	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Orectogyrus conformis	*		
Orectogyrus oscari	*		
Orectogyrus polli	*		
Orectogyrus sp.		*	
Coccinelidae			
Scymus ?fallax	*		
Nephus ?augustus	*		
Hydrophilidae			
Berosus australis		*	
Gen. sp. indet.			*
Hydraenidae			
Ochthebius sp.		*	
Hydraena sp.		*	
Gen. spp. indet.		*	*
Curculionidae			
Baris sp.	*		
Coeliodes celastri	*		
Piezotrachelus magnirostris	*		
Elmidae			
Potamodytes sp.			*
Gen. spp. indet.		*	*
Chrysomelidae			
Melosoma discolor	*		
Halticidae			
Haltica cuprea	*		
Aphthona marshalli	*		
Galerucidae			
Estcourtiana litura	*		
Staphylinidae			
Gen. sp. indet.		*	
DIPTERA			

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Blepharoceridae			
Elporia flavopicta	*		
Elporia hiemis	*		
Elporia natalensis	*		
Elporia scruposa	*		
Psychodidae			
Psychoda alternata	*		
Psychoda dentata	*		
Psychoda sp.		*	
Telmatoscopus sp.	*		
Dixidae			
Dixa bicolor	*		
Chaoboridae			
Chaeoborus microstictus	*		
Culicidae			
Anopheles ardensus	*		
Anopheles cinereus	*		
Anopheles demeilloni	*		
Anopheles listeri	*		
Culex andersoni subsp. bwambanus	*		
Culex salisburiensis	*		
Culex tigripes	*		
Culex univittatus	*		
Culex vansomereni	*		
Theobaldia longiareolata	*		
Anopheles sp.	*		
Simuliidae			
Simulium nigritarse	*		
Simulium bovis	*	*	*
Simulium damnosum s.l.	*	*	*
Simulium cervicornutum			*

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Simulium rotundum	*		
Simulium medusaeforme	*	*	*
Simulium vorax		*	*
Simulium mcmahoni		*	*
Simulium hargreavesi			*
Simulium dentulosum	*		
Simulium impukane		*	*
Simulium debegene	*		
Simulium adersi		*	*
Simulium spp.		*	
Chironomidae			
Tanypodinae			
Pentaneura appendiculatus	*		
Pentaneura cornata	*		
Pentaneura cygnus	*		
Pentaneura dusoleli	*		
Pentaneura nigromarmorata	*		
Pentaneura palpalis	*		
Pentaneura tinctoria	*		
Pentaneura sp. nov.	*		
Pentaneura trifascia	*		
Pentaneura spp.		*	*
Tanypus lacustris	*		
Gen. sp. indet.		*	*
Orthocladiinae			
Corynoneura spp.	*	*	*
Metriocnemis dewulfi	*		
Metriocnemis scotti	*		
Cardiocladius latistilus	*		
Cardiocladius oliffi	*		
Cricotopus albitibia	*		
Cricotopus bizonatus	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Crictopus bergensis	*		
Crictopus harrisoni	*		
Cricotopus obscurus	*		
Cricotopus scottae	*		
Cricotopus sp. nov..	*		
Orthocladius bergensis	*		
Orthocladius lobiger	*		
Procladius brevipetiolatus	*		
Pseudorthocladius similis	*		
Chaetocladius excerptus	*		
Nanocladius vitellinus	*		
Nanocladius ephippium	*		
Nanocladius niveipluma	*		
Limnophyes spinosa	*		
Trichocladius capensis	*		
Trichocladius micans	*		
Pseudosmittia conigera	*		
Thienemanniella sp.?		*	
Gen. spp. indet.		*	*
Chironominae			
Chironomini			
Chironomus albomarginatus	*		
Chironomus biclavatus	*		
Chironomus caffrarius	*		
Chironomus lindneri	*		
Chironomus pulcher	*		
Chironomus reductus	*		
Chironomus forcipatus	*		
Chironomus monilis	*		
Chironomus palustris	*		
Microtendipes lentiginosus	*		

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Microtendipes taitae	*		
Polypedilum kibatiense	*		
Polypedilum scotti	*		
Polypedilum natalensis	*		
Polypedilum pruina	*		
Polypedilum tridens	*		
Polypedilum alticola	*		
Polypedilum quinqueguttatatum	*		
Stictochironomus festivus	*		
Cryptochironomus coronatus	*		
Stempellina truncata	*		
? *Xenochironomus* sp.			*
Gen. sp. indet.		*	*
Tanytarsini			
Cladotanytarsus pseudomancus	*		
Tanytarsus furcus	*		
Tanytarsus nigricornis	*		
Tanytarsus sp.	*	*	
Rheotanytarsus spp.		*	*
Gen. sp. indet.		*	*
Ceratopogonidae			
Atrichopogon hirsutipennis	*		
Atrichopogon sp.	*		
Bezzia pistiae	*		
Bezzia sp.		*	*
Brachypogon sp.	*		
Ceratopogon sp. nov.	*		
Dasyhelea fusca.	*		
Dasyhelea sp.	*	*	
Lasiohelea sp.	*		
Palpomyia oliffi	*		
Gen. sp. indet.		*	*

TAXA	Date of Survey		
	1953/ 1954	1985	1999
Empididae			
Wiedemannia sp.			*
Gen. sp. indet.		*	
Tabanidae			
Gen. sp. indet.		*	*
Tipulidae			
Antocha sp.			*
Muscidae			
Limnophora sp.		*	*
Gen. sp. indet.		*	*

Table 5: List of macroinvertebrate species obtained during various surveys of the Bushman's and Little Bushman's Rivers.

TAXA	**Date of Survey**			
	1960	**1967**	**1985**	**1999**
PORIFERA				
Fam. Gen. Sp. Indet.				*
CNIDARIA				
Hydridae				
Hydra sp. 1	*			
Hydra sp. 2	*			
TURBELLARIA				
Planariidae		*		
Dugesia sp.	*			
Planaria sp.	*			
Gen. sp. indet.			*	*
Dendrocoelidae				
Sorocelis sp.	*	*		
Microstomidae				
Microstomium sp.	*	*		
NEMATODA				
Dorylaimidae				
Nygolaimus sp.	*			
Diplogasteridae				
Diplogaster sp.	*			
Mermithidae				
Gen. sp. indet.		*	*	
TARDIGRADA				
Tardigrada sp. 1	*			
ANNELIDA				
HIRUDINEA				
Glossiphoniidae				
Glossiphonia sp.	*			

TAXA	Date of Survey			
	1960	1967	1985	1999
Gen. sp. indet.			*	*
OLIGOCHAETA				
Aeolosomatidae				
Aelosoma beddardi?	*			
Naididae				
Chaetogaster sp.	*	*		
Nais sp. 1	*	*		
Nais sp. 2	*			
Nais spp.	*		*	
Stylaria sp.	*			
Dero limosa?	*			
Aulophorus furcatus	*			
Naidium sp.	*			
Pristina sp.	*	*		
Gen. sp. Indet.			*	*
Lumbriculidae				
Lumbriculidae sp. 1	*			
Tubificidae				
Tubifex sp.	*	*	*	
Branchiura sowerbyi	*			
Limnodrilus sp.	*	*		
Gen. Sp. Indet.			*	
MOLLUSCA				
GASTROPODA				
Planorbidae				
Planorbia anderssoni	*			
Ancylidae				
Burnupia gordonensis	*			
Burnupia ponsonbyi	*			
Burnupia spp.				*
Ferrissia sp.	*			

TAXA	Date of Survey			
	1960	1967	1985	1999
Ferrissia burnupi	*			
PELECYPODA				
Sphaeriidae				
Pisidium spp.	*	*		
CRUSTACEA				
CLADOCERA				
Daphniidae				
Simocephalus capensis	*			
Simocephalus vetuloides	*	*		
Ceriodaphnia quadrangula	*	*		
Ceriodaphnia cf. pulchella	*			
Moina propinqua?	*			
Bosminidae				
Bosmina longirostris	*			
Macrothricidae				
Macrothrix propinqua	*			
Ilyocryptus sordidus	*			
Chydoridae				
Leydigia microps	*			
Leydigia cf. quadrangularis	*			
Alona cf. affinis	*			
Alona cambouei	*			
Alona costale		*		
Alona gutatta	*	*		
Alona striolata	*			
Chydorus gibsoni	*	*		
Pleuroxus aduncus	*			
Pleuroxus assimilis		*		
Gen. sp. indet.			*	
COPEPODA				
Ameiridae				
Nitocra dubia		*		

TAXA	Date of Survey			
	1960	1967	1985	1999
Cyclopidae				
Cyclops ?agilis		*		
Cyclops albidus		*		
Cyclops ?sublaevis		*		
Cyclops fibriatus poppyi		*		
Cyclops prasinus		*		
Cyclops sp.			*	
Macrocyclops albidus	*			
Tropocyclops confinis	*			
Elaphoidella bidens	*			
Eucyclops eucanthus	*			
Eucyclops cf. sublaevis	*			
Eucyclops cf. speratus	*			
Paracyclops fimbriatus	*			
Paracyclops poppei	*			
Mesocyclops leuckarti	*			
Thermocyclops schuurmanae	*			
Fam. Gen. sp. Indet.			*	
OSTRACODA				
Cyprididae				
Ilyocypris australiensis	*			
Cypria capensis	*			
Cyprilla arcuata	*			
Eucypris sp.	*	*		
Herpetocypris chevreuxi	*			
Cypridopsis hirsuta	*			
Cypridopsis reniformis	*	*		
Cypretta arcuata	*			
Cypretta minna	*			
Cypretta sp.		*		
Zonocypris sp.	*			

TAXA	Date of Survey			
	1960	1967	1985	1999
Fam. Gen. spp. indet.			*	
DECAPODA				
Potamonidae				
Potamonautes sidneyi	*	*		
COLLEMBOLA				
Entomobryidae				*
ARACHNIDA				
ARANAEIDA				
Fam. gen. sp. indet.			*	
HYDRACARINA				
Fam. Gen. spp. indet.	*		*	*
INSECTA				
EPHEMEROPTERA				
Baetidae				
Afroptilum sudafricanum	*			
Afroptilum parvum	*			
?*Afroptilum* spp.	*			
Baetis harrisoni	*	*	*	*
Baetis sp. 1	*			
Baetis sp. 2	*			
Cloeon africanum	*	*		
Cloeon virgiliae	*	*	*	*
Cloeodes inzingae			*	
Cheleocloeon excisum	*	*	*	*
Dabulamanzia indusii	*			
Dabulamanzia media				*
Demoulinia crassi			*	
Pseudocloeon aquacidum			*	
Pseudocloeon bellum	*	*		
Pseudocloeon glaucum		*		*
Pseudocloeon vinosum	*	*		
Pseudocloeon sp.nov?			*	

TAXA	Date of Survey			
	1960	1967	1985	1999
Pseudopannota maculosa	*			
Caenidae				
Caenis capensis	*	*		
Caenis sp. 2			*	*
Caenis sp. 3			*	
Caenis spp. indet.	*	*		
Clypeocaenis umgeni				*
Heptageniidae				
Afronurus peringueyi				*
Afronurus sp.	*			
Leptophlebiidae				
Adenophlebia auriculata	*			
Euthraulus elegans	*	*		*
Tricorythidae				
Tricorythus discolor	*			*
Prosopistomatidae				
Prosopistoma crassi	*			*
PLECOPTERA				
Perlidae				
Neoperla spio				*
ODONATA				
Lestidae				
Lestes plagiatus	*			
Chlorocyphidae				
Chlorocypha spp.	*			
Coenagrionidae				
Pseudagrion natalense	*			
Pseudagrion salisburyense	*	*		
Pseudagrion spp.		*	*	
Gomphidae				
Paragomphus cognatus	*			

TAXA	Date of Survey			
	1960	1967	1985	1999
Libellulidae				
Trithemis sp.	*	*	*	
Zygonyx sp.	*			
Aeshnidae				
Aeshna rileyi	*			
HEMIPTERA				
Veliidae				
Rhagovelia nigricans	*			
Microvelia sp.		*		
Pleidae				
Plea pullula	*			
Naucoridae				
Laccocoris limnigenus	*			
Notonectidae				
Enithares sobria	*			
Anisops varia	*			
Gen. sp. indet.		*	*	
Corixidae				
Micronecta piccanin	*			
Micronecta spp.			*	
NEUROPTERA				
Sisyridae				
Sisyra ?afra.				*
TRICHOPTERA				
Leptoceridae				
Leptocerus sp.		*		
Athripsodes bergensis gp.			*	
Athripsodes harrisoni	*	*		*
Oecetis sp.			*	
Trichosetodes sp.				*
Triaenodes sp. 1				*

TAXA	Date of Survey			
	1960	1967	1985	1999
Triaenodes sp. 2				*
Genus and sp. Nov.				*
Hydropsychidae				
Cheumatopsyche thomasseti	*			
Cheumatopsyche triangularis	*			
Cheumatopsyche maculata	*			
Cheumatopsyche falcifera				*
Cheumatopsyche "type 2"				*
Cheumatopsyche sp. indet.	*			
Hydropsyche ulmeri	*			
Hydropsyche longifurca				*
Macrostemum capense				*
Polycentropodidae				
Paranyctiophylax sp.			*	
Ecnomidae				
Ecnomus spp.	*		*	
Hydroptilidae				
Hydroptila cruciata	*			*
Hydroptila sp.	*			
Dipseudopsidae				
Dipseudopsis sp.	*			
LEPIDOPTERA				
Pyralidae				
Nymphula sp.	*			
COLEOPTERA				
Dytiscidae				
Guignotus harrisoni	*			
Hydaticus sp.		*		
Hydroporus sp.		*		
Laccophilus lineatus	*			
Potamonectes vagrans	*			

TAXA	Date of Survey			
	1960	1967	1985	1999
Gen. spp. indet.		*		
Gyrinidae				
Aulonogyrus abdominalis	*			
Aulonogyrus sesotho	*			
Gyrinus natalensis	*			
Gen. spp. indet.	*	*		*
Hydrophilidae				
Berosus sp.	*	*		
Hydroporus sp.	*			
Gen. sp. indet.		*	*	
Psephenidae				
Eubrianax sp.	*			
Hydroscaphidae				
Gen sp. indet.	*			
Hydraenidae				
Ochthebius spp.	*	*		
Gen. spp. indet.			*	
Elmidae				
Gen. spp. indet.	*	*	*	*
DIPTERA				
Blepharoceridae				
Elporia flavopicta	*			
Psychodidae				
Pericoma sp.	*			
Psychoda alternata	*			
Dixidae				
Dixa sp.	*			
Culicidae				
Anopheles spp.	*	*		
Culex spp.	*	*		
Simuliidae				
Simulium nigritarse	*		*	*

TAXA	Date of Survey			
	1960	1967	1985	1999
Simulium damnosum s.l.				*
Simulium cervicornutum				*
Simulium rotundum	*			*
Simulium medusaeforme	*			*
Simulium vorax				*
Simulium mcmahoni				*
Simulium hargreavesi				*
Simulium adersi				*
Simulium schoutedeni	*			
Simulium wellmani				*
Simulium lumbwanum				*
Simulium spp.	*			
Chironomidae				
Tanypodinae				
Pentaneura spp..	*	*		
Tanypus sp.		*		
Gen. spp. indet.			*	*
Orthocladiinae				
Corynoneura spp.		*		*
Procladius sp. 1	*			
Procladius sp. 2	*			
Orthocladiinae spp	*			
Gen. spp. indet.	*		*	*
Chironominae				
Chironominae spp.	*			
Chironomini				
Gen. sp. indet.	*		*	*
Tanytarsini				
Tanytarsus sp.	*			
Rheotanytarsus spp.	*			*
Gen. sp. indet.			*	*

TAXA	Date of Survey			
	1960	1967	1985	1999
Ceratopogonidae				
Ceratopogonidae sp.	*			
Gen. sp. indet.	*	*		
Empididae				
Argyra sp.	*			
Hemerodromia sp.	*			
Athericidae				
Atherix sp.	*			*
Tabanidae				
Haemapota sp.	*			
Tipulidae				
Antocha sp.			*	
Gen. sp. indet.	*		*	
Muscidae				
Limnophora sp.	*			

Table 6: Record of Ephemeroptera along different zones in the Thukela River as proposed by Oliff 1960a

Species	**Dates of surveys**		
	1953/55	1985	1999
Prosopistomatidae			
Prosopistoma crassi	5,6	7	7
Polymitarcyidae			
Ephoron savigni	*Ephoron savigniEphoron savigniEphoron savigniEphoron savigni*5		
Ephemeridae			
Eatonica schoutedeni	*Eatonica schoutedeniEatonica schoutedeniEatonica schoutedeniEatonica schoutedeni*5		
Oligoneuriidae			
Oligoneuropsis lawrenci	*Oligoneuropsis lawrenciOligoneuropsis lawrenciOligoneuropsis lawrenciOligoneuropsis lawrenci*3		
Elassoneuria trimeniana	*Elassoneuria trimenianaElassoneuria trimenianaElassoneuria trimenianaElassoneuria trimeniana*5,7		5
Baetidae			
Cloeon africanum	*Cloeon africanumCloeon africanumCloeon africanumCloeon africanum*5		6
Cloeon virgiliae	*Cloeon virgiliaeCloeon virgiliaeCloeon virgiliaeCloeon virgiliae*4,5,6,7		
Cloeodes inzingae	*Cloeodes inzingaeCloeodes inzingaeCloeodes inzingaeCloeodes inzingae*3,4,5,6,7		
Pseudopannota maculosa	*Pseudopannota maculosaPseudopannota maculosaPseudopannota maculosaPseudopannota maculosa*4,5	7	
Pseudocloeon vinosum	*Pseudocloeon vinosumPseudocloe*	5,7	6,7

	*on vinosumPseudocloeon vinosumPseudocloeon vinosum*4,5,6,7		
Pseudocloeon bellum	*Pseudocloeon bellumPseudocloeon bellumPseudocloeon bellumPseudocloeon bellum*4,5,6,7		
Pseudocloeon glaucum	*Pseudocloeon glaucumPseudocloeon glaucumPseudocloeon glaucumPseudocloeon glaucum*5,6,7	7	6,7
Pseudocloeon aquacidum	*Pseudocloeon aquacidumPseudocloeon aquacidumPseudocloeon aquacidumPseudocloeon aquacidum*	4,6	
Pseudocloeon piscis		7	7
Baetis harrisoni	3,4,5,6,7	4,5,6,7	4,6,7
Baetis cataractae	3		
Baetis lawrenci	*Baetis lawrenciBaetis lawrenciBaetis lawrenciBaetis lawrenci*1		
Baetis parvulus?	*Baetis parvulus*?*Baetis parvulus*?*Baetis parvulus*?*Baetis parvulus*?3,4		
Demoreptus natalensis	*Demoreptus natalensisDemoreptus natalensisDemoreptus natalensisDemoreptus natalensis*1,2,3,4		4
Demoreptus capensis	*Demoreptus capensisDemoreptus capensisDemoreptus capensisDemoreptus capensis*		4
Demoreptus monticola	*Demoreptus monticolaDemoreptus monticolaDemoreptus monticolaDemoreptus monticola*3		
Afroptilum parvum	*Afroptilum parvumAfroptilum parvumAfroptilum parvumAfroptilum parvum*3,4		
Afroptilum sudafricanum	*Afroptilum sudafricanumAfroptilum*	4	4

	*sudafricanumAfroptilum sudafricanumAfroptilum sudafricanum*1,2,3,4		
Cheleocloeon excisum	*Cheleocloeon excisumCheleocloeon excisumCheleocloeon excisumCheleocloeon excisum*4,5,6,7	4,5,6	6,7
Centroptiloides bifasciata	*Centroptiloides bifasciataCentroptiloides bifasciataCentroptiloides bifasciataCentroptiloides bifasciata*6,7	5,6,7	6,7
Crassabwa flava	*Crassabwa flavaCrassabwa flavaCrassabwa flavaCrassabwa flava*		7
Dabulamanzia media	*Dabulamanzia mediaDabulamanzia mediaDabulamanzia mediaDabulamanzia media*5,6,7		
Dabulamanzia helenae	*Dabulamanzia helenaeDabulamanzia helenaeDabulamanzia helenaeDabulamanzia helenae*	5	
Dabulamanzia indusii	*Dabulamanzia indusiiDabulamanzia indusiiDabulamanzia indusiiDabulamanzia indusii*5,6,7		
Acanthiops varium	*Acanthiops variumAcanthiops variumAcanthiops variumAcanthiops varium*4,5,6		
Acanthiops tsitsa	*Acanthiops tsitsaAcanthiops tsitsaAcanthiops tsitsaAcanthiops tsitsa*		7
Potamocloeon macafertiorum	*Potamocloeon macafertiorumPotamocloeon macafertiorumPotamocloeon macafertiorumPotamocloeon macafertiorum*		6
Caenidae			
Caenis capensis	*Caenis capensisCaenis*		

	*capensisCaenis capensisCaenis capensis*1,2,3,4,5,6,7		
Caenis spp.			4,6,7
Clypeocaenis umgeni	*Clypeocaenis umgeniClypeocaenis umgeniClypeocaenis umgeniClypeocaenis umgeni*	6,7	6,7
Tricorythidae			
Tricorythus discolor	*Tricorythus discolorTricorythus discolorTricorythus discolorTricorythus discolor*3,4,5,6,7		7
Tricorythus reticulatus	*Tricorythus reticulatusTricoryth us reticulatusTricoryth us reticulatusTricoryth us reticulatus*5	7	4,7
Tricorythus "lowveld"	*Tricorythus lowveldTricorythus lowveldTricorythus lowveldTricorythus lowveld*	4,5,7	
Leptophlebiidae			
Aprionyx tricuspidatus	*Aprionyx tricuspidatusAprion yx tricuspidatusAprion yx tricuspidatusAprion yx tricuspidatus*3		
Adenophlebia auriculata	*Adenophlebia auriculataAdenophl ebia auriculataAdenophl ebia auriculataAdenophl ebia auriculata*1,2,3,4		
Adenophlebia sylvatica	*Adenophlebia sylvaticaAdenophleb ia sylvaticaAdenophleb ia sylvaticaAdenophleb ia sylvatica*3		
Castanophlebia calida	*Castanophlebia calidaCastanophlebi a calidaCastanophlebi a calidaCastanophlebi a calida*3		
Euthraulus elegans	*Euthraulus elegansEuthraulus elegansEuthraulus elegansEuthraulus elegans*3,4,5,6,7	6,7	4,6,7
Heptageniidae			

Afronurus peringueyi	*Afronurus peringueyiAfronurus peringueyiAfronurus peringueyiAfronurus peringueyi*4	5,6,7	4,6,7
Compsoneuriella bequaerti	*Compsoneuriella bequaertiCompsoneuriella bequaertiCompsoneuriella bequaertiCompsoneuriella bequaerti*5,6,7		6

Table 7: Comparison of trichopteran species distribution along the zones suggested by Oliff (1960a) for the 1953/54 Oliff survey, 1985 Fowles survey and 1999 (present survey)

Species	Dates of surveys		
	1953/1955	**1985**	**1999**
Leptoceridae *Adicella* sp	5		-
Leptocerus sp.	6		-
Athripsodes corniculans	-	7	7
A. harrisoni	4,5	-	-
A. fissus	4	-	-
Oecetis sp.	5,6	5,6,7	6
Leptocerina sp.	5,6,7	-	-
Ceraclea (Pseudoleptocerus) sp.	-	-	6
Triaenodes sp.	-	-	6
Trichosetodes anysa	-	-	6
Leptoceridae (new genus)	-	-	6,7
Hydropsychidae *Cheumatopsyche afra*	6	5	4
C. thomasseti	4,5,6,7	5	
C. falcifera	7	-	6,7
C. *triangularis*	4,5,6		
C. maculata	3,4		
Cheumatopsyche “Type 10"		6	
C. “Type 9"		5,6,7	6,7
C. “Type 5"			4
C. “Type 2"		6,7	6,7
Amphipsyche scottae		5	
Hydropsyche ulmeri	3,4,5,6,7		
H. longifurca	6,7	5	4,6
Polymorphanisus bipunctatus	5-6		
Polycentropodidae *Polyplectropus*	4		
Pseudoneureclipsis	4,5		
Ecnomidae			

Ecnomus thomasseti	4		7
E. natalensis	4		
Table X2 (cont.)			
Species	**1953/1955**	**1985**	**1999**
Ecnomus spp.	3,4,5		6
Psychomyidae *Lype* sp.	3		
Paduniella ankya	4		
Philopotamidae *Chimarra* sp.	4		
Hydroptilidae *Hydroptila cruciata*	1,2,3,4,5,6,7	5,6,7	6,7
Oxyethira sp.			7
Orthotrichia barnardi		6,7	7
Dipseudopsidae *Dipseudopsis capensis*			7

Table 8: Comparison of simuliid species distribution along the zones suggested by Oliff (1960a) for the 1953/54 Oliff survey, 1985 Fowles survey and 1999 (present survey)

Species	**Dates of surveys**		
	1953/55	**1985**	**1999**
Simulium bovis	6,7	6,7**	6,7
S. wellmani	-	5	4
S. vorax	-	6	7
S. medusaeforme	1-6	5,7	4,6,7
S. hargreavesi	-	-	-
S. mcmahoni	-	5,6,7	6,7
S. adersi	-	5,6,7	6,7
*S. nigritarse**	11	-	-
S. damnosum	5,6,7	5,7	6,7
S. debegene	5	-	-
S. dentulosum	5	-	-
S. rotundum	1	-	-
S. cervicornatum	-	-	6

* Probably mis-identified *S. rutherfoordi*
** abundant numbers?

NOTES

S. *debegene* and *S. dentulosum* not found again. Could be due to very low flows when samples were taken. A gradual move to further upstream sites by these species would occur.

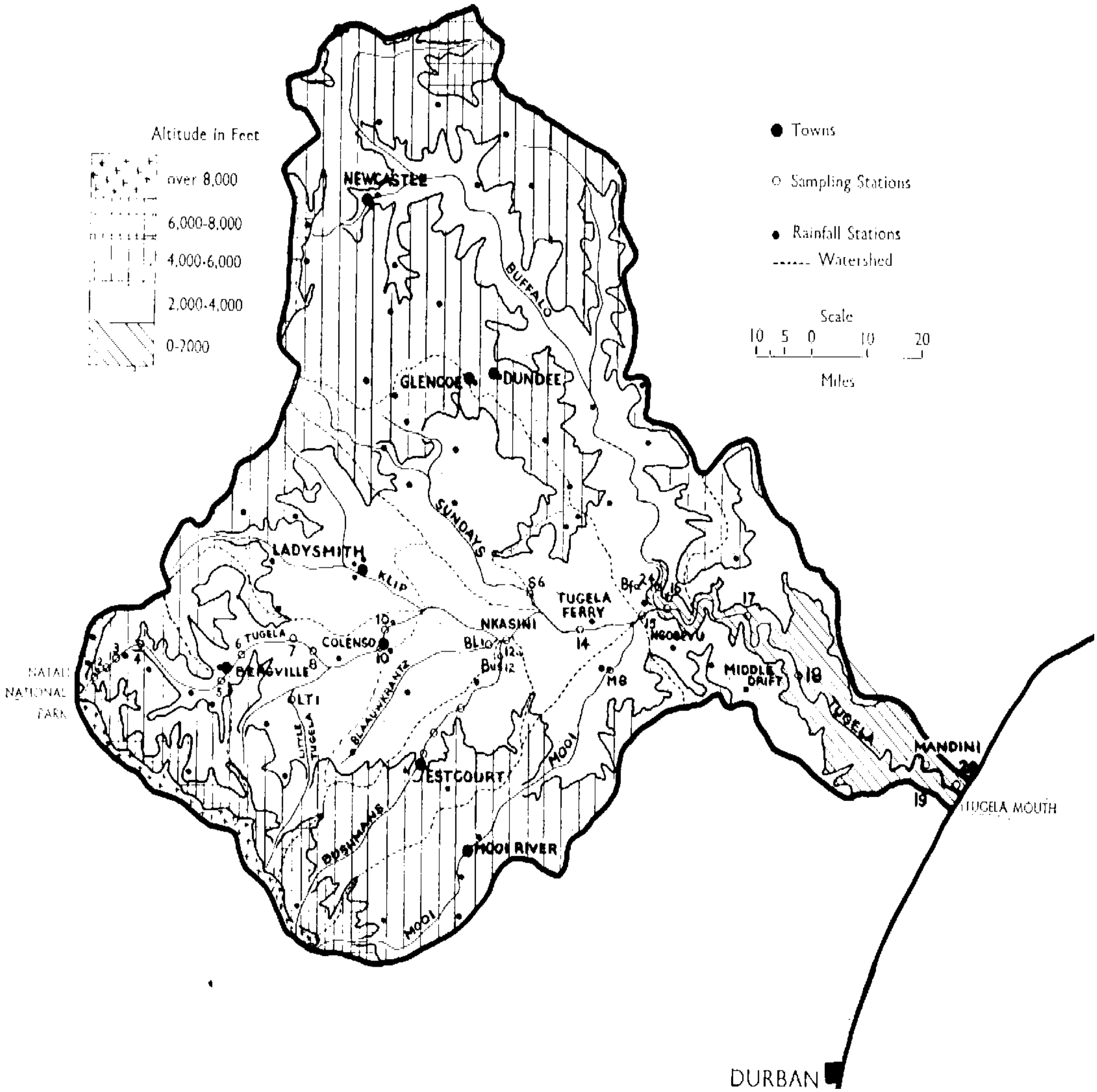

Figure 1: Sampling stations surveyed during the 1953-1955 survey of the Thukela River Catchment from Oliff 1960a

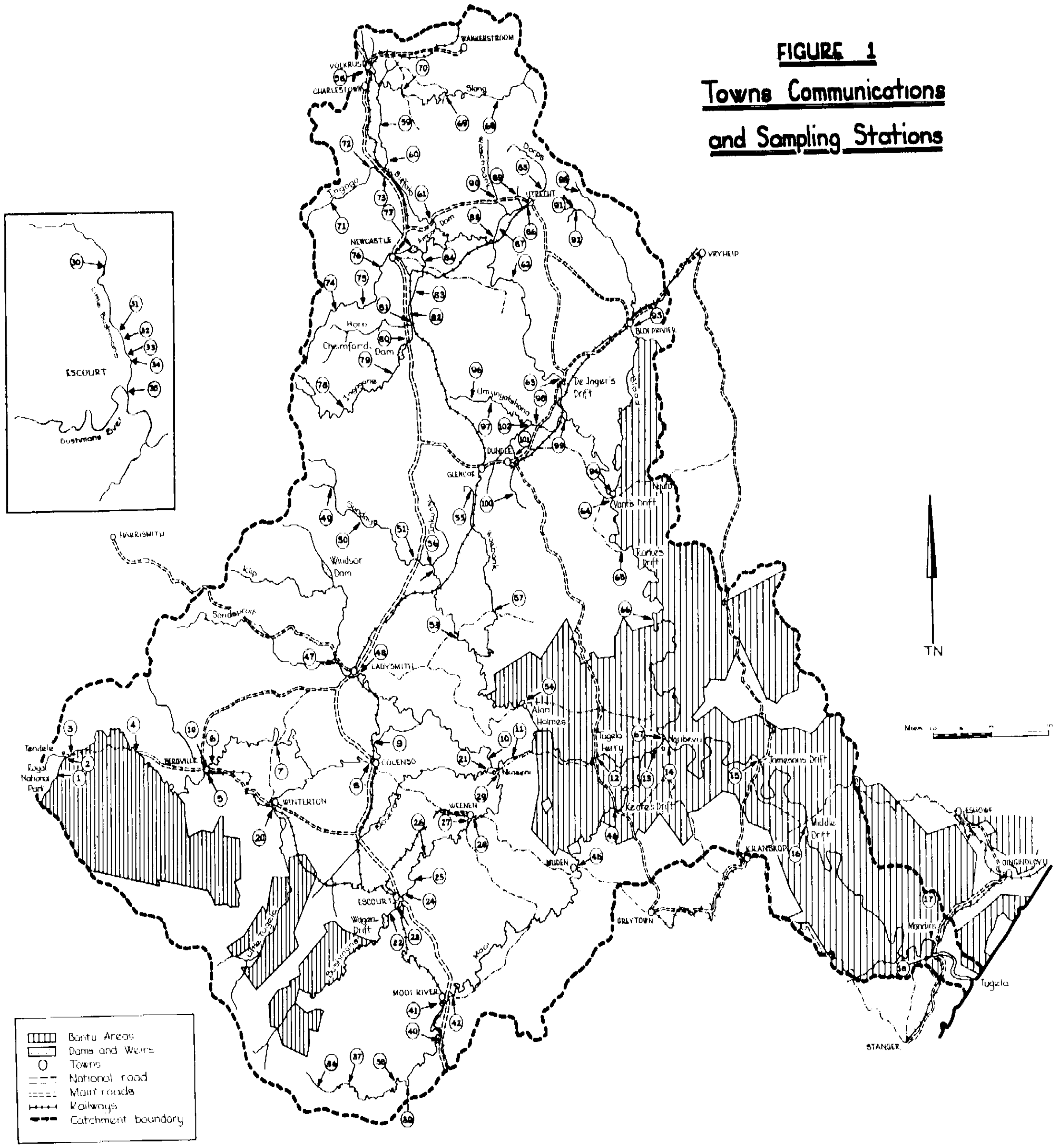

Figure 2: Sampling stations surveyed for the Town and Regional Planning regional survey (Brand *et al* 1967)

APPENDIX 2

RIVERINE PLANT SPECIES ON THE THUKELA RIVER SYSTEM

Appendix 2
Riverine plant species on the Thukela River System

Pteridophyta
Equisetum ramosissimum
Typhaceae
Typha capensis Rourb.
Potamogetonaceae
Potamogeton octandrus Poir.
P. trichoides Cham. & Schlechtd.
P. thunbergii Cham. & Schlechtd.
Aponogetonaceae
Aponogeton natalensis Oliv.
A. spathaceum Hook. F.
Hydrocharitaceae
Largarosiphon major (Ridley) Moss
L. muscoides Harv.
Poaceae
Imperata cylindrica (L.) Beauv.
Miscanthidium capensis (Nees) Stapf.
M. junceum (Stapf.) Stapf.
Eulalia villosa (Thunb.) Nees
Hemarthria altissima Stapf. Et Hubbard
Sorghum versicolor Anderss.
Cymbopogon validus Stapf.
C. excavatus (Hochst.) Stapf.
Hyparrhenia cymbaria (L.) Stapf.
H. filipendula (Hochst.) Stapf.
H. hirta (L.) Stapf.
Arundinella nepalensis Trin.
Paspalum sp.
Echinochloa crusgalli (L.) Beauv.
Phalaris arundinacea
Cyperaceae
Cyperus compactus
C. denudatus
C. fastigiatus
C. immensus
C. latifolius
C. littoralis
C. marginatus
Mariscus congestus
Mariscus dregeanus
Scirpus fluitans
Scirpus falsus
Scirpus littoralis
Scirpus paludicola
Eleocharis dregeanus

Arecaceae
Phoenix reclinata
Hyphaene coriacea
Araceae
Zantedeschia aethiopica
Z. albomaculata
Xyridaceae
Xyris capensis
Eriocaulaceae
Eriocaulon abyssinicum
Juncaceae
Juncus effusus
J.exsertus
J. maritimus
J. oxycarpus
J. punctorius
Asphodelaceae
Kniphofia caulescens
Kniphofia lineariifolia
Alliaceae
Tulbaghia leucantha
Moraceae
Ficus sycamorus
Ficus natalensis
Ficus capreifolius
Ficus natalensis
Ficus ingens
Polygonaceae
Rumex lanceolatus
Persicaria lapathifolium
Persicaria serrata
Persicaria strigosum
Ranunculaceae
Ranunculus multifidus
Monimiaceae
Xymalos monospora
Podostemaceae
Tristicha trifaria
Sphaerothylax algiformis
Leguminosae
Acacia robusta
A. karroo
A. ataxacantha
Sesbania sesban
Aquifoliaceae
Ilex mitis
Lythraceae
Rotala sp.
Lecythidaceae

Barringtonia racemosa
Rhizophoraceae
Cassipourea gerrardii
Cassipourea gummiflua
Combretaceae
Combretum apiculatum
Combretum erythrophyllum
Myrtaceae
Syzygium cordatum
Syzygium guineense
Melastomataceae
Dissotis canescens
Guttiferae
Hypericum revolutum
Halorrhagidaceae
Gunnera perpensa
Sapotaceae
Manilkara dispar
Verbenaceae
Nuxia oppositifolia
Vitex harveyana
Clerodendrum glabrum
Apocynaceae
Tabernaemontana elegans
Voacanga thouarsii
Scrophulariaceae
Limosella longiflora
Limosella maior
Pavetta lanceolata

REVIEW

PROF J H O'KEEFFE, INSTITUTE FOR WATER RESEARCH, RHODES UNIVERSITY

REVIEW OF REPORT 2 FROM THE THUKELA WATER PROJECT : SPECIALIST STUDY ON THE IMPACTS OF THE PROPOSED DAMS ON THE DOWNSTREAM AQUATIC AND RIPARIAN ECOSYSTEMS

GENERAL REVIEW:

Given the time constraints for this project, and its nature as a Feasibility-level extended scoping exercise, this report fulfills the terms of reference.

The project benefitted from the large amount of historical information on the Thukela system, particularly in terms of the aquatic invertebrates and fish. However, very little use was made of the information collected during the IFR assessment of the Thukela and some of its tributaries from 1995 to 1997. This seems odd since a number of the specialists on the present project also contributed to the IFR assessment. In particular, it would have been useful to use Dr Kleynhans' habitat integrity assessment (section 4.1 in the Thukela IFR starter documents, 1995) as part of the description of the historical and current state of the system, especially as this was accompanied by an aerial video of the system. It is stated in the present report that the IFR study did not cover the whole river, but it did include sites down as far as below the Buffalo confluence. I could only find two specific references to the IFR reports (on pages 35 and 74), and both of these are brief. This report should at least have summarised the IFR recommendations from the 1995 and 1997 reports at the 4 sites downsteam of the Jana site on the main Thukela, and the site on the Bushmans River, and perhaps commented on their likely effects.

The major limitations of this study were the absence of the hydrological and detailed geomorphological reports in this series, which were apparently not completed in time to be used for this volume. This is a major drawback for this report which is not the fault of the authors, but which prevented them from making any detailed assessment of the effects of specific flow modifications on the riverine ecosystem. Since the flow regime and the sediment throughput processes are the main drivers of hydraulic habitat in the river, the absence of the above reports must have materially affected the ability of the authors to make detailed predictions.

I have tried to read this report through the eyes of a manager charged with the further investigation and management of the ecological impacts of the dams. I have assessed each section of the report in the context of the 10 questions posed in my terms of reference from Jennifer Mander of the INR. In this review I shall not deal in detail with each question for each section of the report, but will confine myself to those aspects of the report which may not cover some of the questions entirely adequately.

As an overview, the report is clearly written, laid out and presented, with an encouraging absence of technical jargon except where necessary, and concise conclusions, carefully pointing out the limitations of the study and any uncertainties in predictions.

The team assembled to carry out this project have impressive qualifications and a wealth of experience in freshwater ecology and water quality. Their credibility for the task could not be bettered anywhere in South Africa. I am therefore quite comfortable in accepting the accuracy of their observations, and have not tried to examine in detail or validate the specialist work that has been done (in keeping with general comment No. 6 of the terms of reference sent to me).

SPECIFIC COMMENTS

All the sections of the report appear to me to comply with the terms of reference, within the context that I understand from the "Background document and environmental issues report" which accompanied the reports sent to me. Similarly, most of the sections followed a logical train of thought, clarity in setting out and explaining the assessment process, and in explaining the results and conclusions that were drawn. The exceptions are the section on mitigations (section 8) and monitoring (section 9), which I felt did not follow a clear or logical plan. Details are provided below.

The Summary section is a good synthesis of the main points in the report, and clearly identifies the main limitations: a lack of time; and the absence of the crucial accompanying reports on the hydrology and geomorphology. A minor point on page 7: the second bullet refers to "minimum flow requirements". This expression of Instream Flow Requirements is no longer generally used, since it implies drought flows, rather than the full suite of flows required for the maintenance of a healthy riverine ecosystem.

Section 1, the Purpose of the document is clear and concise, and details the scope and limitations of the study.

Section 2, the Methods, describes the historical databases used, but provides little detail on the methods employed in this study. This is probably appropriate in a scoping level study of this nature. The third paragraph of page 17 points out that two different systems of zonation have been used (due to the unavailability of the geomorphological report), and that these are not always comparable. This is very undesirable in a report of this nature, and may cause some confusion for non-specialists. A careful map of the zones, clearly indicating the use and overlap of the two zonation schemes, is needed to minimise this muddle. In section 2.4, the use of the habitat integrity assessment refered to in the general review section above would have materially improved the overall ecological assessment.

Section 3, the Study area, is confined to a map and some unexplained photos of sites. An explanation of why the photos were included, and what information they contain would have been a help to the reader. The map is useful, but does not include the names of the proposed dams, and the zone numbering systems have to be inferred, since no explanation is provided.

Section 4, Historical and current environments, is well written, clear and detailed, especially the vegetation section, with good references to other studies (even briefly reviewing Kemper's 1995 IFR document on the riparian vegetation). The information provided here could have been fitted into the following section on zonation, which contains much repetition, but there is no harm in organising this information in different ways, except that it makes the report longer. In section 4.2, third paragraph, the appendix referred to needs to be numbered (at present it is indicated as ???). In the first bullet on page 28, *Bulinus tropicus* is referred to as a "vector of urinary bilharzia". In the first place, snails are not the vectors of bilharzia, people are - the snails are simply intermediate hosts. In the second place, according to Dr David Brown (1980) there is no evidence that *B. tropicus* is a host of human schistosomes.

Section 5, Zonation, is excellent - well organised, informative, and detailed, despite the confusion of using separate zonation systems referred to in section 5.1.1. As above, sections 4 and 5 could have been combined, since both sections really summarise the historical and present state of the rivers, with only sporadic comments on the possible effects of the proposed dams. I found the information organised by zone to be the most useful, since it focusses on one section of the river at a time, and links the geomorphological state of the river to the biological habitats and communities.

Section 6, Physical and chemical changes as a result of the TWP, provides much more detail on the predicted biological changes than on the water quality changes (in contrast to volume one of the report, which provided much greater detail on the water quality changes predicted in the impoundments). This section could do with an initial description of the dimensions of the dams, the proposed outlet arrangements, and the water release scenarios as far as they may be known. The second paragraph states that this information is not yet known, but I attended a meeting last year at which a fairly detailed plan for the structure of Jana Dam and its stilling pond were presented. This section could also do with some references and comparisons with the detailed studies carried out on the effects of dams in the Palmiet, Buffalo and Great Fish Rivers, specifically on the downstream biotic communities and water quality. These are admittedly smaller dams and on different systems, but many general conclusions were drawn from these studies. In this report, reference is only made to qualitative effects of dams on the Mgeni system. The prediction of changes is made at a superficial level, with little explanation. (eg second bullet on page 51, slight turbidity from the dams in the dry season is predicted, based on indications from Lake Spioenkop, but no explanation is offered as to why this happens. Perhaps at this level of study it is not fair to expect such detail). It is disappointing that so little water quality detail is offered, compared with the wealth of analysis in volume 1 of the report.

Section 7, Possible impacts on the river ecology, provides good detailed predictions, and the information is well organised by river zones, once again leading from the geomorphological changes to the biological consequences. Table 3 from page 67 summarises the generic effects nicely, in standard EIA terminology, but could have been more useful if the effects had been described more specifically and in a sequential order (ie once again in terms of geomorphological changes, riparian consequences and instream habitat and biological consequences). This is one more case where the availability of detailed hydrological and geomorphological information would have added substantially to the value of the predictions. It appears that the third and fourth impacts on page 67 are largely duplicates. On page 54 the report states that little information was available on the flows that would be specified by the IFR process. This is another case where reference to the flow recommendation from the 1995 -1997 IFR process would have been useful.

Section 8, Mitigations, provides general recommendations, but little detail on how these can be achieved. The section is not clearly or logically structured, with eg lots of detail about invertebrates which may be affected, but very rudimentary descriptions of mitigation, confined to "maintaining proper flows .....". In section 8.3 the recommendation is to "mimic the natural flow regime" - not a realistic option if the purpose of the TWP is to supply water to Gauteng. Once again, more details of the structure of the dams and their possible operation were needed to discuss mitigation of their effects (eg section 8.2 second paragraph). On page 76, the option of an eelway is discussed, but needs some description of how this might be done for a 160m dam wall such as Jana.

Section 9, Monitoring, is mostly a list of unconnected sampling activities, with very little description of why and how these activities would be done. The use of a method such as the "Objectives hierarchy" and Threshholds of Probable Concern, described for the Kruger National Park by Rogers and Bestbier (1997), would add greatly to the logic and effectiveness of a monitoring programme for the Thukela. Bullets 4, 5 and 6 on page 78 are management actions, not monitoring activities. Section 9.3 is a useful reminder that monitoring is often undertaken without any coherent plan, and the results may not be useful or usable. This points up the necessity of planning on the basis of the Objectives Hierarchy mentioned above.

Appendix 1 provides the detail of the invertebrate database from which the conclusions and predictions in the report are derived, and is very comprehensive and useful for anyone wishing to interrogate the background database. I was surprised that amongst the recommendations for quite detailed further work, there is no suggestion for studies on the hydraulic habitat requirements of critical species, nor for toxicological studies. The former would help to firm up the IFR recommendations, and the latter would provide sorely needed information on the tolerances of the invertebrate biota to changing water quality. These are surely the information gaps which, if filled, will most clearly increase our ability to carry out the next phase of the TWP ecological investigation?

Appendix 2 is a list of riverine plant species, of limited use without locations, estimated abundances or rarity, sensitivity to flow changes etc.

CONCLUSIONS

This report contains a lot of information, and does provide for the proponent to make an informed decision on proceeding to the next stage of the TWP (question 7 from my terms of reference), if I understand correctly the requirements for proceeding to the next stage (see review of volume 1).

The information could have been better organised, and more use could have been made of the report if a number of improvements were to be made. Some of these were not within the power of the authors to change, but some were:

- The major limitations to the effectiveness of the report were undoubtedly the lack of detailed hydrological and geomorphological information, and the short time allowed for the study. These shortcomings could now be rectified, since the other reports are apparently now available, and more time could presumably be allowed. This may be appropriate for the next phase of the TWP, rather than extending this phase.
- I may be wrong, but I think that there was already sufficient knowledge available about the sizes, structures, release outlets and potential release patterns from the dams to have had a section in this report describing them, and therefore allowing a more detailed examination of their consequences.
- An examination of the starter documents and reports from the 1995 -1997 IFR assessment would have materially improved the ability of the authors to assess the present status of the river, the potential impacts of reduced flows, and the IFR flows that were recommended at that time.
- The report is certainly balanced and impartial, but some sections are not comprehensive, and some are not logical or clear. I have tried to detail those which do not meet these criteria, but briefly: Sections 2. methods, 3. study area, 6. physical and chemical changes (particularly the chemical changes), 8. Mitigations, and 9. Monitoring could not be said to be comprehensive. Sections 8 and 9 are not clearly laid out, and do not really follow a logical pattern to provide information on which decisions could be based.

All of these criticisms can certainly be rectified by more detailed studies in the next phase, and I do not think that any of them will prevent decisions from being taken. There is certainly enough information provided in this report - it is rather the manner in which the information is assessed that could be improved, if this is felt to be necessary at this stage of the TWP.

THUKELA WATER PROJECT FEASIBILITY STUDY

RECEIVING AQUATIC ECOSYSTEMS BASELINE STUDY

Prepared by

F.M. CHUTTER, AFRIDEV

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SUMMARY

The contents of this report consist of its purpose, its terms of reference, the methods used, the geographical limits of the study area, an overview of the past and present condition of the river, the expected major impacts of water from the Thukela Water Project (TWP) on the recipient aquatic ecosystems, mitigation of the impacts and a tabular assessment of the impacts.

- The purpose of this document is to give an overview of the ecological impacts of water from the TWP on recipient aquatic ecosystems.
- The study area consists of Sterkfontein Dam, the Nuwejaarspruit, the Wilge River and Vaal Dam.
- Data from studies made of the As/Liebenbergsvlei/Wilge River in relation to the impact of the release of Lesotho Highlands water (Chutter and Ashton, 1990; Chutter, 1992; Chutter, 1993; Chutter *et al.*, 1997; Chutter, 1998; and the author's study of Vaal Dam Catchment, Chutter, 1967) were used in the preparation of the report.
- The ecology of the Wilge River has been little recorded. Forty years ago it was found to be similar to the Vaal River. It is also biologically similar to the Liebenbergsvlei River, which means that information on the better-known Liebenbergsvlei River can be used in attempting to describe the Wilge River.
- Impacts will be strongly influenced by the manner in which the release of water is managed.
- Impacts were divided into the four ecosystems exposed to the TWP water, that is, Sterkfontein Dam, the Nuwejaarspruit, the Wilge River and Vaal Dam.
- In Sterkfontein Dam a reduction in the residence time of water will take place, but to what degree is presently unknown. It would result in more algae being flushed out of the dam - a beneficial impact. TWP water may raise the load of phosphate on Sterkfontein Dam, increasing phytoplankton abundance. This can be mitigated, if necessary, by taking the steps to control phosphates entering Jana and Mielietuin Dams described in the reports on those dams.
- Impacts recognised in the Nuwejaarspruit were loss of channel stability, dissolved oxygen and water quality and harmful artificial flow regimes. The characteristics of acceptable flow regimes were described and the management of water quality and temperature in the stream can be managed by means of selective withdrawal from depths where temperature and water quality are acceptable. Destructive channel instability, if it occurs, would have to be mitigated by means of engineering works.
- In the Wilge River, the TWP water may negatively impact channel stability, benefit the undesirable *Simulium chutteri* (increase in population size), and disadvantage *Barbus kimberleyensis* and *Austroglanis sclateri*, two threatened fish, but the riparian vegetation is not expected to be damaged. It is likely to have a positive impact through stabilising

the river banks. It is expected that silt-free Sterkfontein Dam water will remove silt from the upper Wilge River, but that due to bank stability associated with the riparian vegetation, this may have a positive impact by deepening the river channel and pools. Potential adverse impacts on the fish, particularly those related to spawning success, can be mitigated by suitable flow regulation before and in the spawning season, while should *S. chutteri* cause serious nuisance, it can be controlled by the larvicide Bti which has tolerable impacts on the river fauna.

- In Vaal Dam, impacts due to siltation and turbidity have been recognised.
- This report has, to a large extent, suffered from a lack of information as to what is actually happening in the ecosystems of concern. Establishing what changes have taken place or are taking place in the river channel and its biota as a result of Lesotho water in the As/Liebenbergsvlei River and Sterkfontein water in the Nuwejaarspruit/Wilge River is an urgent priority.

1 PURPOSE OF THIS DOCUMENT AND TERMS OF REFERENCE

The purpose of this document is to meet a request from the leader of the River Ecosystem Project to the author to "compile, at desktop level of study, a report on the likely major impacts of water from the TWP on Sterkfontein Dam, the Nuwejaarspruit, the Wilge River and Vaal Dam. The format of the report should follow the format of the preliminary assessment of impacts in the Thukela River ecosystem".

This report has had to be prepared within a very limited budget and time frame. Indeed, the author has not seen the Wilge River upstream of Frankfort for 40 years. Time did not permit an extensive literature search and no new data have been collected. Since the author's understanding of river ecology was to be used in this report, the lack of new data is not necessarily important at the level of study requested.

2 METHODS AND APPROACH

The methods employed in this report have been to use a broad knowledge based on many years of working with rivers and dams and information available from studies of the Liebenbergsvlei River (see reference list), which is a tributary of the Wilge River.

My approach is initially to consider the dam and river ecosystems in 1999 and the factors governing their ecology. Surely they are not presently in a natural state, if for no other reasons than that the size of Sterkfontein Dam is disproportionate to its natural catchment and it is filled with water from beyond its catchment, the Nuwejaarspruit and the Wilge River have been intermittently subject to supplementation of flow from Sterkfontein, and Vaal Dam now receives large quantities of “foreign” water. I shall then consider what I view as the likely major impacts of the dams and rivers and the manners in which they may be mitigated.

The study area consists of the dams, stream and rivers which will receive the water transferred by the TWP up to Vaal Dam.

3 THE RECIPIENT ECOSYSTEMS

3.1 Description of historical and current environment and ecology

Land use in the upper reaches of the Wilge catchment, that is upstream of the Nuwejaarspruit confluence, is predominantly grazing of cattle and sheep. Arable agriculture becomes progressively more extensive down the river. There are nowhere very high human population densities. The riparian zone is for the most part in a natural state (given that the willow tree, *Salix babylonica*, is an exotic) and not overexploited by grazing.

Sterkfontein Dam is known to be an oligotrophic, clear water dam with a low nutrient content. This may appear to be contradictory to the analysis of water quality in the Thukela River where moderately high levels of phosphates have been recorded. However, it should be remembered that dams act as nutrient sinks, so that the phosphate concentrations in the water transferred after storage in Woodstock Dam would be expected to be lower than in the inflows to the dam. Summer thermal stratification takes place in Sterkfontein Dam.

The Nuwejaarspruit below Sterkfontein Dam flows in an open valley and the channel gradient is low. Consequently, when releases are made from Sterkfontein Dam the stream bursts its banks and covers the open valley. No major erosion of the stream channel is apparent from the Harrismith to Phuthaditjhaba road, but this is not a satisfactory viewing site.

Little is known about the Wilge River between the Nuwejaarspruit confluence and Frankfort. Chutter (1967) had sampling points just downstream of Harrismith (pollution evident), about half way to Frankfort and at Frankfort. These sampling points were infrequently visited, their main purpose being to establish whether the Wilge River was faunally similar to the Vaal River. The data on the invertebrate communities was sufficient to show that they were similar to those in the upper Vaal River. This has been confirmed by subsequent recent and more intensive studies in the Liebenbergsvlei River, which is a tributary of the Wilge River.

An important fact is that *Simulium chutteri* has been found in both the Vaal River upstream of Grootdraai Dam and in the lower Liebenbergsvlei River. It is certain to be in the Wilge River, albeit possibly in low numbers. No-one has yet looked for this species in the Wilge River. The presence of *S. chutteri* gives cause for concern, for huge populations of this species in the lower Vaal, Orange and Great Fish Rivers have been associated with modified flow regimes. The adult females of this species are aggressive feeders on the blood of man and his livestock. The habitat of the filter-feeding aquatic larvae is substrata in swiftly flowing water.

Two fish species in the river are of concern to ichthyologists and conservation authorities on account of their apparent decline in numbers, which could be due to many factors, including fragmentation of their populations due to weirs and dams. They are the yellowfish, *Barbus kimberleyensis*, which is South Africa's largest yellowfish, and *Austroglanis sclateri*, the rock barbel.

At many places the riparian zone of the river lives up to the Wilge River's name. This may be seen in the Harrismith/Swinburne area and upstream of Frankfort where willow trees stand shoulder to shoulder along both banks. At places where the gradient is steeper and the river bottom rocky, the riparian zone supports grasses and other small plants. Only one possibly new plant species was found in the baseline study of the riparian zone of the Liebenbergsvlei River (Chutter *et al*., 1998). With regard to the appearance of the riparian zone, the Wilge River is very similar to the Liebenbergsvlei River.

The water flowing out of both the Sterkfontein Dam and the Trans-Caledon Tunnel is clear, but by the time it reaches Frankfort it is a turbid, gray colour (Heath, pers. comm.). The channel of the As River has already been severely eroded in places.

Vaal Dam is a relatively shallow turbid dam. Thermal stratification is present in summer. Algal blooms occur fairly regularly in Vaal Dam and require attention when scums accumulate in sheltered bays due to wind action. It is considered that turbidity tends to ameliorate the intensity of algal blooms (Bruwer, pers. comm.). The impact of inflowing water on the turbidity of the dam is an obvious concern.

3.2 Impacts of the TWP water on the nature of the ecosystems

In the following list of changes, it is assumed that there is no mitigation of impacts.

- Sterkfontein Dam - General Ecology
  There is a possibility that TWP water may have a higher phosphate content than the water presently pumped to Sterkfontein. This is perceived to be the only potentially serious impact of TWP water on Sterkfontein Dam. The residence time of water in the dam will drop, which means that plankton might be carried out of the dam sufficiently fast to reduce their population density, compensating perhaps for the possible increase in plankton due to phosphates from the TWP.

- Nuwejaarspruit - Channel Stability
  There is need for a closer inspection of the stream to confirm whether or not its channel has been modified by previous discharges from Sterkfontein Dam, which have been as

high as $85m^3/s$ (Heath, pers. comm.) for weeks on end. Mitigation in the form of engineering works might be needed.

- Nuwejaarspruit - Temperature and Water Quality
  Water temperature and the condition of the water at the depth from which it is discharged could have adverse impacts on the receiving waters, when the dam is stratified in the summer.

- Nuwejaarspruit, Wilge River - Flow
  There are several impacts that can arise from the manner in which the flow of water from Sterkfontein Dam might be managed. Intermittent flows, frequent changes in flow and sudden changes in flow can damage a flowing water ecosystem, due to scouring of the river channel and killing many of the organisms living in the river or stranding organisms when the flow recedes suddenly.

- Wilge River - Channel Stability
  Due to the additional flow of sediment-free water which will pick up sediment in the river channel, it is to be expected that the rate of sediment transport, particularly in the reaches of the river nearer to Sterkfontein Dam will increase. This may induce instability in the river channel, which would ultimately result in changes in the position of the river within its valley.

- Wilge River - *Simulium chutteri*
  It is probable that the increased flow of the Wilge River due to TWP water will result in increases in the habitat available to *S. chutteri* in the dry season, which would appear to be the critical season for the annual build-up of the larval population and, hence, the subsequent severity of the impact of the adult flies.

- Wilge River - Threatened Fish
  B. kimberleyensis and *A. sclateri* populations will respond positively to the increase in habitat made available by the increased flow, but at the same time flow-based triggers for the onset of breeding behaviour at the wrong time of the year could result in the serious reduction in the size of year-classes and ultimately in the size of the population as a whole. Fish have relatively short life-cycles and it would only need a succession of annual recruitment failures for the population to quietly become locally extinct.

- Wilge River - Riparian Zone
  The riparian vegetation of the Wilge River, including the willow trees, will stabilise the river banks, contributing to the stability of the river channel, which should deepen rather than erode laterally as silt is transported away. A deeper river is better habitat for many freshwater animals than a shallower river - compare the sand bed river making up the lower Thukela River.

- Vaal Dam - Sediments
  If the TWP water transports large amounts of sediment down to Vaal Dam there will be an acceleration of the rate at which Vaal Dam fills with sediment.

- Vaal Dam - Turbidity
  Due to the turbidity picked up between Sterkfontein Dam and Vaal Dam, it is unlikely that the water from the TWP will lower turbidity in Vaal Dam and it will not stimulate algal growth.

3.3 Summary of impacts

Table 3.1 summarises the author's perceptions as to the severity, probability and extent of the above impacts. It should be noted that the situation after mitigation is that assessed (following the instructions to specialists).

Table 3.1: Assessment of the impacts of TWP water on Sterkfontein Dam, the Nuwejaarspruit, the Wilge River and Vaal Dam

Impact	Magnitude /Intensity	Extent/ Scale	Duration	Sign	Certainty	Significance
Sterkfontein Dam - residence time of water and plankton flushing	moderate	local, dam basin	long term	positive	probable	low
Sterkfontein Dam phosphate increase	moderate	local, dam basin	long term	negative	probable	low
Nuwejaarspruit channel stability	moderate	local, downstream river	long term	negative	probable	medium
Nuwejaarspruit temperature and water quality	moderate	local, downstream river	long term	negative	improbable	medium
Nuwejaarspruit and Wilge River flow	moderate	local, downstream river	long term	negative	probable	medium
Wilge River channel stability	moderate	local, downstream river	long term	negative	probable	medium
Wilge River *Simulium chutteri*	high	local, downstream river	long term	negative	probable	medium
Wilge River fish-breeding conditions	high	local, downstream river	long term	negative	probable	medium
Wilge River riparian zone/channel conditions	moderate	local, downstream river	long term	positive	probable	medium
Vaal Dam sediments	moderate	local, dam basin	long term	negative	probable	medium
Vaal Dam turbidity	moderate	local, dam basin	long term	negative	definite	medium

4 SUGGESTED MITIGATORY ACTIONS - RECIPIENT ECOSYSTEMS

In this section, all the identified impacts are addressed, although in several cases it is pointed out that the impacts are not of such a nature that they require mitigation or mitigation is not possible.

- Sterkfontein Dam - General Ecology
  A decrease in the residence time of water in Sterkfontein Dam is regarded as a positive impact of the transfer of TWP water. The extent of this reduction can readily be calculated from the volume of the dam and the inflow and outflow volume. The calculation will give an estimate of the change and the possible scale of the impact on the plankton. There is a possibility that the TWP water may have a higher phosphate content than the water presently pumped to Sterkfontein. This is perceived to be the only potentially serious impact of TWP water on Sterkfontein Dam. Mitigation should take place at the source of the problem in the Thukela Valley, as suggested in the reports on the conditions in Jana and Mielietuin Dams.

- Nuwejaarspruit - Channel Stability
  Should releases from Sterkfontein Dam have negatively impacted the Nuwejaarspruit, the first step in mitigation should be to establish the extent of the problem. There might be engineering solutions (modifying present channel), although if the channel has withstood flows of $85m^3/s$, mitigation is unlikely to be necessary.

- Nuwejaarspruit - Temperature and Water Quality
  Water temperature and the condition of the water at the depth from which it is discharged could have adverse impacts on the receiving waters when the dam is stratified in the summer. Selection of the depth from which to discharge water should take account of the temperature and quality of the water would reduce this problem. (This section has been written in ignorance of whether or not Sterkfontein Dam has a multiple level discharge facility).

- Nuwejaarspruit, Wilge River - Flow
  There are a number of principles which should be applied to the management of flows released from dams. They should be made to mimic the seasonal variation in the base flow, with greater releases in the wet season than in the dry. This is often not possible, but the untested alternative, to discharge at a constant rate year-round, might be ecologically acceptable. Flows should not be frequently changed or interrupted, but if they have to be, then the rate of change of flow should, if possible, be similar to that which occurs naturally in floods and freshets. For the Liebenbergsvlei River the rate of

increase was 12% per hour and the rate of decrease 5% per hour (Chutter, 1998). Should it be necessary to test and service release valves, this should be done in February or March at the latter part of the rainy season when the ecosystem is naturally exposed to rapid changes in flow. The situation regarding release valves at Sterkfontein is not known to the author, but it would certainly help were there to be more than one valve, so that testing could take place one valve at a time. The recommended rates of change in flows should apply on the opening and closing valves in non-emergency situations.

- Wilge River - Channel Stability
  It is possible that the channel of the Wilge River will be eroded of fine particles to the point where the banks become unstable and collapse and large amounts of silt are transported downstream. It is perhaps fortunate that this is rather unlikely, due to the riparian vegetation, as there is no obvious mitigation other than to convey the water in a pipeline.

- Wilge River - *Simulium chutteri*
  There is a very strong possibility that this species will increase in abundance. Without having seen the river from the air or aerial photographs, it is likely that the breeding sites are widely spaced. From their occurrence mainly in the lower reaches of the Liebenbergsvlei River it is suspected that they will be confined to the lower Wilge River. While *Simulium* population size regulation has been achieved through manipulating the flow volume at Warrenton on the Vaal River, it would be impossible to apply flow regulation at the top of the Wilge River to control populations of the lower river, on account of the attenuation of flow over the distance involved. *Simulium* control would have to be undertaken by dosing the river with Bti, a natural larvicide specific to aquatic flies, including *Simulium*.

- Wilge River - Threatened Fish
  The mitigation of impacts on these fish must be achieved through the management of flow in a manner suited to their needs. In addition to the factors described in the paragraph, “Nuwejaarspruit, Wilge River - Flow” above, consideration should be given to the flow requirements of the spawning behaviour of the fish. For the Liebensbergvlei River it was suggested that increases in managed flow should not be allowed to happen between August and mid-October as they would be unseasonally early and trigger premature spawning behaviour (Chutter,1998). A response to a premature trigger would result in a failure of breeding for the summer involved.

- Wilge River - Riparian Zone
  The riparian zone of the river, with its good cover of plants, may be expected to be resistant to erosion and might result in the deepening of the channel rather than its broadening in response to silt erosion. This impact would be regarded as beneficial, especially to fish populations as it would provide them with more deep pool habitat.

- Vaal Dam - Sediments
  The only mitigation of the siltation of dams known to the author is to raise the dam wall or to build a replacement dam elsewhere.

- Vaal Dam - Turbidity
  Turbid inflows will contribute to the control of the size of algal populations in the dam and should be regarded as a positive impact not in need of mitigation.

5 BASELINE AND FUTURE MONITORING

5.1 Baseline monitoring

- Baseline monitoring should attempt to establish the condition of the recipient ecosystems now, before transfer of TWP water commences.
- It is suggested that water quality data, water temperature data, data on transects of the river and the extent of armouring of the river bed and quantitative or quasi-quantitative data on representative components of the instream and riparian biota should be gathered at intervals appropriate to the rapidity of change within each ecosystem component concerned.
- It will not be necessary to monitor every ecosystem component which might change, but the components likely to be most impacted should receive priority.
- Experts on these ecosystem components should be invited to propose baseline studies.
- The proposals should be reviewed as to their relevance and their quality by a panel of environmentalists, none of whom should be otherwise involved in the baseline studies.
- Gathering data on the present temperature of the river water should enjoy immediate attention so that guideline temperatures for the release of water from the dam will be available. A one year database for river water temperature will not be adequate for this purpose. Water temperatures should be recorded (automatically) in the Wilge River upstream of the confluence of the Nuwejaarspruit to provide information on the desirable temperature of water to be released from the dam.

5.2 Future monitoring

- Baseline results should be reviewed to identify redundant or overlooked components of the baseline study so that the monitoring programme can be refined as to frequency of sampling, sampling points and components to be included.
- Future monitoring is concerned with what comes out of the Sterkfontein Dam and what happens to the rivers.
- Volume discharged on a daily basis, discharge point (spill, depth of discharge, valves), water temperature (daily), and quality of water released from the dam should be measured.
- As far as possible, the components of the baseline study should continue to be measured at the sampling points and at the sampling intervals used in the baseline study.

5.3 Data management, interpretation and river management

- Baseline and future monitoring will waste money unless they are backed up by a determination to use the data gathered to manage the river, in particular the depths and manner of withdrawal of water from the dam.
- This means that there must be a dedicated, defined system to manage the data (including quality assurance and quality control), to interpret the data and to implement the findings.

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7 CREDENTIALS

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F.M. Chutter is a river ecologist. He made a reconnaissance study of the Thukela/Mhlatuze transfer scheme and was study leader for the biophysical aspects of the Vaal Augmentation Planning Study (VAPS) Thukela option in its reconnaissance and pre-feasibility phases. He is study leader for the determination of the environmental reserve of the Olifants River, Mpumalanga for Department of Water Affairs and Forestry.

REVIEW

PROF J H O'KEEFFE, INSTITUTE FOR WATER RESEARCH, RHODES UNIVERSITY

REVIEW OF A REPORT FROM THE THUKELA WATER PROJECT : RECEIVING AQUATIC ECOSYSTEMS BASELINE STUDY BY F M CHUTTER

GENERAL REVIEW:

The author himself comments that this report was carried out "within a very limited budget and time-frame". It appears that he did not have time or budget even to visit the rivers and dams of concern, but had to rely on his very considerable experience and expertise, historical knowledge of the systems, and information available from the literature.

Taking these limitations into account, this is a well-organised and clear account of the general ecological conditions in the recipient systems, the likely effects of the additional inflows from the TWP, suggested mitigatory actions, and very general proposals for monitoring.

CONCLUSIONS:

Following the 10 questions posed in the terms of reference supplied to me:

1. The report does comply with the limited terms of reference supplied to the author.
2. The report is certainly balanced and unbiased, and is probably as comprehensive as it could be within the limitations of a desk-top study in a short time frame.
3. The report can certainly be used to identify the priority issues, and to decide on what further studies should be undertaken in the next phase.
4. The report is very clear and logical, and well laid out. The process used to come to conclusions was fairly simple, as the author points out - it was based on his expert opinion .
5. At this level of study, I do not believe that it is possible to address complex issues.
6. Within the terms of reference, the report addresses the relevant issues. I am not aware that alternatives were available to be considered
7. Once again, the methods and techniques were based on the experience and expertise of the author.
8. The obvious deficiencies are those of a lack of first hand studies and in-depth analysis, which are inherent in a desk-top study of this nature.
9. Informed decisions from this report should be restricted to those pertaining to further studies and monitoring activities necessary for the next stage of the TWP.
10. The study has achieved its limited aims, and further action should await the next phase of the TWP.

Report Number: PB-V000-00-6799

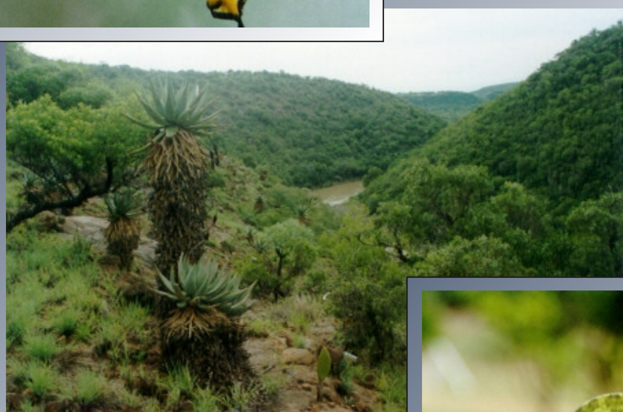
Republic of South Africa
Department of Water Affairs and Forestry

Thukela Water Project Feasibility Study

Volume 5: Baseline Studies

A) Plant Diversity Baseline Study
B) Animal Diversity Baseline Study
C) Palaeontological Baseline Study

June 2000



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THUKELA WATER PROJECT FEASIBILITY STUDY

PLANT DIVERSITY BASELINE STUDY

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SUMMARY

The Thukela system is far from pristine. The diversity of the vegetation of the Mielietuin Basin has been drastically reduced by years of mismanagement. Vegetation of the basin belongs to Valley Bushveld (Acocks, 1988). This vegetation is noted for the prevalence of spiny xerophytes and succulents, with a higher proportion of grasses in the northern parts of its range. Many of the palatable grasses have been severely reduced within the basin. Currently the upper reaches of the basin are heavily impacted by cultivation and the lower reaches are dominated by *Acacia nilotica-Acacia karroo* savanna. Areas of high floral diversity sit, for the most part, above the inundation levels, in grasslands which are subjected to fairly frequent fires. The alluvial deposits adjacent to the rivers host a range of hygrophilous species. These communities have been heavily impacted by grazing pressure in most of the reaches of the Thukela, and the Mielietuin Basin is no exception. Riparian vegetation forms a continuum within the river system and the communities are well represented out of the area which will be inundated.

Despite the altered nature of the vegetation in the Mielietuin Basin, considerable biodiversity (430 spp.) has been recorded in this preliminary report (Appendix 3). This inventory was compiled through field work and consultation of the plant database (PRECIS) at the National Herbarium in Pretoria.

Sixty-five percent of the Jana Basin is little modified and near-pristine. This is an exceptionally high value relative to other catchments of Valley Bushveld in the province where higher levels of degradation and transformation are recorded. Valley Bushveld has a high conservation value. The Jana Basin contains one of few extensive, little-altered remnants of this important Bioresource Group and Biome.

The impoundments will also have an impact on the availability of ethnic plant resources both for crafts and for medicinal purposes. Qualitative lists are provided (Appendices 1 and 2). However, the quantification of this impact on local communities is beyond the brief of this document.

The aqueduct routes have been surveyed briefly. Much of the uncultivated land along these routes is utilised for grazing and is likely to show reduced levels of plant diversity. However, a comprehensive study of these areas across a number of seasons is required if a comprehensive species inventory is to be generated. The impact on uncultivated land is very high in both scenarios which utilise the canal options.

Two very serious potential problems with the development, are the invasion of exotic species due to ecological disruptions at the construction zones and the potential for massive erosion. This will lead to rapid degradation of a system already under considerable stress. The critical weed species which require careful monitoring and control are *Acacia mearnsii*, *A. delbata*, *Solanum mauritianum*, *Caesalpinia decapetala*, *Rubus* spp. and *Lantana camara*. It is clear that these are long term ecological problems and will require monitoring and mitigation for the foreseeable future. The occurrence of aliens should be recorded through aerial surveys and GIS and the dynamics of these populations should be monitored and controlled. It is essential that these aspects are built into the project budget.

This study was limited due to (i) severe time constraints in terms of sampling, and (ii) the restriction of sampling to winter and early spring. It is essential that the sampling period of the Environmental Impact Assessment addresses these inadequacies through comprehensive sampling across spring and summer months. Rare and endangered species known to occur in the basins and their levels of conservation priority are listed. Extensive searches, during the flowering seasons, are required if the full extent of these populations is to be recorded. Once the full extent of the populations has been evaluated within the context of each species, steps may be formulated regarding their rehabilitation. It is essential that populations of these species are recorded and are protected during the construction phase. The feasibility of *in situ* conservation needs to be assessed through parochial transplantation.

The Jana Basin is exceptionally remote and rugged with few access points. The vegetation for the most part is very dense and difficult to traverse. The length of the river below FSL is over 30km. Given these conditions and approximately 50 hours allocated to field work at this site, it was an immense task to provide the level of detail in this report. Follow up studies must account for this.

1 PURPOSE OF THIS DOCUMENT AND TERMS OF REFERENCE FOR THE STUDY

This study provides a brief overview of the vegetation which will be inundated with the construction of dams at Jana and Mielietuin. The Terms of Reference, laid out in consultation with the Institute of Natural Resources, require a rough estimate of the loss of habitat and biodiversity as a result of the inundation of the dam basins, the construction of the dam walls and the construction of aqueduct routes between the respective basins and Kilburn Dam.

(a) Description of the terrestrial environments, physiognomy and biodiversity:
  (i) Jana
  (ii) Mielietuin
  (iii) Aqueduct routes
(b) Inventory of the plant species important to local communities
(c) Provide proposals on mitigation to limit the impacts of the development (Table 1.1).

Plant physiognomy and biodiversity are covered within the confines of the limited budget and inappropriate seasonal time allocation. The initial brief was to conduct a pilot study which was to be used in a feasibility assessment. Such studies are precursory and based on superficial data. Clearly an impact assessment is a much more rigorous study and will require considerably more time to complete. In addition, impact assessments need to be conducted across, at the very least, one full average season otherwise cryptophytic herbs will be overlooked. This life form includes a number of important families (Hyacinthaceae, Colchicaceae, Amaryllidaceae, Alliaceae, Iridaceae, Orchidaceae). Other families are notoriously difficult to locate and identify when not in flower (Cyperaceae, Juncaceae Acanthaceae, Fabaceae, Scrophulariaceae, Asteraceae, Campanulaceae) and this includes a substantial part of the plant diversity on the eastern seaboard. The current survey was conducted during an early season drought and this has seriously limited our ability to assess plant biodiversity. Thus the following points are **inadequately** addressed within this report:

(a) Cryptophytic species of conservation importance
(b) Rare and threatened species
(c) Cryptophytic species with significant traditional importance.

Table 1.1: Conventions for definitions and terminology used in the description, evaluation and assessment of environmental impacts

Category	Description or Definition
Type	A brief written statement, conveying what environmental aspect is impacted by a particular project activity or action, or policy or statutory provision.
Magnitude and Intensity	The severity of the impact
· very high · high · moderate · low · no effect · unknown	- Complete disruption of process; death of all affected organisms; total demographic disruption - Substantial process disruption, death of many affected organisms; substantial social disruption - Real, measurable impact, which does not alter process or demography - Small change, often only just measurable - No measurable or observable effect - Insufficient information available on which to base a judgement
Extent / Spatial Scales	The geographical extent or area over which the direct effects of the impact are discernable, i.e. the area within which natural systems or humans directly endure the effects of the impact.
· international · national · regional · local	- Southern Africa - South Africa - KwaZulu-Natal and the Thukela catchment, the UThukela region - dam basin, conveyance servitude, river reach, specific site locality
Duration	The term or time period over which the impact is expressed, **not** the time until the impact is expressed. Where necessary the latter must be specified separately.
· short term · medium term · long term	- up to 5 years (or construction phase only) - 5 to 15 years 9 (or early commissioning and operational phases) - > 15 years (or operational life)
Sign	Denotes the perceived effect of the impact on the affected area
· positive (+) · negative (-)	beneficial impacts impacts which are deleterious
Certainty	A measure of how sure, in the professional judgement of the assessor, that the impact will occur or that mitigatory activity will be effective
· improbable · probable · definite	- low likelihood of the impact actually occurring - distinct possibility that the impact may occur - impact will occur regardless of prevention measures
Significance	An integration (i.e. opinion) of the type, magnitude, scale and duration of the impact. Judgements as to what constitutes a significant impact require consideration of both context and intensity. It is the assessor's best judgement of whether the impact is important or not within the broad context in which its direct effects are felt. (see Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823)
· high · medium · low	- Could (or should) block the project/policy; totally irreversible (-ve impact) or provides substantial and sustained benefits (+ve impact) - Impact requires detailed analysis and assessment, and often needs substantial mitigatory actions. - Impact is real but not sufficient to alter the approach used. Probably no mitigation action necessary.

Some Explanations and Definitions

1 Environmental impact - An environmental change caused by some human act. (DEA 1992. *The Integrated Environmental Procedure*. Vol 5).

2 Environmental impact - Degree of change in an environment resulting from the effect of an activity on the environment whether discernable or undesirable. Impacts may be the direct consequence of an organisation's activities or may be indirectly caused by them. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

3 Affected environment - Those parts of the socio-economic and bio-physical environment impacted on by the development. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

4 Environmental issue - A concern felt by one or more parties about some existing, potential or perceived environmental impact. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

5 Environment - means the surroundings within which humans exist and that are made up of:
- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of (i) and (ii) and the interrelationships among and between them;
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being. (National Environmental Management Act No 107 of 1998).

6 Significance - (See Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823. Also in, DEA 1992. *The Integrated Environmental Procedure*. Vol 4).

7 Significance - "The definition of significance with regard to environmental effects is a key issue in EIA. It may relate *inter alia* to scale of the development. To sensitivity of location and to the nature of adverse effects." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 13).

8 Significance - "Once impacts have been predicted, there is a need to assess their relative significance. Criteria for significance include the magnitude and likelihood of the impact and its spatial and temporal extent, the likely degree of recovery of the affected environment, the value of the affected environment, the level of public concern, and political repercussions." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 124).

9 Significance -" The question of significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective - technical, conceptual or philosophical - the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant." (Beanlands, G. 1983. *An ecological Framework for Environmental Impact Assessments in Canada*. Institute for Resource and Environmental studies. Dalhausie University. Sections 7: 43).

10 Environment - Surroundings in which an organisation operates, including air, water, natural resources, flora, fauna, humans and their interrelation. (ISO 14001. 1996). Note - Surroundings in this context extend from within an organisation to the global system.

11 Environmental aspect - Element of an organisation's activities, products or services that can interact with the environment. (ISO 14001. 1996).
Note - A significant environmental aspect is an environmental aspect that has a or can have a significant environmental impact.

12 Environmental impact - Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services. (ISO 14001. 1996).

2 METHODS AND APPROACH

Field work was delayed for as long as possible, within the tight time constraints, due to the seasonal dormancy of the vegetation. Site visits were conducted in April, late September, October and early November. Community structure of the vegetation was recorded and, where possible, species diversity was sampled. Where necessary, material was tagged and identified at Natal University Herbarium (NU) and Killick Herbarium (CPF). This allowed a broad overview of the current vegetation status. This data was cross-referenced with the available topographical data and aerial photographs to provide insight into physical habitat with repetitive floristic composition and physiognomy. From aerial photographs, 1:50 000 maps, 1:10 000 orthophotos and ground truthing it was possible to build up an idea of :

(a) heterogeneity of habitat and communities along the aqueduct routes
(b) plant diversity
(c) accessibility
(d) proportions of cultivated and uncultivated land.

- A digitised map of the vegetation on the farms Groot Mielietuin and Bosman Riviers Poort is available in Camp (1995). Maps of the Mielietuin and Jana Basins are supplied in this report.

- Broad categories of soil types were noted in the field and correlated, where possible, with plant communities.

- Floristic data was retrieved from the PRECIS at the National Herbarium (PRE) for the grid squares which constitute the two dam basins. This data was augmented with diversity data generated by the Killick Herbarium and the Natal University Herbarium (NU). The latter institution houses the collections of Denzil Edwards which are pertinent to this study.

- To cover the rare and endangered plant taxa, use was made of the Red Data List (Hilton-Taylor, 1996) and the data generated for Rare and Threatened Plants of KwaZulu-Natal (Scott-Shaw, 1999).

- Plants inventories of ethnobotanical importance were generated by cross-referencing with Zulu Medicinal Plants (Hutchings *et al.*, 1996), Institute of Natural Resources Report 162 (Mander *et al.*, 1997) and Harvesting of Natural Resources in the Thukela Biosphere Reserve (Ellery *et al.*, 1997).

3 THE PLANT DIVERSITY OF THE STUDY SITES

The plant ecology of the Thukela Basin was covered, fairly comprehensively, by the studies of Edwards (1963, 1964 and 1967), who outlined synecology and some of the process-driven changes in the vegetation. The vegetation of the Thukela Basin, including the dam sites, is Valley Bushveld (Acocks, 1988), experiencing rainfall between 600 and 800mm in the drier interior. The vegetation of the Weenen area was covered in a survey by West (1949). Further useful vegetation studies were undertaken by Camp & Richardson (1990) and Camp (1995). These provide benchmark species composition for 'pristine' Valley Bushveld and a list of increaser and decreaser species for evaluating veld status. Degradation of veld due to overgrazing is invariably accompanied with loss of plant diversity.

Edwards (1964) and Camp (1995) suggest that Valley Bushveld of the Thukela system was formerly dominated by sweetveld grasses but that the steep topography and high evaporative rates, in combination with mismanagement, have caused dramatic shifts in the composition of the vegetation. Because of the reduction of fuel loads, the incidence of fire in the vegetation has been dramatically reduced and this has favoured the expansion of the woody communities. This shift is self-perpetuating because the shading generated by woody vegetation further suppresses the grass component of the community.

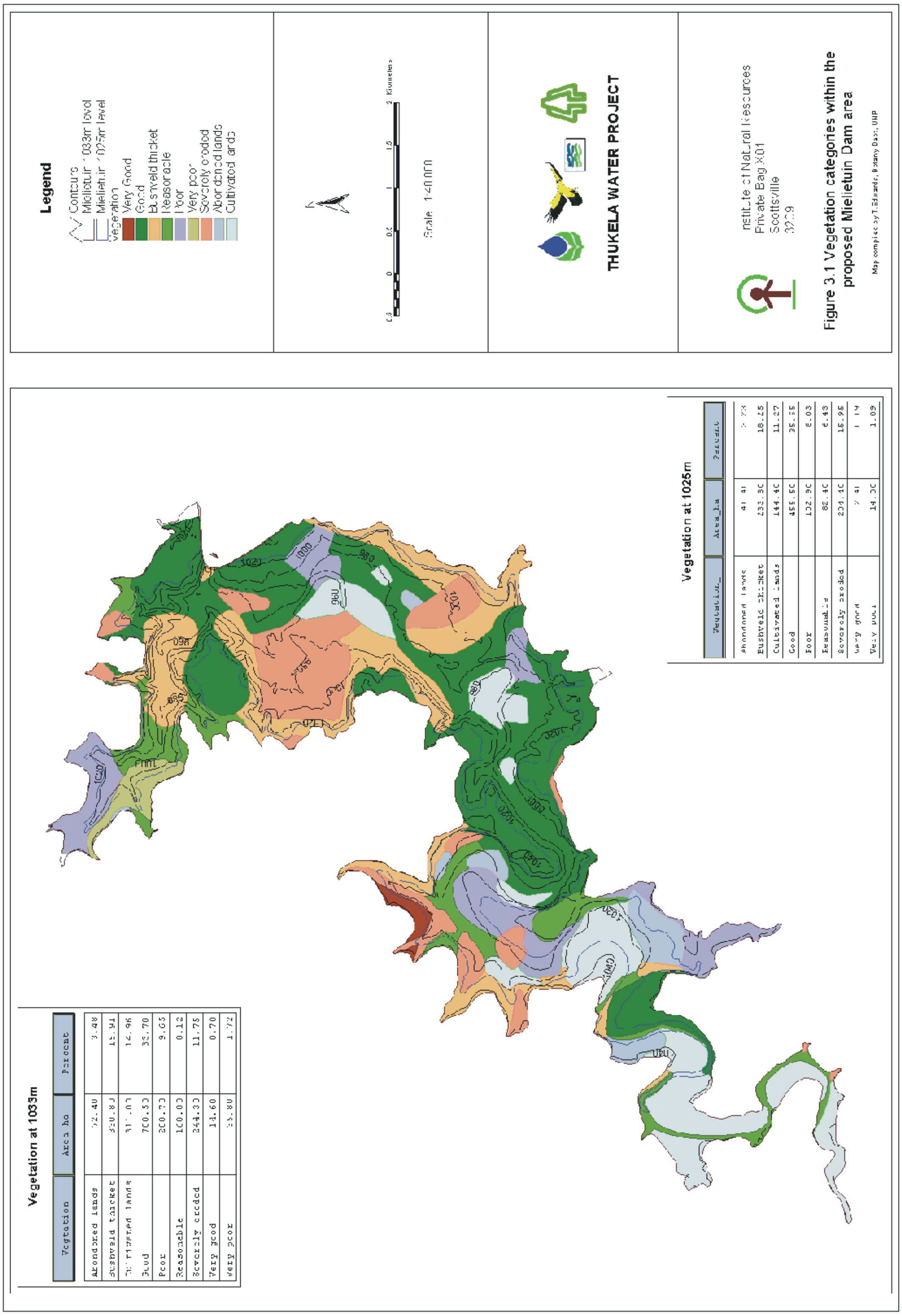
Acocks (1988) includes the vegetation in his Northern variation of Valley Bushveld which is dominated by xerophytic tropical elements such as *Euphorbia ingens*, *E. tirucalli*, *Dombeya cymosa*, *Dalbergia obovata*, *Acacia nilotica* and *A. robusta*. In its pristine state this northern variation of Valley Bushveld is characterised by open savanna with a far higher percentage of grasses than its southern counterparts. The floristic shifts in the vegetation, which are the product of reduced fires and overgrazing, have reduced its suitability for grazing because the toxic and unpalatable plant species have become dominant.

3.1 The Mielietuin Basin

The survey by Camp (1995) covers the vegetation status of the farm, Groot Mielietuin, in some detail. This area, and the adjacent farms Roode Draay and Ronde Dray, constitute the major part of the inundated area. The dam wall will be situated on the farm Bosman Riverspoort and so this area will also be heavily impacted, especially in the construction phase.

The vegetation of the Mielietuin Basin (Figure 3.1) is very altered and major shifts in physiognomy have occurred in the recent past. A considerable portion of the plant diversity within the system was probably associated with the open grassy savannas which supported a range of grass species and associated pyrophytes. Increases in the woody composition of the

Figure 3.1: Vegetation categories within the proposed Mielietuin Dam area



basin have gone hand in hand with decreases in the fire-dependent species and this has led to a general impoverishment in species diversity.

Fairly large areas of the basin are covered by veld which is in reasonable condition but shows an increase in woody species, most notably *Acacia karroo* and *A. nilotica*. Edwards (1964) recognizes five main variants of this *Acacia karroo-Acacia nilotica* Thornveld. Four of these types occur in the basin. However, the boundaries between these are ill-defined and consequently they are not used extensively in the report:

(i) The *Acacia karroo* Consociation occurs in moister areas (often at higher altitude) and frequently forms sharp interfaces with grassland. In the Mielietuin Basin this vegetation type is common along drainage lines. The associated trees include *Euclea crispa, Schotia brachypetala, Dombeya cymosa, Ziziphus mucronata, Combretum apiculatum* and *Combretum erythrophyllum.* The herbaceous layer is dominated by *Peristrophe, Hypoestes* and *Isoglossa*.

(ii) The *Acacia nilotica* Consociation is characteristic of drier areas and is frequent on stoney slopes of northerly aspect, i.e. the southern boundary of Groote Mielietuin and the northern boundary of Van Der Merwes Kraal.

(iii) The common *Acacia karroo-A. nilotica* Fasciation in which an equilibrium exists between the two species. This is the prominent consociation of the Mielietuin Basin. It is unclear to what extent this vegetation type is secondary.

(iv) Marginal Dry Valley Scrub/Savanna Fasciation in which key savanna elements are present such as *Acacia tortilis, Schotia brachypetala, Olea africana, Premna mooiensis, Euclea schimperi, Vitex rehmannii, Acacia robusta, Acacia nilotica, Acacia caffra, Ozoroa paniculosa, Maytenus heterophylla* and *Rhus pentherii*. This vegetation type occurs on some of the koppies in the basin.

South-facing outcrops with steep gradients reduce grass productivity and, hence, fuel loads required to destroy woody vegetation seldom develop. Such outcrops have a history of low grass productivity, which equates to cool fires, allowing the establishment and maintenance of woody species. It is probable that these rocky areas constitute historical refugia for the woody component of Valley Bushveld before anthropogenic influences altered the fire regime. In these areas, basal grass cover ranges from 5% to 9% which correlates with the respective levels of erosion. Decreaser grass species are the same as those present in pristine Valley Bushveld. Veld of this intermediate grazing quality is common along the ridge to the east of the Groote

Mielietuin property, which will form the eastern barrier to innundation. At the foot of this ridge, the quality of the veld decreases significantly and the woody component is far denser.

Bushveld thicket of high density occurs along the steep gradients which lie to the north of Bushman's River, on the farms Rondedraai and Riversdale. Bushveld thicket is well represented above the1033m contour and the inundated areas (on Riversdale) will not severely impact upon the parochial occurrence of this vegetation.

The slopes with a northern aspect occur to the south of the Bushman's River. Bushveld thicket is less developed in this area and, while the floristic composition shows large overlap with the south-facing thicket, there is an increased dominance of *Acacia* in accordance with the *Acacia nilotica* Consociation of Edwards (1964).

(a) Woody species

Acacia robusta subsp. *robusta*
Acacia seiberiana
Acacia tortilis subsp. *heteracantha*
Acocanthera oppositifolia
Allophylus melanocarpus
Allophylus decipiens
Apoodytes dimidiata var. *dimidiata*
Boscia albitrunca var. *albitrunca*
Boscia foetida subsp. *longipedicellata*
Buddleja saligna
Cassine aethiopica
Cassine transvaalensis
Clerodendrum glabrum
Calpurnia aurea subsp. *aurea*
Canthium mundtianum
Chionanthus foveolatus subsp. *foveolatus*
Clausena anisata
Combretum apiculatum
Combretum erythrophyllum
Commiphora harveyi
Croton gratissimus
Dias coitnifolia
Diospyros lycioides
Diospyros whyteana
Dombeya cymosa
Dovyalis zeyheri
Dovyalis caffra
Erythroxylum pictum
Euclea crispa
E uclea schimperi var. *daphnoides*
Euphorbia triangularis
Ehretia rigida
Grewia occidentalis var. *occidentalis*
Heteromorpha arborescens var. *abyssinica*
Heteromorpha stenophylla var. *transvaalensis*
Maerua caffra
Maytenus undata
Maytenus peduncularis
Maytenus senegalensis
Olea europaea subsp. *africana*
Premna mooiensis
Ptaeroxylon obliquum
Rhus rehmanniana var. *rehmanniana*
Rhus chirindensis
Schotia brachypetala
Sideroxylon inerme
Smodingium argutum
Suregada africana
Tarchonanthus camphoratus
Trimeria trinervis
Vepris lanceolata
Vitex harveyana
Ziziphus mucronata

b) Climbers of this vegetation include:

Asparagus plumosus
Asparagus suvaeolens
Acacia ataxacantha
Barleria obtusa
Buddleja dysophylla
Capparis sepiaria var. *citrifolia*
Cassinopsis ilicifolia
Cerapegia carnosa
Clematis brachiata
Coccinia variifolia
Cyphostemma hypoleucum
Cyphostemma humile
Cyphostemma natalitium
Cyphostemma woodii
Dalbergia obovata
Helinus integrifolius
Isoglossa grantii
Jasminum angulare
Jasminum multipartitum
Jasminum stenolobum
Jasminum breviflorum
Dalechampia capensis
Peristrophe cernua
Rhynchosia reptabunda
Rhynchosia minima var. *prostrata*
Rhynchosia carribaea
Rhynchosia crassifolia
Sarcostemma viminale
Scutia myrtina
Secamone filiformis
Senecio deltoideus

The ground layer of the dense bushveld thickets are virtually devoid of grass species. Herbaceous diversity is generally rather impoverished but with reasonable representation of Acanthaceae, Asparagaceae, Leguminosae and Euphorbiaceae:

Argyrolobium tomentosum
Asparagus cooperi
Asparagus coddii
Asparagus virgatus
Chaetacanthus burchellii
Chamaesyce inaequilatera
Cheilanthes viridis
Chlorophytum modestum
Chlorophytum comosum
Clutia pulchella
Cotyledon orbiculata
Crassula lanceolata subsp. *transvaalensis*
Crassula pellucida
Dicliptera clinopodia
Drimiopsis maculata
Huernia hystrix
Hypoestes aristata
Hypoestes forskoalii
Justicia protracta
Kalanchoe crenata subsp. *crenata* var. *crenata*
Kalanchoe rotundifolia
Plectranthus verticillatus
Sansevieria hyacinthoides
Teucrium kraussii

In the current vegetation, patches with reasonable grass cover and sparse woody vegetation are limited to the dolerite-derived soils associated with koppies. These areas usually include sporadic tree elements *(Vitex rehmannii, Acacia karroo, Acacia nilotica, A.sieberiana, Acacia caffra, Ozoroa paniculosa, Maytenus heterophylla* and *Rhus pentherii).* The following species have been recorded from the areas of savanna in which the tree cover is sparse (i.e. areas designated as reasonable and good on the Mielietuin map, Figure 3.1). These areas are prone to fire and the increased occurrence of pyrophytic herbs is notable. Species composition of the community includes the following species:

Abutilon grantii
Acalypha glabrata var. *glabrata*
Aloe spectabilis
Asparagus africanus
Barleria sp.
Blepharis integrifolia var. *integrifolia*
Blepharis longispica
Brachylaena elliptica
Bulbine narcissifolia
Bulbine frutescens
Cassine aethiopica
Cassine transvaalensis
Cassinopsis ilicifolia
Ceropegia carnosa
Chionanthus foveolatus subsp. *foveolatus*
Clausena anisata
Cienfuegosia gerrardii
Cleome monophylla
Cleome gynandra
Clerodendrum caeruleum
Coddia rudis
Corchorus asplenifolius
Crabbea acaulis
Crabbea hirsuta
Crassula lineolata
Crassula rubicunda
Crassula alba
Cuscuta campestris
Cynodon dactylon
Cyperus compactus
Dichondra repens
Dichrostachys cinerea
Digitaria eriantha
Echinochloa crusgalli
Echinochloa crus-galli
Erianthemum dregei
Eriocaulon abyssinicum
Erythrina humeana
Euphorbia striata var. striata
Euphorbia clavarioides var. *truncata*
Gnidia caffer
Hibiscus trionum
Hippobromus pauciflorus
Ledebouria asperifolia
Leucas martinicensis
Leucas capensis
Lippia javanica
Lycium cinereum
Maerua angolensis
Maytenus nemorosa
Maytenus tenuispina
Mohria caffrorum
Monopsis decipiens
Myrsine africana
Nolletia rarifolia
Ochna serrulata
Oenothera rosea
Orthosiphon wilmsii
Orthosiphon suffrutescens
Orthosiphon labiatus
Oxalis corniculata
Pachystigma macrocalyx
Pappea capensis
Pavetta cooperi
Pavetta lanceolata
Pavetta gardeniifolia var. *gardeniifolia*
Pellaea calomelanos
Phyllanthus maderaspatensis
Phyllanthus glaucophyllus
Pleurostylia capensis
Pollichia campestris
Polygala gymnoclada
Polygala serpentaria
Priva cordifolia
Rhoicissus tridentata
Rhus pyroides
Rhus gerrardii
Schizoglossum bidens
Schizoglossum decipiens
Senna italica
Sida rhombifolia
Solanum coccineum
Solanum incanum
Solanum tomentosum
Trichoneura grandiglumis

Camp (1995) indicates that the decreaser grass species (highly palatable grasses which decrease with grazing) within the dam basin are *Themeda triandra, Digitaria eriantha, Eustachys paspaloides* and *Cymbopogon plurinodis.* Pristine areas approaching 10% basal cover are restricted to the tops of koppies due north of the inundation zone on the farms Rondedraai, Riversdale and Groot Mielietuin. These areas carry the highest levels of plant diversity and may provide prospective habitats for transplanting rare pyrophytic species from the basin. Species composition of these communities is diverse and the occurrence of cryptophytes necessitates field work spanning all seasons. The inventory listed below will undoubtedly expand with spring and summer field work:

Abutilon grantii
Acacia nilotica
Acacia seiberiana
Acacia tortilis subsp. *heteracantha*
Acalypha villicaulis
Acalypha peduncularis
Agapanthus campanulatus
Agrostis lachnantha var. *lachnantha*
Aloe mudenensis
Aloe ecklonis
Aloe greatheadii var. *davyana*
Aloe spectabilis
Aloe dominella
Aloe cooperi
Anthospermum pumilum
Anthospermum herbaceum
Antizoma angustifolia
Apodytes dimidiata var. *dimidiata*
Aptenia sp.
Argyrolobium molle
Argyrolobium tomentosum
Argyrolobium tuberosum
Aristida congesta
Asclepias dregeana var. *calceola*
Asparagus cooperi
Asparagus africanus
Astragalus atropilosulus subsp. *burkeanus*
Barleria obtusa
Barleria greenii
Berkheya erysithales
Blepharis integrifolia var. *integrifolia*
Blepharis longispica
Bothriochloa insculpta
Brachylaena elliptica
Brachymenium acuminatum
Buddleja saligna
Bulbine narcissifolia
Bulbine frutescens
Bulbostylis oritrephes
Bulbostylis scleropus
Calodendrum capense
Calpurnia aurea subsp. *aurea*
Canthium mundtianum
Capparis sepiaria var. *citrifolia*
Cassine aethiopica
Cassine transvaalensis
Cassinopsis ilicifolia
Cephalaria oblongifolia
Ceratotheca triloba
Ceropegia carnosa
Chaetacanthus burchellii
Chamaesyce inaequilatera
Cheilanthes viridis
Chenopodium album
Chenopodium schraderianum
Chionanthus foveolatus subsp. *foveolatus*
Chironia palustris
Chlorophytum modestum
Chlorophytum comosum
Clausena anisata
Cienfuegosia gerrardii
Clematis brachiata
Cleome monophylla
Cleome gynandra
Clerodendrum caeruleum
Clerodendrum glabrum
Combretum apiculatum
Combretum erythrophyllum

Commelina africana
Crabbea acaulis
Crabbea hirsuta
Crassula lineolata
Crassula rubicunda
Crassula alba
Crassula lanceolata subsp. *transvaalensis*
Crotalaria capensis
Cuscuta campestris
Cyanotis speciosus
Cymbopogon excavatus
Cymbopogon marginatus
Cymbopogon plurinodis
Cymbopogon validus
Cynodon dactylon
Cyperus esculentus
Cyperus compactus
Cyphostemma hypoleucum
Cyphostemma natalitium
Cyrtanthus galpinii
Cyrtanthus contractus
Dalbergia obovata
Dalechampia capensis
Dias coitnifolia
Dichondra repens
Dicliptera clinopodia
Digitaria eriantha
Diospyros lycioides
Diospyros whyteana
Dombeya cymosa
Ehretia rigida
Elephantorrhiza woodii
Elephantorrhiza elephantina
Eragrostis curvula
Eragrostis chloromelas
Erianthemum dregei
Eriocaulon abyssinicum
Eriosema lucipetalum
Eriosema kraussianum
Eriosema salignum
Eriospermum abyssinicum
Erythrina humeana
Eulalia villosa
Eulophia ovalis
Euphorbia striata var. striata
Euphorbia clavarioides var. *truncata*
Eustachys paspaloides
Felicia filifolia
Festuca caprina
Ficus ingens
Garuleum latiolium
Gazania linearis
Gerbera piloselloides
Gerbera ambigua
Gladiolus crassifolius
Gnidia meisnerianus
Gnidia caffer
Gnidia anthylloides
Grewia hispida
Habenaria tridens
Heteropogon contortus
Helichrysum coriaceum
Helichrysum oxyphyllum
Helichrysum rugulosum
Helichrysum athrixiifolium
Helichrysum pallidum
Helichrysum hyphocephalum
Helichrysum lineare
Hermannia grandistipula
Hermannia parviflora
Heteropogon contortus
Hibiscus aethiopicus
Hibiscus trionum
Hibiscus pusillus
Hoffmanseggia sandersoni
Hyparrhenia cymbaria
Hyparrhenia filipendula
Hyparrhenia hirta
Hypericum aethiopicum
Hypoxis multiceps
Hypoxis hemerocallidea
Hypoxis rigidula
Indigastrum argyraeum
Indigifera torulosa
Indigofera acanthoclada
Indigofera tenuissima
Indigofera ionii
Indigofera velutina
Ipomoea crassipes
Ipomoea sinensis subsp. *blepharosepala*
Ipomoea oblongata
Ischaemum fasciculatum

Jasminum angulare
Jatropha natalensis
Ledebouria ovatifolia
Ledebouria asperifolia
Leonotis ocymifolia var. *raineriana*
Leucas martinicensis
Leucas capensis
Lippia javanica
Melinis nerviglumis
Melhania didyma
Melolobium microphyllum
Menodora africana
Monopsis decipiens
Ornithogalum sp.
Osteospermum calendulaceum
Pachystigma macrocalyx
Panicum coloratum
Panicum deustum
Panicum volutans
Pappea capensis
Paspalum sp.
Pelargonium luridum
Pelargonium alchemilloides
Pellaea calomelanos
Pennisetum thunbergii
Peristrophe cernua
Pentaschistis aurea subsp. *pilosogluma*
Peucedanum caffrum
Phyllanthus maderaspatensis
Phyllanthus glaucophyllus
Plectranthus hadiensis var. *tomentosus*
Plectranthus calycinus
Poa binata
Polygala gymnoclada
Polygala serpentaria
Polygala hottentotta
Pygmaeothamnus chamaedendrum var. *setulosus*
Rhus dentata
Rhus pyroides
Rhynchosia reptabunda
Rhynchosia minima var. prostrata
Rhynchosia totta
Ruellia cordata
Ruellia baurii
Scabiosa columbaria
Schizoglossum bidens
Schizoglossum decipiens
Schizostephium griseum
Sebaea longicaulis
Senecio glaberrimus
Senecio scoparius
Senecio digitalifolius
Senecio affinis
Senecio rhomboideus
Senna italica
Silene pilosellifolia
Solanum coccineum
Solanum tomentosum
Sorghum versicolor
Sporobolus capensis,
Sporobolus festivus
Sporobolus fimbriatus
Sporobolus pyrimidalis
Stachys natalensis var. *galpinii*
Stachys natalensis var. *natalensis*
Striga elegans
Suregada africana
Sutera noodsbergensis
Sutera floribunda
Sutera atropurpurea
Tarchonanthus camphoratus
Teramnus labialis subsp. *labialis*
Themeda triandra
Thesium cytisoides
Thunbergia neglecta
Trachyandra saltii var. *saltii*
Trachyandra asperata var. *nataglencoensis*
Tragus racemosus
Trichoneura grandiglumis
Tritonia lineata var. *lineata*
Vernonia oligocephala
Vernonia hirsuta
Vitex rehmannii
Wahlenbergia paucidentata
Wahlenbergia grandiflora
Walafrida densiflora
Zaluzianskya glareosa
Ziziphus mucronata

The ridges surrounding the prospective dam basin are dissected by drainage lines which show marked degradation in vegetation. This is because heavier grazing pressure exists on the moister soils of the drainage lines. These are in turn the most susceptible areas to physical erosion. This pattern is especially marked along annual tributaries such as the iGujwana on the south-east boundary and the tributary running from Bassons Kraal on the north-west of the property. The destabilisation of drainage lines initially leads to an increase in pioneer grasses such as *Eragrostis curvula, Cynodon dactylon, Sporobolus capensis, Sporobolus fimbriatus, Sporobolus pyrimidalis, Panicum maximum, Melinis repens, Chloris filifolia* and *Tragus berteronianus.* However, in badly eroded areas only ruderals remain, including *Felicia filifolia* and *Blepharis integrifolia.*

In areas of heavy grazing, away from the drainage lines, denser tree canopies, dominated by *Acacia karroo* and *Acacia nilotica* have developed. Here, there is a conspicuous increase in the number of shade-tolerant dicotyledonous species (*Peristrophe cernua, Hypoestes forskoalii, Justicia betonica, Isoglossa grantii* and *Dicliptera clinopodia*). Grass cover is sparse (2% - 4%), species-impoverished and dominated by the occurrence of pioneers, including *Enneapogon scoparius, Fingerhuthia africana, Urochloa masambicensis, Melinis repens, Aristida congesta, Chloris virgata* and *Tragus berteronianus.* In these heavily grazed areas the composition of grass communities differs according to season and substrate. *Urochloa masambicensis* and the annual, *Tragus berteronianus,* are plentiful during moist periods but are ephemeral within the ecosystem. Taller tussock grasses (*Panicum, Eragrostis* and *Sporobolus*) dominate where the *Acacia* canopies are sparse and *Aristida congesta* and *A. diffusa* are prominent on the clay soils derived from shales. Many of the pyrophytic species, which once formed a considerable slice of the diversity in these areas, have been shaded out.

Cultivation of the alluvial soils associated with the flood plain is fairly intensive in the upper reaches of the basin (farms Oatlands and Rondedraai) and subsequent losses of plant diversity in this area will be minimal. The most species-impoverished areas within the Mielietuin Basin occur in the valley bottom adjacent to cultivated lands and near the Bushman’s River. The reduced diversity of these areas is due to years of heavy utilisation, and many pioneers and ruderals are present. Riparian and floodplain species are listed below and these include a fair number of exotic species (*) indicative of degradation. Hygrophilous grass species such as *Arundinella nepalensis* and *Miscanthus sorghum* occur within the river channel. Some degree of alluvial consolidation results from the growth of *Phragmites australis* and *Juncus* spp. along the water margin. It seems likely that *Persicaria* was once a prominent component of the riparian fringe but these populations have crashed and are currently represented by sporadic individuals. The riparian vegetation and that of the alluvial flanks includes the following species:

Acacia ataxacantha
Acacia karroo
Acacia nilotica
Acacia robusta subsp. *robusta*
Acalypha villicaulis
Amaranthus sp.
Arundinella nepalensis
Asclepias fruticosa
Asparagus africanus
Bidens pilosa *
Blepharis integrifolia var. *integrifolia*
Blepharis longispica
Bulbine narcissifolia
Bulbostylis scleropus
Ceratotheca triloba
Chamaesyce inaequilatera
Chenopodium album
Chenopodium schraderianum
Cleome monophylla
Clerodendum glabrum
Combretum erythrophyllum
Corchorus asplenifolius
Crinum macowanii
Crinum bulbispermum
Cymbopogon excavatus
Cymbopogon validus
Cynodon dactylon
Cyperus denudatus
Cyperus rubicunda
Cyperus difformis
Cyperus esculentus
Cyperus latifolius
Cyperus fastigiatus
Cyperus latifolius
Cyperus marginatus
Cyperus distans
Cyperus compactus
Cyrtanthus breviflorus
Datura stramonium *
Denekia capensis
Dichrostachys cinerea
Dissotis canescens
Echinochloa crusgalli
Eleocharis dregeanus
Equisetum ramosissimum
Eragrostis curvula
Eriocaulon abyssinicum
Euclea crispa
Eulalia villosa
Eustachys paspaloides
Felicia filifolia
Fimbristylis dichotoma
Gnidia caffer
Hemarthria altissima
Hibiscus trionum
Hyparrhenia filipendula
Hyparrhenia hirta
Imperata cylindrica
Ischaemum fasciculatum
Juncus lomatophyllus
Juncus oxycarpus
Juncus exsertus
Juncus effusus
Juncus punctorius
Kniphofia lineariifolia
Lepidium bonariense *
Leucas martinicensis
Limosella longiflora
Limosella maior
Malva parviflora var. *parviflora*
Mariscus dregeanus
Mariscus congestus
Matricaria nigellaefolia
Melasma scabra
Miscanthidium capensis
Miscanthidium junceum
Oenothera rosea *
Oxalis corniculata *
Paspalum sp. *
Pavetta cooperi
Peristrophe cernua
Persicaria serrata
Persicaria strigosum
Persicaria lapathifolium
Phragmites australis
Phalaris arundinacea
Polygala hottentotta
Priva cordifolia
Ranunculus multifidus
Rotala sp.
Rumex sagittatus
Rumex lanceolatus

Salix mucronata
Salvia aurita var. *galpinii*
Salvia runcinata
Schizostylis coccinea
Schkuhria pinnata *
Schoenoplectus muricinux
Scirpus paludicola
Scirpus falsus
Senna septemtrionalis *
Senna italica
Sesbania punicea *
Sida rhombifolia
Solanum incanum
Sorghum versicolor
Striga elegans
subsp. *labialis*
Teucrium kraussii
Typha capensis
Verbena bonariensis *
Verbena tenuisecta *
Vitellariopsis dispar
Xanthium spinosa *
Ziziphus mucronata

Table 3.1: Mielietuin vegetation classes - areas

Vegetation Class	Area (ha)	Conservation Value
Abandoned lands	72.36 (3.5%)	Negligible
Bushland thicket - reasonable	278.7 (13.4%)	Biodiversity reasonably high but community well represented outside the basin
Bushland thicket - poor	52 (2.5%)	Species diversity low
Cultivated lands	310.86 (15%)	Flanked by generalist species
Good	700.6 (33.7%)	Species composition slightly impoverished but diversity still reasonable
Poor	200.73 (9.7%)	Species diversity impoverished, dominated by unpalatable pioneers and ruderals
Reasonable	168.67 (8.1%)	Areas of fairly high utilisation but with a fair compliment of species
Severely eroded	244.47 (11.8%)	Areas of steep gradient, usually along drainage lines, with severe loss of species
Very good	14.64 (0.7%)	Low density of trees, savanna with high herbaceous diversity, conservation worthy
Very poor	35.82 (1.7%)	High loss of species, communities of pioneers, ruderals and exotic invaders

The riparian vegetation of the dam basin is not distinct from the reaches below the proposed dam wall and thus no significant biodiversity losses will be incurred with inundation. Currently, the riparian communities are dominated by species reliant on silt deposition. Arborescent species in the phreatic zone and on the riparian fringe are the exotic riverine poplar *(Populus deltoides**), which is sporadically common along consolidated banks. *Salix mucronata* occurs sporadically and may have once been much more common as a small riparian tree. Other woody species occur in the phreatic zone and include *Combretum erythrophyllum, Ziziphus mucronata, Calpurnia aurea, Clerodendrum glabrum, Cassinopsis ilicifolia* and *Chionanthus foveolatus.*

Elevated precipitation runoff is often a product of reduced basal cover in catchments. Pratt and Gwynne (1977) provided correlative data relating basal cover, percentage runoff and effective rainfall in East African Rangeland (Table 3.2). This provides a useful insight into the potential of vegetation physiognomy to (i) affect water retention within the terrestrial environment and (ii) affect flow regimes within the rivers. The biome type and comparative rainfall closely approximate the situation in the Mielietuin catchment.

Table 3.2: Correlated figures for basal vegetation cover, percentage rainfall runoff and the efficacy of rainfall in a thornveld area with an average rainfall of 600mm per annum (modified from Camp, 1995)

Basal Cover	% Runoff	Effective Rainfall
10%	10%	540mm
6%	50%	300mm
3%	66%	200mm
1%	70%	180mm

Valley Bushveld has proven to be particularly sensitive to mismanagement. Current stresses in the Mielietuin Basin revolve around poor veld management practices which lead to the loss of basal vegetation cover followed by major loss of topsoil. Any major damage to the vegetation should be considered in the light of its poor regenerative ability.

3.1.1 Rare and endangered species within the Mielietuin Basin

The taxa recorded in this list of rare plants have been recorded from the dam basin and its immediate vicinity. The resources allocated to this study and the seasonal constraints have made it impossible to plot populations of the listed taxa. Mitigatory measures against the destruction of populations of rare and endangered species require comprehensive plotting of the populations within the affected area and an evaluation of the significance of these populations relative to the whole gene pool for the particular species. It must be stressed that rescue operations require careful monitoring because mass removal of genetic material from the area does nothing to further the cause of conservation. If the genetic diversity of the species is to be retained, then conservation must occur *in situ* so as to strengthen the mutualisms which are an important part of the ecosystems. These mutualisms include specialised pollinators and specialised predators.

An overview of the list of rare and endangered species reveals that it includes primarily heliophytic species. The open savanna habitat of these species has been drastically reduced by the expansion of closed *Acacia* thicket due to veld mismanagement.

A single tree species, *Vitellariopsis dispar*, is recorded in the list of rare and endangered taxa. However, this species is also present in the riverine vegetation below the dam wall on the Bushman's River and on the Thukela. The populations require a proper census which includes data regarding phenology, i.e. flowering period, fruiting period, germination requirements. It is probable that the riparian nature of the species has lead to the evolution of phenological triggers which relate to water availability. There is also no information available on how *Vitellariopsis dispar* responds to river pollutants and heavy sediment loads, which will occur during construction. For these reasons it is imperative that nursery-germinated saplings are produced to bolster the natural populations which may languish during construction. Following construction, careful monitoring of populations below the respective dam sites is required to gauge the impacts of altered flow regimes. Careful cognisance needs to be taken of requirements of the adult trees and recruitment of seedlings during the formulation of the IFR.

Table 3.3: Rare and endangered species within the Mielietuin Basin

Taxon	Category	Tractability
Aloe greatheadii var. *davyana*	Insufficiently known	Transplantable
Aloe dominella	Rare	Transplantable
Barleria greenii	Vulnerable	Transplantable
Callilepis leptophylla	Rare	Transplantable
Elephantorrhiza woodii	Insufficiently known	Not transplantable
Huernia hystrix	Rare	Transplantable
Indigofera acanthoclada	Insufficiently known	Not transplantable
Panicum volutans	Insufficiently known	Transplantable
Vitellariopsis dispar	Rare	Not transplantable

Insufficiently known: Taxa which are suspected of being rare and endangered but insufficient information exists
regarding their current status.
Vulnerable: Rare taxa in decline due to over-exploitation or habitat destruction.
Rare: Taxa with small world populations that are not presently endangered or vulnerable.
Species usually with narrow geographic ranges.

The tractability of the rare and endangered species, with respect to transplantation, varies considerably. The prognosis for transplanting adult specimens of Fabaceae and Sapotaceae is not good. Instead these families should be grown from seed harvested, carefully, to include maximum genetic representation. Seed should be nursery raised and then relocated to suitable habitats above the inundation levels. Relocated populations need to be monitored for at least one season. Reserve seed or stud plants should be cultivated to compensate for transplantation losses.

The impact of habitat loss in rare and endangered species is exacerbated if the species have limited distributions. Such species are termed endemics and require special consideration in the impact assessment phase of this project.

Aloe dominella is a narrow endemic in northern KwaZulu-Natal and is restricted to rocky slopes in open savanna.
Barleria greenii is a recently described species with a very narrow distribution in open savanna (usually on ridges). Most populations will be above the inundated areas but may be susceptible to ancillary construction, i.e. access roads.
Vitellariopsis dispar occurs in riverine vegetation of the Thukela. The species is also recorded from Swaziland where its conservation status is poorly known.

3.2 The Jana Basin

(Note that the term Jana Basin is to be read as that area to be inundated at a full supply level of 860m)

3.2.1 Description of plant diversity at a landscape level

The following systems have been used to evaluate this level of diversity: Camp Bioresource Groups and Acocks Veld Types. For all practical purposes their boundaries in this area of the Thukela Basin are the same and for the province they do not differ significantly. Quotes on Acocks conservation values are therefore applied equally to Camp systems for the purposes of this report. Furthermore, the Jana Basin falls entirely within the Valley Bushveld (21) Bioresource Group and Veld Type. It should be noted that Valley Thicket (the equivalent of Valley Bushveld) is treated by Low and Rebelo (1996) as part of unique Biome, i.e separate from the Savanna Biome.

The apportionment of the vegetation categories of Valley Bushveld can be seen in Figure 3.2 and is summarised in Table 3.4.

On a 4-level scale, 65% (12.3 + 52.7%) of the Jana Basin is little modified and near-pristine. This is an exceptionally high value relative to other catchments of Valley Bushveld in the province where higher levels of degradation and transformation are recorded (Camp, 1995; Scott-Shaw *et al.*, 1996). These are largely subjective assessments but nevertheless support the view that **the Jana basin contains a part of one of few extensive, little-altered remnants of this important Bioresource Group and Biome**.

The high conservation importance of Valley Bushveld is highlighted by Camp (1995), Scott-Shaw *et al.* (1996) and Scott-Shaw (1999) who quote that Valley Bushveld is the most seriously degraded Veld Type in KwaZulu-Natal; is more than 90% endemic; is over 60% transformed; is less than 1% protected; and is relatively rich in numbers of threatened species. The potential loss of this area and this high value Valley Bushveld is significant.

Table 3.4: Categories of vegetation cover in the Jana Basin - refer to map (Figure 3.2)

Categories* of Vegetation Cover	% Remaining	Ha
Near-pristine plant communities	12.33	334
Little-modified plant communities	52.78	1430
Degraded natural plant communities	14.15	383
Transformed plant communities	10.45	283

Note: The surface area of the Thukela and Klip River account for 254ha, the total area @fsl of 860m is 2430ha.

* Near-pristine plant communities - contain over 90% of their natural species composition
Little-modified plant communities - contain over 50-90% of their natural species composition
Degraded natural plant communities - contain over 10-50% of their natural species composition
Transformed plant communities - contain less than 10% of their natural species composition

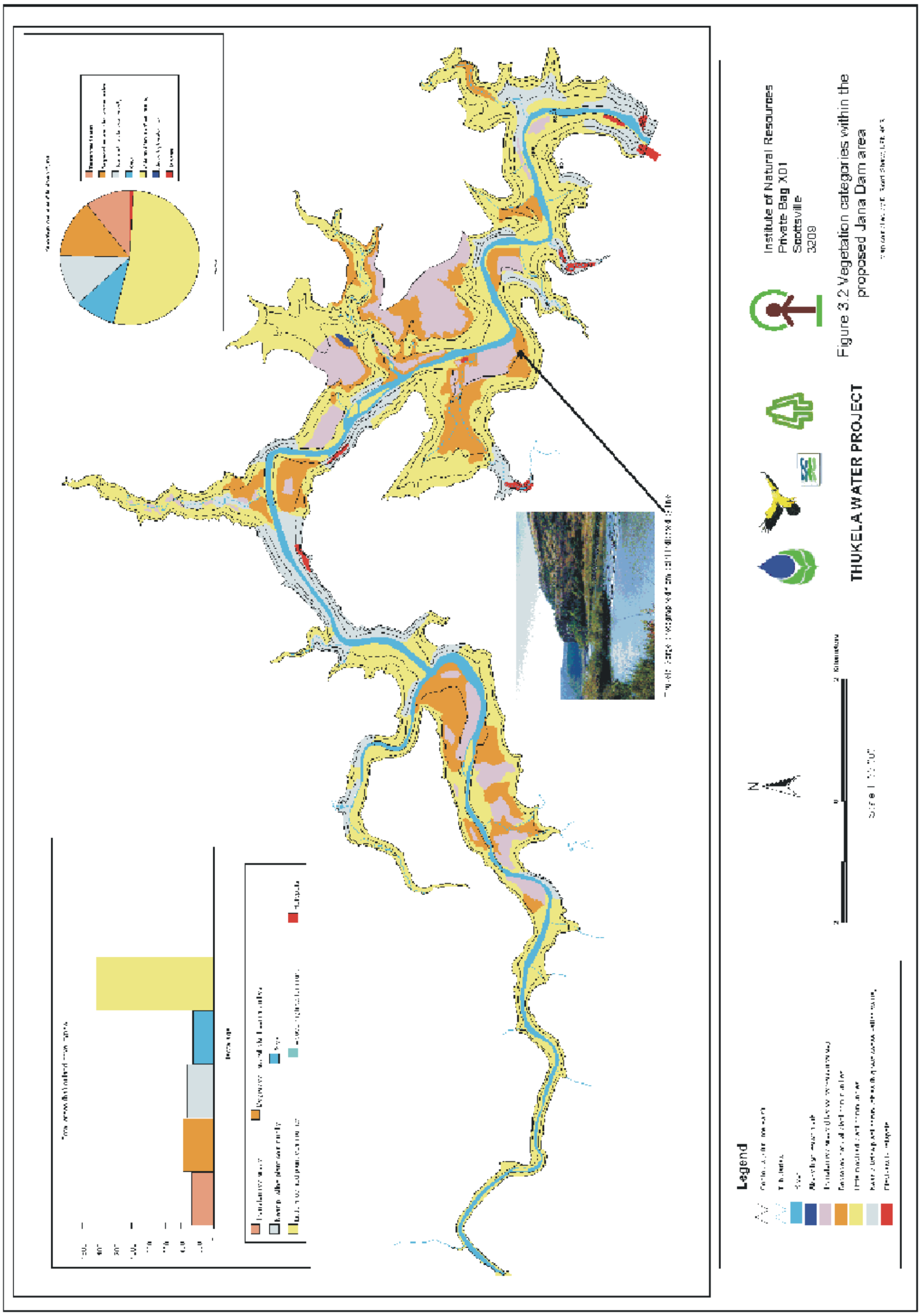
The narrow central gorge (29^0 58' 30" E) and the far-eastern gorge and tributaries (30^0 3' E) are the largest areas of little-modified and near-pristine vegetation (Figure 3.2). These contain attributes (special communities and red data species) that would make them qualify as Natural Heritage Sites given other non-biophysical conditions prevailing. Future assessments of this basin should therefore note this.

The composition of the Jana Basin Valley Bushveld differs from that to the east and at lower altitudes (but upstream of Jamesons Drift) where the humidity and rainfall is higher - over 630mm pa (Edwards, 1967). Jana is less species rich and has fewer succulent plant forms, especially those represented by the families Euphorbiaceae and Asclepiadaceae. It does, however, have elements of the neighbouring Bioresource Groups such as Southern Tall

Grassveld. Also there is gradient within the Jana Basin from west to east as seen in the greater numbers of trees such as *Spirostachys* and *Sclerocarya* closer to the Jana wall site.

It is important to note that in the Jana Basin the modified and degraded areas are almost alien plant free; have higher species richness and soil loss is less than that compared to the other areas of the Thukela Basin under subsistence farming. It, therefore, is likely to show a greater potential to restore itself. Consequently, the conservation importance of the Jana Basin should be that much greater.

Figure 3.2: Vegetation categories within the proposed Jana Dam area



3.2.2 Description of plant diversity at the community level

Table 3.5: Assessment of special plant communities in the Jana Basin

Description of Community	Conservation Value	% Area (original)
Tall riverine forest - open canopy - little disturbed - very low gradient river stage meandering - valley bottom Edwards (1967) equivalent (in part) = Valley Woodland - Semi-deciduous Indicator spp. *Spirostachys africana, Ekebergia, Celtis*	Very high value: tree spp. at range limits; high uniqueness; high avifauna diversity	4 (10)
Sandstone cliffs - 65˚ ➜ 85˚ - South facing - little disturbed - scrub covered (not cliffs) *Rhus, Canthium, Pavetta, Vepris, Grewia, Heteropyxis, Heteromorpha, Calpurnia,*	High value: endemic forbs high uniqueness high refugia high spp. richness high structural diversity	2 (3)
Rock outcrop scrub - north facing - mainly above the sandstones - tree dominated (Edwards, 1967 p.100) *Euphorbia tirucalli, Crassula arborescens*	High value: high uniqueness	8 (12)
Semi-deciduous bush (Edwards, 1967 p.102).	Medium value	50 (70)

3.2.3 Description of plant diversity at a species level

An inventory of flowering plants excluding graminoids was compiled. Against each local and regional scale distribution was noted and relative abundance in the Jana Basin recorded. Noteworthy taxa are identified (Tables 3.6 and 3.7) and annotated as Red Data, endemic, keystone, traditional use and salvage-worthy/relocate. Approximately 260 species have thus far been recorded excluding graminoids and lower plants. Ninety voucher specimens have been collected and processed through the Killick Herbarium so that these data are available for future studies.

The PRECIS database list for the grid square 2830 CA is very short and inadequately represents the real diversity. (This is because, due to inaccessibility, it is a relatively undercollected grid square.) Consequently this data was not used. A list of the woody plants observed is provided in Appendix 4.

The most important sites for the species listed in Table 3.7 are shown on Figure 3.2. Also shown on the map are **hotspots.** These are sites which have been rated as important following a simple rating system based as follows: A hotspot scores a 4 or higher.

(a) presence of high-ranking Red Data Book species = 3
(b) presence of low-ranking Red Data Book species = 1
(c) presence of other species important for conservation = 2
(d) presence of special plant communities which are unique to the Thukela Basin = 2
(e) very high community diversity = 2
(f) near-pristine communities = 2

The purpose of this evaluation is to highlight special sites as objectively as this limited survey allows for the benefit of other biologists working the area. Since not all potential sites were visited on foot, these must be regarded as only some of the hotspots.

Table 3.6: Hotspots

Hotspot Number	Size (ha)	Score	Criteria
1 wall site - west of river	4.28	14	a,b,c,d,e,f
2 600m upstream	1.88	4	a,b
3 upper Jana stream	3.67	5	b,d,e,f
4 Jana stream	1.2	5	a,b,c,e,
5	1.83	3	a
6	2.1	9	b,d,e,f
7	5.52	7	b,d,e,f
8	1.91	6	c,d,e,f
9 nr. Klip Dam wall site	2.73	9	a,c,d,e,f
10 nr. wall site east of river	1.86	10	b,e,f

Table 3.7: Noteworthy plant species, including Red Data Book species, in the Jana Basin

Species	Description
Pleurostylia capensis	locally rare; bark used for traditional medicine; salvage-worthy / relocate
Cassine transvaalensis	locally rare; bark used for traditional medicine; salvage-worthy / relocate
Suregada africana	rare
Maerua rosmarinoides	rare
Commiphora woodii	uncommon
Aloe rupestris	uncommon
Orbea woodii ?	salvage-worthy / relocate
Huernia hystrix	Red Data; endemic; very rare; a popular medicinal plant; salvage-worthy / relocate
Delosperma smythiae / gracile ?	Red Data; endemic; very rare; salvage-worthy / relocate
Euphorbia pseudocactus	rare; endemic; ephemeral?; salvage-worthy / relocate
Aloe mudenensis	Red Data; endemic; rare; salvage-worthy / relocate
Dioscorea sylvatica	uncommon; a popular medicinal plant; Red Data; rare; a popular medicinal plant; salvage-worthy / relocate
Vitellariopsis dispar	Red Data; endemic; rare; salvage-worthy / relocate
Ledebouria sp. nov.	unknown - assume: Red Data; endemic; very rare; salvage-worthy / relocate (Figures 3.3 and 3.4)
Aloe sp. nr. zebrina	unknown - assume: Red Data; endemic; very rare; salvage-worthy / relocate ; prob. significant range extension
Mystacidium capense	traditional medicine; salvage-worthy / relocate

Table 3.8: Rare and threatened plants recorded in the Jana Dam Basin by IUCN category (following Scott-Shaw, 1999)

Taxon	Notes
Vulnerable *Huernia hystrix*	 1
Data Deficient *Delosperma smythiae / gracile ?* *Euphorbia pseudocactus*	 white-flowered 3 rated 1
Lower Risk (Near Threatened) *Aloe mudenensis* *Dioscorea sylvatica*	 2 2
Lower Risk-Rare Only *Vitellariopsis dispar*	 2
Data Deficient *Euphorbia pseudocactus*	
Provisionally Data Deficient - requires evaluation *Ledebouria sp nov* *Aloe sp. nr. zebrina*	 1 1

Key: 5-level rating applied where 5 = abundant; 4 = very common; 3 = common; 2 = uncommon; 1 = rare at the spatial scale of the dam basin

3.2.4 Endemics

The following are confirmed Thukela Basin endemics:
Aloe mudensis
Euphorbia pseudocactus
Vitellariopsis dispar

The assessment of the following species must be regarded as provisional pending further investigation on taxonomic, conservation status and phytogeographic issues:
Ledebouria sp*. nov.* (Figures 3.3 and 3.4)
Aloe sp*. nr. zebrina*
These are requirements for further investigation beyond the times scales of this report. Refer to Section 6 for details.

Figure 3.3: *Ledebouria* sp.nov. Found in the Jana Basin.

Figure 3.4: Site of the *Ledebouria* sp.nov. (circled) in the Jana Dam Basin on Ramak Farm. The position of the proposed dam wall is also indicated.
(Photographs - O. Bourquin)

3.3 The ethnobotanical resources of the Jana and Mielietuin Basins

The harvesting of plant species for medicinal and craftwork in the Muden area was covered in a report prepared by the Institute of Natural Resources (Mander, McKean, McKechnie and Makhaye, 1997). The aim of this report was the identification of potential commercial ventures using species in ethnic demand. This information was generated for nine Land Reform farms. An additional report on the use of indigenous hardwoods for woodcarving in the Thukela Biosphere is also available (Ellery, Bill, McKenzie, Murphy and Tooley, 1997).

The proximity of Muden to the Mielietuin Basin means that the data in the above-mentioned reports are geographically pertinent. Cross-referencing the medicinal list of Mander *et al.* (1997) with the data in Hutchings *et al.* (1996) indicates that the former is not a comprehensive list with respect to medicinal plants. In the inventories prepared below, we have corroborated our information with all of the above reports. It is, however, beyond the scope of this document to provide market-related information with regard to supply and demand or remedial information.

3.4 The aqueduct routes

The aqueduct routes traverse Valley Bushveld and Southern Tall Grassveld (Veld Type 65) near the Jana and Mielietuin Basins. For the most part the aqueduct routes are situated in Southern Tall Grassveld. This vegetation type occurs between altitudes of 1050 and 1350m and is characterised by open *Acacia sieberiana* savanna. In pristine condition, the grasslands are dominated by *Themeda triandra* and *Hyparrhenia hirta* and, in summer, provide good grazing. Extensive agricultural use is made of the veld type with the result that very few pristine examples remain and clearly such utilisation has a negative impact on species diversity. The soils and subsoils of Southern Tall Grassveld are highly erodible. In parts, the aqueduct routes span the transition zones between Southern Tall Grassveld and Valley Bushveld, which are marked by the prominent occurrence of *Acacia caffra*-savanna.

The aqueduct routes provide a number of alternative scenarios. In terms of their impact on plant diversity and loss of habitat, a number of criteria need to be considered:

(i) habitat damage as a result of access roads and construction
(ii) disturbance as a site of alien infestation - rehabilitation
(iii) permanent habitat loss due to above ground structures

In terms of the aqueduct routes, three alternative options have been proposed. These are (i) a canal system and (ii) a pipeline system (iii) a combination of pipeline and canal.

This study is incomplete because the data relating to service roads has not been finalised and will require careful examination during the EIA. Unless carefully constructed and rehabilitated, access roads have the potential to introduce large scale degradation in the form of erosion gullies. This is especially true in areas where there is a steep gradient such as a number of ridge areas through which the canal will pass.

The canal will cover a distance of 183km
The pipeline will cover a distance of 122km
The combined canal / pipeline option will cover a distance of 153km

The uncultivated land traversed by the aqueduct routes is not pristine in most instances. In an attempt to provide information on veld condition the list below was constructed. This provides limited information relating to vegetation cover, communities and erosion. More comprehensive species diversity data is listed in the cited appendices.

Sites of highest conservation value include:

- the proposed crossing points over the Thukela River and the 600 m approaches thereof - mostly on Zuurlager 1040;
- the neck between the kopjies just north of Ndanyana Hill on Sterkspruit 912.

SPECIES DIVERSITY FROM 2829CA AQUEDUCT ROUTE (Conservation sensitive species in bold)

Killburn - This area is dominated by Southern Tall Grassveld, the hills through which the canal and pipelines will pass are primarily *Acacia sieberana*-savanna which appears to be in good condition, with little loss of basal cover or erosion.

Drakensville - These grasslands are fairly heavily utilised for grazing and the species composition is likely to be somewhat depauperate as a result. The pipeline and canal routes are likely to have similar impacts.

Thembalhle - Southern Tall Grassveld in moderate condition although utilised as pastures. Some of the ridges through which the canal will pass are on fairly steep gradients associated with increases in woody species.

1 ***Acalypha angustata* Sond.** Near threatened
2 *Acalypha peduncularis* E.Mey. ex Meisn.
3 *Acalypha schinzii* Pax
4 *Adenocline acuta* (Thunb.) Baill.
5 *Agapanthus campanulatus* Leight. subsp. *campanulatus*
6 *Albuca shawii* Baker
7 *Alchemilla woodii* Kuntze
8 *Alepidea natalensis* J.M.Wood & M.S.Evans
9 *Alepidea setifera* N.E.Br.
10 *Andrachne ovalis* (Sond.) Müll.Arg.

11 *Andropogon schirensis* A.Rich.
12 *Anthospermum rigidum* Eckl. & Zeyh. subsp. rigidum
13 *Asclepias macropus* (Schltr.) Schltr.
14 *Aspidonepsis diploglossa* (Turcz.) Nicholas & Goyder
15 *Aster bakeranus* Burtt Davy ex C.A.Sm.
16 *Aster pleiocephalus* (Harv.) Hutch.
17 *Barleria monticola* Oberm.
18 *Becium obovatum* (E.Mey. ex Benth.) N.E.Br. subsp. obovatum var. obovatum
19 *Brunsvigia grandiflora* Lindl.
20 *Bulbostylis humilis* (Kunth) C.B.Clarke
21 *Cardamine africana* L.
22 *Cephalaria oblongifolia* (Kuntze) Szabó
23 *Cheilanthes quadripinnata* (Forssk.) Kuhn
24 *Chrysanthemoides monilifera* (L.) Norl. subsp. canescens (DC.) Norl.
25 *Convolvulus sagittatus* Thunb.
26 *Conyza pinnata* (L.f.) Kuntze
27 *Cotula hispida* (DC.) Harv.
28 *Crassula peploides* Harv.
29 *Crassula vaginata* Eckl. & Zeyh. subsp. vaginata
30 *Cycnium racemosum* Benth.
31 *Cymbopogon prolixus* (Stapf) E.Phillips
32 *Cynoglossum hispidum* Thunb.
33 *Cynoglossum lanceolatum* Forssk.
34 *Cyperus rupestris Kunth* var. *parvinux* (C.B.Clarke) Kük.
35 *Diclis rotundifolia* (Hiern) Hilliard & B.L.Burtt
36 *Dipcadi marlothii* Engl.
37 *Dipcadi viride* (L.) Moench
38 *Disa versicolor* Rchb.f.
39 *Eleocharis palustris* R.Br.
40 *Entodon macropodus* (Hedw.) C.Müll.
41 *Eragrostis capensis* (Thunb.) Trin.
42 *Eriosema salignum* E.Mey.
43 *Euryops transvaalensis* Klatt subsp. *setilobus* (N.E.Br.) B.Nord.
44 *Festuca costata* Nees
45 *Festuca scabra* Vahl
46 *Ficinia gracilis* Schrad.
47 *Ficinia stolonifera* Boeck.
48 *Galtonia candicans* Decne.
49 *Geranium ornithopodon* Eckl. & Zeyh.
50 *Geranium wakkerstroomianum* R.Knuth
51 *Gladiolus crassifolius* Baker
52 *Gladiolus dalenii* Van Geel subsp. dalenii
53 *Gnaphalium filagopsis* Hilliard & B.L.Burtt
54 *Gnidia kraussiana* Meisn. var. *kraussiana*
55 *Graderia scabra* (L.f.) Benth.
56 *Habenaria dives* Rchb.f.

57 *Habenaria laevigata* Lindl.
58 *Haplocarpha scaposa* Harv.
59 *Harpochloa falx* (L.f.) Kuntze
60 *Helichrysum acutatum* DC.
61 *Helichrysum adenocarpum* DC. subsp. *adenocarpum*
62 *Helichrysum aureum* (Houtt.) Merr. var. *monocephalum* (DC.) Hilliard
63 *Helichrysum aureum* (Houtt.) Merr. var. *scopulosum* (M.D.Hend.) Hilliard
64 *Helichrysum caespititium* (DC.) Harv.
65 *Helichrysum cephaloideum* DC.
66 *Helichrysum cymosum* (L.) D.Don subsp. *calvum* Hilliard
67 *Helichrysum fulvum* N.E.Br.
68 *Helichrysum grandibracteatum* M.D.Hend.
69 *Helichrysum herbaceum* (Andrews) Sweet
70 *Helichrysum infaustum* J.M.Wood & M.S.Evans
71 *Helichrysum krookii* Moeser
72 *Helichrysum nanum* Klatt
73 *Helichrysum nudifolium* (L.) Less.
74 *Helichrysum oreophilum* Klatt
75 *Helichrysum pilosellum* (L.f.) Less.
76 *Helichrysum platypterum* DC.
77 *Helichrysum spiralepis* Hilliard & B.L.Burtt
78 *Helichrysum splendidum* (Thunb.) Less.
79 *Helictotrichon turgidulum* (Stapf) Schweick.
80 *Hemarthria altissima* (Poir.) Stapf & C.E.Hubb.
81 *Hesperantha baurii* Baker subsp. baurii
82 *Hesperantha radiata* (Jacq.) Ker Gawl.
83 *Heteromma simplicifolium* J.M.Wood & M.S.Evans
84 *Heteropogon contortus* (L.) Roem. & Schult.
85 *Hibiscus trionum* L.
86 ***Hoffmannseggia sandersonii* (Harv.) Engl. Natal endemic**
87 *Homeria pallida* Baker
88 *Hybanthus parviflorus* (L.f.) Baill.
89 *Hyparrhenia tamba* (Steud.) Stapf
90 *Hypoxis filiformis* Baker
91 *Indigofera longebarbata* Engl.
92 *Indigofera rostrata* Bolus
93 *Inulanthera calva* (Hutch.) Källersjö
94 *Kniphofia triangularis* Kunth subsp. triangularis
95 *Kohautia amatymbica* Eckl. & Zeyh.
96 *Kyllinga pulchella* Kunth
97 *Ledebouria cooperi* (Hook.f.) Jessop
98 *Lessertia perennans* (Jacq.) DC. var. *perennans*
99 *Linum thunbergii* Eckl. & Zeyh.
100 *Lotononis eriantha* Benth.
101 *Lotononis foliosa* Bolus
102 *Moraea trifida* R.C.Foster

103 ***Muraltia alticola* Schltr. Data deficient**
104 ***Pachycarpus campanulatus* (Harv.) N.E.Br. Eastern seaboard endemic**
105 *Pachystigma pygmaeum* (Schltr.) Robyns
106 *Panicum natalense* Hochst.
107 *Pearsonia grandifolia* (Bolus) Polhill subsp. *grandifolia*
108 *Pelargonium luridum* (Andrews) Sweet
109 *Pennisetum unisetum* (Nees) Benth.
110 *Pentanisia angustifolia* (Hochst.) Hochst.
111 *Phymaspermum bolusii* (Hutch.) Källersjö
112 *Polygala gracilenta* Burtt Davy
113 *Polygala hottentotta* C.Presl
114 *Psammotropha myriantha* Sond.
115 *Pycnostachys reticulata* (E.Mey.) Benth.
116 *Pycreus rehmannianus* C.B.Clarke
117 *Rhoicissus tridentata* (L.f.) Wild & R.B.Drumm. subsp. *tridentata*
118 *Rhus dentata* Thunb.
119 *Rhynchosia foliosa* Markötter
120 *Rhynchosia stenodon* Baker f.
121 *Rubus rigidus* Sm.
122 *Rumex crispus* L.
123 *Rumex lanceolatus* Thunb.
124 *Salvia stenophylla* Burch. ex Benth.
125 *Satyrium longicauda* Lindl. var. *longicauda*
126 *Satyrium neglectum* Schltr. subsp. *neglectum* var. *neglectum*
127 *Schistostephium crataegifolium* (DC.) Fenzl ex Harv.
128 *Schizoglossum bidens* E.Mey. subsp. *pachyglossum* (Schltr.) Kupicha
129 *Schizoglossum peglerae* N.E.Br.
130 *Scilla nervosa* (Burch.) Jessop
131 *Selaginella caffrorum* (Milde) Hieron.
132 *Selago galpinii* Schltr.
133 *Senecio discodregeanus* Hilliard & B.L.Burtt
134 *Senecio rhomboideus* Harv.
135 *Senecio subrubriflorus* O.Hoffm.
136 *Sporobolus centrifugus* (Trin.) Nees
137 *Stachys grandifolia* E.Mey. ex Benth.
138 *Stiburus conrathii* Hack.
139 *Sutera neglecta* (J.M.Wood & M.S.Evans) Hiern
140 *Thesium scirpioides* A.W.Hill
141 *Trachypogon spicatus* (L.f.) Kuntze
142 *Tragia rupestris* Sond.
143 *Tulbaghia leucantha* Baker
144 *Ursinia montana* DC. subsp. *montana*
145 *Vernonia hirsuta* (DC.) Sch.Bip. ex Walp.
146 *Vernonia natalensis* Sch.Bip. ex Walp.
147 *Wahlenbergia androsacea* A.DC.
148 *Wahlenbergia lycopodioides* Schltr. & Brehmer

149 *Wahlenbergia polytrichifolia* Schltr. subsp. *polytrichifolia*
150 *Wahlenbergia virgata* Engl.
151 *Walafrida densiflora* (Rolfe) Rolfe
152 *Watsonia lepida* N.E.Br.
153 *Wurmbea angustifolia* B.Nord.
154 *Xysmalobium involucratum* (E.Mey.) Decne.
155 *Xysmalobium parviflorum* Harv. ex Scott-Elliot

SPECIES DIVERSITY FROM 2829CB AQUEDUCT ROUTE (Conservation sensitive species in bold)

Mapalala - Southern Tall Grassveld in good condition.

Bergville - Southern Tall Grassveld, moderately grazed and in areas showing a decrease in basal cover and erosion gullies, increaser species common.

Schoongezicht - Moderately grazed *Acacia sieberiana*-savanna.

Ndanyana - Heavily grazed Southern Tall Grassveld with gully erosion evident.

1 *Adhatoda* andromeda (Lindau) C.B.Clarke
2 *Afrotysonia* glochidiata (R.R.Mill) R.R.Mill
3 *Agrostis* lachnantha Nees var. *lachnantha*
4 ***Alepidea* amatymbica Eckl. & Zeyh. var. *amatymbica* Near threatened**
5 *Alloteropsis* semialata (R.Br.) Hitchc. subsp. *eckloniana* (Nees) Gibbs-Russ.
6 *Aloe cooperi* Baker subsp. *cooperi*
7 *Andropogon appendiculatus* Nees
8 *Andropogon eucomus* Nees
9 *Anthospermum herbaceum* L.f.
10 *Argyrolobium robustum* Eckl. & Zeyh.
11 *Aristida congesta* Roem. & Schult. subsp. *barbicollis* (Trin. & Rupr.) De Winter
12 *Artemisia afra* Jacq. ex Willd.
13 *Asclepias humilis* (E.Mey.) Schltr.
14 *Asparagus microraphis* sensu Jessop, non (Kunth) Baker
15 *Asparagus virgatus* Baker
16 *Aster perfoliatus* Oliv.
17 *Athrixia angustissima* DC.
18 *Buchnera dura* Benth.
19 *Bulbostylis scleropus* C.B.Clarke
20 *Carex spicato-paniculata* C.B.Clarke
21 *Cerastium capense* Sond.
22 *Cheilanthes viridis* (Forssk.) Sw. var. *viridis*
23 *Chrysocoma ciliata* L.
24 *Cineraria lyrata* DC.
25 *Cissus cussonioides* Schinz
26 *Clutia hirsuta* E.Mey. ex Sond. var. *hirsuta*
27 *Conyza obscura* DC.
28 *Crassula lanceolata* (Eckl. & Zeyh.) Endl. ex Walp. subsp. *lanceolata*

29 *Crinum bulbispermum* (Burm.f.) Milne-Redh. & Schweick.
30 *Cymbopogon validus* (Stapf) Stapf ex Burtt Davy
31 *Cynodon hirsutus* Stent
32 *Denekia capensis* Thunb.
33 *Diclis reptans* Benth.
34 *Digitaria flaccida* Stapf
35 *Digitaria tricholaenoides* Stapf
36 *Diheteropogon amplectens* (Nees) Clayton
37 *Ehrharta erecta* Lam. var. *erecta*
38 *Eleusine coracana* (L.) Gaertn. subsp. *africana* (Kenn.-O'Byrne) Hilu & de Wet
39 *Elionurus muticus* (Spreng.) Kunth
40 *Eragrostis curvula* (Schrad.) Nees
41 *Eragrostis pilosa* (L.) P.Beauv.
42 *Eragrostis plana* Nees
43 *Eragrostis planiculmis* Nees
44 *Eragrostis racemosa* (Thunb.) Steud.
45 *Eulophia welwitschii* (Rchb.f.) Rolfe
46 *Eulophia zeyheriana* Sond.
47 *Euphorbia* striata Thunb. var. striata
48 *Euryops* montanus Schltr.
49 *Felicia filifolia* (Vent.) Burtt Davy subsp. *filifolia*
50 *Felicia rosulata* Yeo
51 *Festuca caprina* Nees.
52 *Fimbristylis complanata* (Retz.) Link
53 *Gerbera piloselloides* (L.) Cass.
54 *Gladiolus longicollis* Baker var. *longicollis*
55 *Gymnopentzia bifurcata* Benth.
56 *Haplocarpha nervosa* (Thunb.) P.Beauv.
57 *Helichrysum aureonitens* Sch.Bip.
58 *Helichrysum gymnocomum* DC.
59 *Helichrysum marginatum* DC.
60 *Helichrysum miconiifolium* DC.
61 *Helichrysum pallidum* DC.
62 Helichrysum *rugulosum* Less.
63 *Helichrysum sutherlandii* Harv.
64 *Helichrysum trilineatum* DC.
65 *Hyparrhenia anamesa* Clayton
66 *Hyparrhenia hirta* (L.) Stapf
67 *Hypericum aethiopicum* Thunb. subsp. *sonderi* (Bredell) N.Robson
68 *Hypochaeris radicata* L.
69 *Ipomoea crassipes* Hook.
70 *Ipomoea oblongata* E.Mey. ex Choisy
71 *Jamesbrittenia pristisepala* (Hiern) Hilliard
72 *Kalanchoe rotundifolia* (Haw.) Haw.
73 *Kniphofia parviflora* Kunth
74 *Kyllinga melanosperma* Nees

75 *Lactuca inermis* Forssk.
76 *Ledebouria revoluta* (L.f.) Jessop
77 *Leonotis leonurus* (L.) R.Br.
78 *Leonotis ocymifolia* (Burm.f.) Iwarsson var. *ocymifolia*
79 *Loudetia simplex* (Nees) C.E.Hubb.
80 *Mariscus capensis* (Steud.) Schrad.
81 *Maytenus heterophylla* (Eckl. & Zeyh.) N.Robson subsp. *heterophylla*
82 *Metalasia densa* (Lam.) P.O.Karis
83 *Monocymbium ceresiiforme* (Nees) Stapf
84 *Nemesia umbonata* (Hiern) Hilliard & B.L.Burtt
85 *Nidorella anomala* Steetz
86 *Nidorella resedifolia* DC. subsp. *resedifolia*
87 *Ophioglossum lancifolium* C.Presl
88 *Osteospermum jucundum* (E.Phillips) Norl.
89 *Osteospermum thodei* Markötter
90 *Oxalis obliquifolia* Steud. ex Rich.
91 *Paspalum dilatatum* Poir.
92 *Paspalum scrobiculatum* L.
93 *Pentzia cooperi* Harv.
94 *Peucedanum caffrum* (Meisn.) E.Phillips
95 *Pimpinella caffra* (Eckl. & Zeyh.) D.Dietr.
96 *Poa binata* Nees
97 *Pseudognaphalium undulatum* (L.) Hilliard & B.L.Burtt
98 *Rabdosiella calycina* (Benth.) Codd
99 *Rhus pyroides* Burch. var. *gracilis* (Engl.) Burtt Davy
100 *Rhus pyroides* Burch. var. *integrifolia* (Engl.) Moffett
101 *Rhynchosia reptabunda* N.E.Br.
102 *Ruellia cordata* Thunb.
103 *Schistostephium crataegifolium* (DC.) Fenzl ex Harv.
104 ***Scilla natalensis* Planch.Vulnerable**
105 *Scilla nervosa* (Burch.) Jessop
106 *Sebaea natalensis* Schinz
107 *Senecio barbatus* DC.
108 *Senecio cryptolanatus* Killick
109 *Senecio deltoideus* Less.
110 *Senecio inaequidens* DC.
111 *Senecio isatideus* DC.
112 *Senecio lygodes* Hiern
113 *Senecio macrocephalus* DC.
114 *Senecio speciosus* Willd.
115 *Senecio subrubriflorus* O.Hoffm.
116 *Senecio tugelensis* J.M.Wood & M.S.Evans
117 *Setaria nigrirostris* (Nees) T.Durand & Schinz
118 *Silene pilosellifolia* Cham. & Schltdl.
119 *Solanum retroflexum* Dunal
120 *Sporobolus fimbriatus* (Trin.) Nees

121 *Stachys caffra* E.Mey. ex Benth.
122 *Stiburus alopecuroides* (Hack.) Stapf
123 *Tephrosia* capensis (Jacq.) Pers. var. *acutifolia* E.Mey.
124 *Thesium asterias* A.W.Hill
125 *Thesium lobelioides* A.DC.
126 *Thunbergia atriplicifolia* E.Mey. ex Nees
127 Trachyandra reflexipilosa (Kuntze) Oberm.
128 *Trachypogon spicatus* (L.f.) Kuntze
129 *Trifolium africanum* Ser. var. *africanum*
130 *Tristachya leucothrix* Nees
131 *Urginea macrocentra* Baker
132 *Ursinia alpina* N.E.Br.
133 *Verbena tenuisecta* Briq.
134 *Vernonia capensis* (Houtt.) Druce
135 *Vernonia hirsuta* (DC.) Sch.Bip. ex Walp.
136 *Wahlenbergia androsacea* A.DC.
137 *Wahlenbergia virgata* Engl.
138 *Xysmalobium undulatum* (L.) Aiton f.
139 *Zaluzianskya ovata* (Benth.) Walp.
140 *Zaluzianskya spathacea* (Benth.) Walp.

SPECIES DIVERSITY FROM 2829DD AQUEDUCT ROUTE (Conservation sensitive species in bold)

Selby - moderately grazed pastures.
Hillside - Old fallow lands, Southern Tall Grassveld, heavily grazed with considerable erosion.
Broadview - *Acacia sieberiana* - *Acacia caffra* savanna heavily grazed, with erosion evident.
Moordkraal - *Acacia sieberiana* - *Acacia caffra* transitional savanna very heavily grazed with a noticeable drop in basal cover.

1 *Acacia robusta* Burch. subsp. *robusta*
2 *Acacia tortilis* (Forssk.) Hayne subsp. *heteracantha* (Burch.) Brenan
3 *Acalypha glabrata* Thunb. var. *glabrata*
4 *Agrostis lachnantha* Nees var. *lachnantha*
5 *Allophylus decipiens* (Sond.) Radlk.
6 *Allophylus melanocarpus* (Sond.) Radlk.
7 *Aloe ecklonis* Salm-Dyck
8 *Aloe* greatheadii Schönland var. *davyana* (Schönland) Glen & D.S.Hardy
9 ***Aloe mudenensis* Reynolds** Near threatened
10 *Aloe spectabilis* Reynolds
11 *Anthospermum herbaceum* L.f.
12 *Antizoma angustifolia* (Burch.) Miers ex Harv.
13 *Apodytes dimidiata* E.Mey. ex Arn. var. *dimidiata*
14 *Asclepias dregeana* Schltr. var. *calceola* (S.Moore) N.E.Br.
15 *Asparagus coddii* (Oberm.) Fellingham & N.L.Mey.

16 *Asparagus cooperi* Baker
17 *Asparagus suaveolens* Burch.
18 *Barleria obtusa* Nees
19 *Blepharis integrifolia* (L.f.) E.Mey. ex Schinz var. *integrifolia*
20 *Blepharis longispica* C.B.Clarke
21 *Boscia* albitrunca (Burch.) Gilg & Gilg-Ben. var. *albitrunca*
22 *Boscia* foetida Schinz subsp. *longipedicellata* (Gilg) Toelken
23 *Brachylaena elliptica* (Thunb.) DC.
24 *Buddleja saligna* Willd.
25 *Bulbine frutescens* (L.) Willd.
26 *Bulbine narcissifolia* Salm-Dyck
27 *Bulbostylis oritrephes* (Ridl.) C.B.Clarke
28 *Bulbostylis scleropus* C.B.Clarke
29 *Calpurnia aurea* (Aiton) Benth. subsp. *aurea*
30 *Canthium mundianum* Cham. & Schltdl.
31 *Capparis sepiaria* L. var. *citrifolia* (Lam.) Toelken
32 *Cassine aethiopica* Thunb.
33 *Cassine transvaalensis* (Burtt Davy) Codd
34 *Chamaesyce inaequilatera* (Sond.) Soják
35 *Chenopodium schraderianum* Roem. & Schult.
36 *Clematis brachiata* Thunb.
37 *Cleome gynandra* L.
38 *Clerodendrum caeruleum* N.E.Br.
39 *Clerodendrum glabrum* E.Mey. var. *glabrum*
40 *Coddia rudis* (E.Mey. ex Harv.) Verdc.
41 *Corchorus asplenifolius* Burch.
42 *Crabbea acaulis* N.E.Br.
43 *Crinum macowanii* Baker
44 *Cyperus difformis* L.
45 *Cyphostemma humile* (N.E.Br.) Desc. ex Wild & R.B.Drumm. subsp. *humile*
46 *Dalbergia obovata* E.Mey.
47 *Dovyalis zeyheri* (Sond.) Warb.
48 *Ehretia rigida* (Thunb.) Druce
49 *Elephantorrhiza elephantina* (Burch.) Skeels
50 *Elephantorrhiza woodii* E.Phillips var. *woodii*
51 *Eragrostis curvula* (Schrad.) Nees
52 *Eriosema kraussianum* Meisn.
53 *Eriospermum abyssinicum* Baker
54 *Erythroxylum pictum* E.Mey. ex Sond.
55 *Euclea schimperi* (A.DC.) Dandy var. *daphnoides* (Hiern) De Winter
56 *Euphorbia clavarioides* Boiss. var. *truncata* (N.E.Br.) A.C.White, R.A.Dyer & B.Sloane
57 *Euphorbia striata* Thunb. var. *striata*
58 *Festuca caprina* Nees
59 *Ficus burtt-davyi* Hutch.
60 *Gerbera ambigua* (Cass.) Sch.Bip.
61 *Grewia hispida* Harv.

62 *Grewia occidentalis* L. var. *occidentalis*
63 *Habenaria tridens* Lindl.
64 *Helichrysum athrixiifolium* (Kuntze) Moeser
65 *Helichrysum coriaceum* Harv.
66 ***Helichrysum hyphocephalum* Hilliard KwaZulu-Natal endemic**
67 *Helichrysum lineare* DC.
68 *Helichrysum rugulosum* Less.
69 *Helinus integrifolius* (Lam.) Kuntze
70 *Hermannia grandistipula* (Buchinger ex Hochst.) K.Schum.
71 *Heteromorpha arborescens* (Spreng.) Cham. & Schltdl. var. *abyssinica* (A.Rich.) H.Wolff
72 *Heteromorpha stenophylla* Welw. ex Schinz
73 *Hyparrhenia cymbaria* (L.) Stapf
74 *Hypoxis multiceps* Buchinger ex Baker
75 *Indigastrum argyraeum* (Eckl. & Zeyh.) Schrire
76 *Indigofera acanthoclada* Dinter
77 *Indigofera ionii* Jarvie & C.H.Stirt.
78 *Indigofera* tenuissima E.Mey.
79 *Ipomoea oblongata* E.Mey. ex Choisy
80 *Ipomoea sinensis* (Desr.) Choisy subsp. *blepharosepala* (Hochst. ex A.Rich.) Verdc.
81 *Ischaemum fasciculatum* Brongn.
82 *Jasminum multipartitum* Hochst.
83 *Jasminum stenolobum* Rolfe
84 ***Jatropha natalensis* Müll.Arg. Data deficient**
85 *Kalanchoe crenata* (Andrews) Haw. subsp. *crenata* var. *crenata*
86 *Kalanchoe rotundifolia* (Haw.) Haw.
87 *Kedrostis africana* (L.) Cogn.
88 *Lepidium bonariense* L.
89 *Lycium cinereum* Thunb. sensu lato
90 *Maerua caffra* (DC.) Pax
91 *Malva parviflora* L. var. *parviflora*
92 *Maytenus* heterophylla (Eckl. & Zeyh.) N.Robson subsp. *heterophylla*
93 *Maytenus* nemorosa (Eckl. & Zeyh.) Marais
94 *Melolobium* microphyllum (L.f.) Eckl. & Zeyh.
95 *Ochna* serrulata (Hochst.) Walp.
96 *Olea* europaea L. subsp. *africana* (Mill.) P.S.Green
97 *Oxalis corniculata* L.
98 *Pachystigma macrocalyx* (Sond.) Robyns
99 *Panicum volutans* J.G.Anderson
100 *Pappea capensis* Eckl. & Zeyh.
101 *Pavetta gardeniifolia* A.Rich. var. gardeniifolia
102 *Pelargonium alchemilloides* (L.) L'Hér.
103 *Pennisetum thunbergii* Kunth
104 *Plectranthus hadiensis* (Forssk.) Schweinf. ex Spreng. var. *tomentosus* (Benth.) Codd
105 *Poa binata* Nees
106 *Pollichia campestris* Aiton
107 ***Polygala gymnoclada* MacOwan Data deficient**

108 *Premna mooiensis* (H.Pearson) W.Piep.
109 *Ptaeroxylon* obliquum (Thunb.) Radlk.
110 *Pygmaeothamnus* chamaedendrum (Kuntze) Robyns var. *setulosus* Robyns
111 *Rhus chirindensis* Baker f.
112 *Rhus pentheri* Zahlbr.
113 *Rhus rehmanniana* Engl. var. *rehmanniana*
114 *Rhynchosia minima* (L.) DC. var. *prostrata* (Harv.) Meikle
115 *Rhynchosia reptabunda* N.E.Br.
116 *Ruellia cordata* Thunb.
117 *Rumex sagittatus* Thunb.
118 *Schizoglossum bidens* E.Mey. subsp. *pachyglossum* (Schltr.) Kupicha
119 *Schoenoplectus muricinux* (C.B.Clarke) J.Raynal
120 *Scirpus falsus* C.B.Clarke
121 *Scutia myrtina* (Burm.f.) Kurz
122 *Sebaea longicaulis* Schinz
123 *Senecio affinis* DC.
124 *Senecio deltoideus* Less.
125 *Senecio glaberrimus* DC.
126 *Senna septemtrionalis* (Viv.) Irwin & Barneby
127 *Silene pilosellifolia* Cham. & Schltdl.
128 *Stachys natalensis* Hochst. var. *galpinii* (Briq.) Codd
129 *Stachys natalensis* Hochst. var. *natalensis*
130 *Striga elegans* Benth.
131 *Sutera floribunda* (Benth.) Kuntze
132 *Tapinanthus natalitius* (Meisn.) Danser subsp. *natalitius*
133 *Tarchonanthus camphoratus* L.
134 *Thesium cytisoides* A.W.Hill
135 *Tortula muralis* Hedw.
136 *Trachyandra asperata* Kunth var. *nataglencoensis* (Kuntze) Oberm.
137 *Trachyandra saltii* (Baker) Oberm. var. *saltii*
138 *Tragus racemosus* (L.) All.
139 *Trimeria grandifolia* (Hochst.) Warb. subsp. *grandifolia*
140 *Trimeria trinervis* Harv.
141 *Tritonia lineata* (Salisb.) Ker Gawl. var. *lineata*
142 *Verbena bonariensis* L.
143 *Viscum rotundifolium* L.f.
144 *Vitex rehmannii* Gürke
145 *Wahlenbergia paucidentata* Schinz
146 *Xanthium strumarium* L.
147 *Xysmalobium parviflorum* Harv. ex Scott-Elliot
148 *Zanthoxylum capense* (Thunb.) Harv

SPECIES DIVERSITY FROM 2829DC AQUEDUCT ROUTE (Conservation sensitive species in bold)

Greenlands - The canal will pass through open *Acacia sieberiana*-savanna, recruitment of trees is high in some areas suggesting a reduction in fire intensity due to overgrazing. Soil erosion is also evident in some areas.

Swinburne - Heavily grazed with reduced basal cover and soil erosion.

Kopleegte - Southern Tall Grassveld in reasonable condition.

Blue Bell - Acacia sieberiana- savanna heavily grazed.

1 *Abildgaardia ovata (*Burm.f.) Kral
2 *Agapanthus caulescens* Spreng. subsp. *caulescens*
3 *Ambrosia artemisiifolia* L.
4 *Aristida congesta* Roem. & Schult. subsp. *barbicollis* (Trin. & Rupr.) De Winter
5 *Asclepias stellifera* Schltr.
6 *Aspidoglossum woodii* (Schltr.) Kupicha
7 *Bothriochloa bladhii* (Retz.) S.T.Blake
8 *Bothriochloa insculpta* (A.Rich.) A.Camus
9 *Brachiaria serrata* (Thunb.) Stapf
10 *Brunsvigia natalensis* Baker
11 *Bulbostylis schoenoides* (Kunth) C.B.Clarke
12 *Carex spicato-paniculata* C.B.Clarke
13 *Centella asiatica* (L.) Urb.
14 *Chironia palustris* Burch. subsp. *palustris*
15 *Cymbopogon plurinodis* (Stapf) Stapf ex Burtt Davy
16 *Cynodon bradleyi* Stent
17 *Cynodon hirsutus* Stent
18 *Cyperus esculentus* L. var. *esculentus*
19 *Cyperus haematocephalus* Boeck. ex C.B.Clarke
20 *Cyperus obtusiflorus* Vahl var. *flavissimus* (Schrad.) Boeck.
21 *Dierama latifolium* N.E.Br.
22 *Eragrostis curvula* (Schrad.) Nees
23 *Eragrostis pseudosclerantha* Chiov.
24 *Euryops laxus* (Harv.) Burtt Davy
25 *Felicia filifolia* (Vent.) Burtt Davy subsp. *filifolia*
26 *Festuca elatior* L.
27 *Fimbristylis dichotoma* (L.) Vahl
28 *Galium capense* Thunb. subsp. *capense*
29 *Gerbera ambigua* (Cass.) Sch.Bip.
30 *Gnidia nodiflora* Meisn.
31 *Helichrysum aureonitens* Sch.Bip.
32 ***Helichrysum hypoleucum* Harv**. Natal endemic
33 *Hermannia parviflora* Eckl. & Zeyh.
34 *Hyparrhenia dregeana* (Nees) Stapf
35 *Hyparrhenia rudis* Stapf

36 *Hypericum aethiopicum* Thunb. subsp. *sonderi* (Bredell) N.Robson
37 *Hypericum revolutum* Vahl subsp. *revolutum*
38 *Hypochaeris microcephala* (Sch.Bip.) Cabrera var. *albiflora* (Kuntze) Cabrera
39 *Ipomoea oblongata* E.Mey. ex Choisy
40 *Kohautia virgata* (Willd.) Bremek.
41 *Ledebouria revoluta* (L.f.) Jessop
42 *Mariscus squarrosus* (L.) C.B.Clarke
43 *Melinis repens* (Willd.) Zizka subsp. *repens*
44 *Mohria vestita* Baker
45 *Muraltia flanaganii* Bolus
46 *Oenothera grandiflora* Aiton
47 *Ornithogalum juncifolium* Jacq.
48 *Paspalum dilatatum* Poir.
49 *Paspalum scrobiculatum* L.
50 *Poa binata* Nees
51 *Pycreus macranthus* (Boeck.) C.B.Clarke
52 *Rabdosiella calycina* (Benth.) Codd
53 *Rhus discolor* E.Mey. ex Sond.
54 *Rubus cuneifolius* Pursh
55 *Salvia runcinata* L.f.
56 *Schoenoplectus muriculatus* (Kük.) Browning
57 *Schoenoplectus paludicola* (Kunth) Palla ex J.Raynal
58 *Setaria sphacelata* (Schumach.) Moss var. *sphacelata*
59 *Sida chrysantha* Ulbr.
60 *Sonchus nanus* Sond. ex Harv.
61 *Stipa dregeana* Steud. var. *dregeana*
62 *Themeda triandra* Forssk.
63 *Trachypogon spicatus* (L.f.) Kuntze
64 *Tulbaghia leucantha* Baker
65 *Urochloa panicoides* P.Beauv.
66 *Wahlenbergia krebsii* Cham. subsp. *krebsii*
67 *Zantedeschia albomaculata* (Hook.) Baill. subsp. *albomaculata*
68 *Zornia capensis* Pers. subsp. *capensis*

SPECIES DIVERSITY FROM 2829DA AQUEDUCT ROUTE (Conservation sensitive species in bold)

Valerie - Transition vegetation between Valley Bushveld and Southern Tall Grassveld.
Rietvallei - Southern Tall Grassveld, moderate grazing and gully erosion.

1 *Ajuga ophrydis* Burch. ex Benth.
2 *Aloe cooperi* Baker subsp. *cooperi*
3 *Argyrolobium robustum* T.J.Edwards
4 *Asparagus virgatus* Baker
5 *Chironia palustris* Burch. subsp. *transvaalensis* (Gilg) I.Verd.
6 *Corchorus asplenifolius* Burch.

7 *Corchorus trilocularis* L.
8 *Cyanotis speciosa* (L.f.) Hassk.
9 *Eriosema cordatum* E.Mey.
10 *Eriosema cordatum* E.Mey. x E. *salignum* E.Mey.
11 *Erythrina zeyheri* Harv.
12 *Gnidia gymnostachya* (C.A.Mey.) Gilg
13 *Grewia hispida* Harv.
14 *Hibiscus pusillus* Thunb.
15 *Hypoxis acuminata* Baker
16 *Hypoxis angustifolia* Lam. var. *angustifolia*
17 *Hypoxis iridifolia* Baker
18 *Hypoxis rigidula* Baker var. *rigidula*
19 *Indigofera spicata* Forssk. var. *spicata*
20 *Indigofera tenuissima* E.Mey.
21 *Ipomoea oblongata* E.Mey. ex Choisy
22 *Moraea stricta* Baker
23 *Oenothera rosea* L'Hér. ex Aiton
24 *Otholobium polystictum* (Benth. ex Harv.) C.H.Stirt.
25 *Phyllanthus incurvus* Thunb.
26 *Phyllanthus maderaspatensis* L.
27 *Ranunculus multifidus* Forssk.
28 *Rhynchosia nervosa* Benth. & Harv. var. *nervosa*
29 *Rhynchosia sordida* (E.Mey.) Schinz
30 *Seddera capensis* (E.Mey. ex Choisy) Hallier f.
31 *Sida dregei* Burtt Davy
32 *Stipagrostis uniplumis* (Licht.) De Winter var. *uniplumis*
33 *Tephrosia capensis* (Jacq.) Pers. var. *capensis*
34 *Tephrosia elongata* E.Mey. var. *elongata*
35 *Tephrosia macropoda* (E.Mey.) Harv. var. *macropoda*
36 *Teramnus labialis* (L.f.) Spreng. subsp. labialis
37 *Thunbergia atriplicifolia* E.Mey. ex Nees
38 *Tragia minor* Sond.
39 *Trifolium africanum* Ser. var. *africanum*
40 *Vigna vexillata* (L.) A.Rich. var. *vexillata*
41 *Zornia capensis* Pers. subsp. *capensis*

SPECIES DIVERSITY FROM 2829DB AQUEDUCT ROUTE (Conservation sensitive species in bold)

Suurlaer - Valley Bushveld ranging from good condition to eroded, woody element prominent. Cromley Bank, Ndanyana, Mapalala - Valley Bushveld, in good condition.

1 *Acacia caffra* (Thunb.) Willd.
2 *Acacia karroo* Hayne
3 *Acacia luederitzii* Engl. var. *luederitzii*
4 *Acacia sieberiana* DC. var. *woodii* (Burtt Davy) Keay & Brenan

5 *Acacia tortilis* (Forssk.) Hayne subsp. *heteracantha* (Burch.) Brenan
6 *Acalypha glabrata* Thunb. var. *pilosior* (Kuntze) Prain
7 *Ajuga ophrydis* Burch. ex Benth.
8 *Allophylus transvaalensis* Burtt Davy
9 *Alloteropsis semialata* (R.Br.) Hitchc. subsp. *eckloniana* (Nees) Gibbs-Russ.
10 *Aloe arborescens* Mill.
11 *Aloe cooperi* Baker subsp. *cooperi*
12 ***Aloe dominella*** **Reynolds Near endemic to KwaZulu-Natal**
13 *Aloe greatheadii* Schönland var. *davyana* (Schönland) Glen & D.S.Hardy
14 *Aloe marlothii* A.Berger subsp. *marlothii*
15 ***Aloe prinslooi*** **I.Verd. & D.S. Hardy Thukela Basin endemic**
16 *Andropogon ravus* J.G.Anderson
17 *Argyrolobium robustum* T.J.Edwards
18 *Argyrolobium tuberosum* Eckl. & Zeyh.
19 *Aristida sciurus* Stapf
20 *Asclepias adscendens* (Schltr.) Schltr.
21 *Asclepias brevipes* (Schltr.) Schltr.
22 *Asclepias meyeriana* (Schltr.) Schltr.
23 *Asclepias multicaulis* (E.Mey.) Schltr.
24 *Asparagus coddii* (Oberm.) Fellingham & N.L.Mey.
25 *Aster lydenburgensis* Lippert
26 *Barleria obtusa* Nees
27 *Blepharis longispica* C.B.Clarke
28 *Boerhavia erecta* L.
29 *Bothriochloa* bladhii (Retz.) S.T.Blake
30 *Bothriochloa insculpta* (A.Rich.) A.Camus
31 *Brachiaria serrata* (Thunb.) Stapf
32 *Buchnera glabrata* Benth.
33 *Bulbine narcissifolia* Salm-Dyck
34 *Bulbostylis hispidula* (Vahl) R.W.Haines
35 *Bulbostylis oritrephes* (Ridl.) C.B.Clarke
36 *Callilepis leptophylla* Harv.
37 *Chaetacanthus setiger* (Pers.) Lindl.
38 *Chamaecrista mimosoides* (L.) Greene
39 *Cheilanthes eckloniana* (Kunze) Mett.
40 *Cleome monophylla* L.
41 *Commiphora harveyi* (Engl.) Engl.
42 *Commiphora neglecta* I.Verd.
43 *Conyza podocephala* DC.
44 *Corchorus asplenifolius* Burch.
45 *Crinum macowanii* Baker
46 *Croton gratissimus* Burch. var. *gratissimus*
47 *Cyphostemma humile* (N.E.Br.) Desc. ex Wild & R.B.Drumm. subsp. *humile*
48 *Cyphostemma natalitium* (Szyszyl.) J.J.M.van der Merwe
49 *Datura ferox* L.
50 *Datura stramonium* L.

51 *Dicoma gerrardii* Harv. ex F.C.Wilson
52 *Dicoma* zeyheri Sond. subsp. argyrophylla (Oliv.) G.V.Pope
53 *Digitaria* eriantha Steud.
54 *Ehretia rigida* (Thunb.) Druce
55 *Elephantorrhiza elephantina* (Burch.) Skeels
56 *Elephantorrhiza woodii* E.Phillips var. woodii
57 *Eragrostis chloromelas* Steud.
58 *Eragrostis curvula* (Schrad.) Nees
59 *Eragrostis planiculmis* Nees
60 *Eragrostis sclerantha* Nees subsp. *sclerantha*
61 *Eragrostis superba* Peyr.
62 *Eriosema cordatum* E.Mey.
63 *Eriosema cordatum* E.Mey. x E. *salignum* E.Mey.
64 *Eriospermum cooperi* Baker var. *natalense* (Baker) P.L.Perry
65 *Eulophia clitellifera* (Rchb.f.) Bolus
66 *Euphorbia striata* Thunb. var. *striata*
67 *Ficus abutilifolia* (Miq.) Miq.
68 *Gazania linearis* (Thunb.) Druce var. *linearis*
69 *Gerbera ambigua* (Cass.) Sch.Bip.
70 *Gnidia burchellii* (Meisn.) Gilg
71 *Gnidia capitata* L.f.
72 *Gomphocarpus fruticosus* (L.) Aiton f.
73 *Grewia hispida* Harv.
74 *Helichrysum miconiifolium* DC.
75 *Helichrysum pallidum* DC.
76 *Hermannia depressa* N.E.Br.
77 *Hermannia grandistipula* (Buchinger ex Hochst.) K.Schum.
78 *Hermannia oblongifolia* (Harv.) Hochr.
79 *Hibiscus pusillus* Thunb.
80 *Hyparrhenia anamesa* Clayton
81 *Hyparrhenia cymbaria* (L.) Stapf
82 *Hyparrhenia hirta* (L.) Stapf
83 *Hyparrhenia quarrei* Robyns
84 *Hypericum aethiopicum* Thunb. subsp. *sonderi* (Bredell) N.Robson
85 *Hypoxis angustifolia* Lam. var. *angustifolia*
86 *Hypoxis hemerocallidea* Fisch. & C.A.Mey.
87 *Hypoxis rigidula* Baker var. rigidula
88 *Indigastrum argyraeum* (Eckl. & Zeyh.) Schrire
89 *Indigofera poliotes* Eckl. & Zeyh.
90 *Indigofera sessilifolia* DC.
91 *Indigofera tenuissima* E.Mey.
92 *Ipomoea oblongata* E.Mey. ex Choisy
93 *Jamesbrittenia* montana (Diels) Hilliard
94 *Jasminum angulare* Vahl
95 *Jasminum multipartitum* Hochst.
96 *Jasminum streptopus* E.Mey. var. *transvaalensis* (S.Moore) I.Verd.

97 *Jatropha capensis* (L.f.) Sond.
98 ***Jatropha natalensis* Müll.Arg**. Data deficient
99 *Jatropha woodii* Kuntze
100 *Juncus rigidus* Desf.
101 *Kedrostis africana* (L.) Cogn.
102 *Koeleria capensis* (Steud.) Nees
103 *Kohautia caespitosa* Schnizl. subsp. *brachyloba* (Sond.) D.Mantell
104 *Lablab purpureus* (L.) Sweet subsp. *uncinatus* Verdc.
105 *Lactuca inermis* Forssk.
106 *Ledebouria floribunda* (Baker) Jessop
107 *Ledebouria luteola* Jessop
108 *Ledebouria revoluta* (L.f.) Jessop
109 *Lippia javanica* (Burm.f.) Spreng.
110 *Lotononis laxa* Eckl. & Zeyh.
111 *Maytenus heterophylla* (Eckl. & Zeyh.) N.Robson subsp. heterophylla
112 *Melica racemosa* Thunb.
113 *Menodora africana* Hook.
114 *Monsonia angustifolia* E.Mey. ex A.Rich.
115 *Nicandra physalodes* (L.) Gaertn.
116 *Oenothera tetraptera* Cav.
117 *Osteospermum muricatum* E.Mey. ex DC. subsp. *muricatum*
118 *Pachystigma macrocalyx* (Sond.) Robyns
119 *Pavetta gardeniifolia* A.Rich. var. *gardeniifolia*
120 *Plectranthus grandidentatus* Gürke
121 *Pycreus unioloides* (R.Br.) Urb.
122 *Pygmaeothamnus chamaedendrum* (Kuntze) Robyns var. *setulosus* Robyns
123 *Pyrenacantha grandiflora* Baill.
124 *Raphionacme hirsuta* (E.Mey.) R.A.Dyer ex E.Phillips
125 *Rhus rehmanniana* Engl. var. *rehmanniana*
126 *Rhus undulata* Jacq.
127 *Rhynchosia sordida* (E.Mey.) Schinz
128 *Rhynchosia totta* (Thunb.) DC.
129 *Ruellia cordata* Thunb.
130 *Schkuhria pinnata* (Lam.) Cabrera
131 *Scleria dregeana* Kunth
132 *Sebaea grandis* (E.Mey.) Steud.
133 *Seddera capensis* (E.Mey. ex Choisy) Hallier f.
134 *Senecio achilleifolius* DC.
135 *Senecio albanensis* DC. var. *doroniciflorus* (DC.) Harv.
136 *Senecio anomalochrous* Hilliard
137 *Senecio retrorsus* DC.
138 *Setaria appendiculata* (Hack.) Stapf
139 *Setaria incrassata* (Hochst.) Hack.
140 *Setaria nigrirostris* (Nees) T.Durand & Schinz
141 *Setaria sphacelata* (Schumach.) Moss var. *sphacelata*
142 *Sida spinosa* L. var. spinosa

143 *Sisymbrium capense* Thunb.
144 *Solanum panduriforme* E.Mey.
145 *Solanum tomentosum* L.
146 *Stephania abyssinica* (Quart.-Dill. & A.Rich.) Walp. var. *tomentella* (Oliv.) Diels
147 *Striga bilabiata* (Thunb.) Kuntze var. *bilabiata*
148 *Striga elegans* Benth.
149 *Tapinanthus natalitius* (Meisn.) Danser subsp. *natalitius*
150 *Tarchonanthus camphoratus* L.
151 *Tephrosia capensis* (Jacq.) Pers. var. *hirsuta* Harv.
152 *Themeda triandra* Forssk.
153 *Thunbergia atriplicifolia* E.Mey. ex Nees
154 *Tolpis capensis* (L.) Sch.Bip.
155 *Trachyandra asperata* Kunth var. asperata
156 *Trichoneura grandiglumis* (Nees) Ekman var. *minor* Rendle
157 *Trichostomum brachydontium* Bruch ex F.A.Müll.
158 *Tulbaghia nutans* Vosa
159 *Verbena officinalis* L.
160 *Verbena tenuisecta* Briq.
161 *Vernonia capensis* (Houtt.) Druce
162 *Vernonia gerrardii* Harv.
163 *Vitex rehmannii* Gürke
164 *Zinnia peruviana* (L.) L.
165 *Ziziphus mucronata* Willd. subsp. *mucronata*

The proportion of vegetation types affected by the three options varies considerably (Table 3.9).

Table 3.9: Approximate and proportional differences in the impact on Valley Bushveld and Southern Tall Grassveld in the uncultivated land on the aqueduct routes from Jana and Mielietuin Dams

Option	Valley Bushveld	Southern Tall Grassveld
Canal	55km (39%)	89km (61%)
Pipeline	35km (44%)	45km (56%)
Combination	39km (30%)	93km (70%)

Discounting the construction of access roads, the proportions of cultivated and uncultivated lands affected by these options are outlined in Table 3.10.

Table 3.10: Approximate area of cultivated and uncultivated land affected by the different aqueduct options for Jana and Mielietuin Dams

Option	1) Canal	2) Pipeline	3) Combination
Cultivated	ca. 37km (20.4%)	ca. 42km (34.5%)	ca. 20km (31%)
Uncultivated	ca. 145km (79.6%)	ca. 80km (65.5%)	ca. 133km (69%)

Thus, the difference in areas directly affected by the aqueduct alternatives 1, 2 and 3 is moderate with respect to cultivated lands but very significant with respect to uncultivated land. The uncultivated lands directly affected are 45% greater in the canal option and 40% greater in the combination option. Clearly uncultivated land carries the highest levels of plant diversity and, thus, in the context of conservation, the canal and combination options are the most destructive.

Within Southern Tall Grassveld considerable diversity is associated with rock outcrops because fuel loads tend to be lower on the shallow substrates and as a consequence fires and grazing pressures tend to be less intense. The contour route followed by the canal in both options 1 and 3 will, of necessity, pass through ridges and rock outcrops harbouring such diversity. Within the seasonal constraints of this survey, it has not been possible to generate comprehensive inventories of the diversity on the ridges associated with the canal options. It is, however, important that an EIA includes a thorough survey of each affected ridge, across a number of seasons, to provide information on diversity and of rare and endangered species in these areas.

3.5 Accessibility

The pipeline route is relatively accessible due to its proximity to cultivated lands for much of its length. Thus, habitat degradation with respect to new access roads for construction and maintenance is less than in the canal option. This difference is accentuated by the fact that the canal is reliant on gravity flow and must follow contours which are some distance from existing roads. No information has been provided regarding the accessory construction routes for the pipeline and canal options. Clearly, access to this information is needed before an accurate EIA can be provided.

Southern Tall Grassveld occurs on shallow topsoils with very erodible subsoils making this vegetation type particularly susceptible to erosion (Acocks, 1988). The construction of temporary roads will, therefore, require careful planning and rehabilitation to prevent serious environmental degradation in the form of erosion and infestation by alien vegetation.

4 IMPACTS ON THE TERRESTRIAL BIODIVERSITY

4.1 Mielietuin

Table 4.1 provides the assessment, and summaries of each impact are given below.

Table 4.1: Impacts on the terrestrial biodiversity for Mielietuin

CATEGORY	Plant diversity	Weed invasion	Erosion	Red Data species
TYPE -see para. no.:	1 - loss of gene pool	2 - ecosystem disruption	3 - ecosystem degradation	4 - loss of gene pool
MAGNITUDE AND INTENSITY	· high	· high	· high	· high
EXTENT / SPATIAL SCALES	· regional	· local	· national	· international
DURATION	· long term	- long term	· long term	· long term
SIGN · positive (+) · negative (-)	· negative	· negative	· negative	· negative
CERTAINTY	· definite	· definite	· definite	· definite
SIGNIFICANCE	· medium	· medium	· medium	· high

1 Impact - The loss of biodiversity and populations of rare and threatened plant species through construction activities and inundation needs careful consideration in terms of the size of the populations to be lost and their contribution to the overall gene pool of the species concerned. In situations where the populations are significant, mitigatory measures must be proposed in the EIA.

2 Impact - Weedy species are associated with sites of ecological disturbance and perennial species, of this kind, will invade ecosystems adjacent to the construction sites. It is necessary, therefore, to rehabilitate construction sites and access roads, ensuring that low levels of infestation result from the construction phases. This problem will be especially marked in areas from which fire is excluded, thus special attention must be given to the rock outcrops associated with ridges, across which the aqueduct will pass. Invasion of veld by perennial exotics reduces the value of the resources and poses serious threats to rare taxa in the adjacent grasslands.

3 Impact - Erosion is a serious problem in both Valley Bushveld and Southern Tall Grassveld. The construction of aqueduct routes and access roads along steep gradients has the potential to exacerbate erosion in these areas. Without careful mitigation, this will lead to veld degradation and this may ultimately impinge on the quality of the water produced by the project.

4 Impact - It is impossible to quantify the impact of gene pool losses on species without seasonal censes being undertaken. These censes are particularly important in terms of the rare and endangered taxa of the basin.

4.2 Jana

Table 4.2 provides the assessment, and summaries of each impact are given below.

Table 4.2: Impacts on the terrestrial biodiversity for the Jana Dam Basin

CATEGORY	Jana Red Data species A & B	Jana Red Data species C, D, & E	Jana - Valley Bushveld	Loss of useful plants
TYPE -see para. no.:	5 - loss of gene pool	6 - loss of gene pool	7 - reduction of extent	8
MAGNITUDE AND INTENSITY	· very high	· high	· high	· moderate
EXTENT / SPATIAL SCALES	· international	· regional	· national	· local
DURATION	· long term	· long term	· long term	· long term
SIGN · positive (+) · negative (-)	· negative	· negative	· negative	· negative
CERTAINTY	· definite	· definite	· definite	· definite
SIGNIFICANCE	· high	· medium	· high	· medium

5 Impact - Red Data species *Aloe* sp. *nr. zebrina; Ledebouria* sp. *nov.* will be destroyed. The magnitude of the impact of the proposed dam on the gene pool of these taxa (Table 4.2) is **very high** and **definite** - resulting in local extinctions at the dam basin scale and possibly global extinctions since no populations are recorded elsewhere. Note that an EIA will need to quantify this.

6 Impact - Red Data species *Aloe mudensis, Heurnia hystrix* var. *hystrix* and *Dioscorea sylvatica* will be destroyed. The magnitude of the impact of the proposed dam on the gene pool of these taxa (Table 4.2) is **high** and **definite** - resulting in local extinctions at the dam basin scale and high levels of impact at a global (= international) scale because they are southern

African savanna endemics and rare across their distribution range. Note that *Aloe mudensis* is a Thukela Basin endemic. Note that an EIA will need to quantify this.

7 Impact - The 1786ha of little-modified, contiguous and diverse Valley Bushveld in the Jana Basin will be destroyed. Impact at the national scale (Table 4.2) is **high** in that it will substantially reduce the extent of this vegetation type and equivalent habitat type. Note that this Bioresource Group and its equivalent Acocks Veld Type is a KwaZulu-Natal endemic and already has a high conservation value.

8 Impact - The loss of plant species of medicinal and craft importance will be moderate and may have serious implications for the local community. The parochial value of this resource should be quantified. An attempt should be made to predict the effect of increased harvesting from adjacent areas following the inundation of the dam basins.

4.3 Aqueduct routes

Table 4.3 provides the assessment, and summaries of each impact are given below.

Table 4.3: Impacts on the terrestrial biodiversity for the aqueduct routes

CATEGORY	Weed invasion	Erosion
TYPE -see para. no.:	2 - ecosystem disruption	3 - ecosystem degradation
MAGNITUDE AND INTENSITY	· high	· high
EXTENT / SPATIAL SCALES	· local	· national
DURATION	· long term	· long term
SIGN · positive (+) · negative (-)	· negative	· negative
CERTAINTY	· definite	· definite
SIGNIFICANCE	· medium	· medium

2 Impact - Weedy species are associated with sites of ecological disturbance and perennial species, of this kind, will invade ecosystems adjacent to the construction sites. It is necessary, therefore, to rehabilitate construction sites and access roads, ensuring that low levels of infestation result from the construction phases. This problem will be especially marked in areas from which fire is excluded, thus special attention must be given to the rock outcrops associated with ridges, across which the aqueduct will pass. Invasion of veld by perennial exotics reduces the value of the resources and poses serious threats to rare taxa in the adjacent grasslands.

3 Impact - Erosion is a serious problem in both Valley Bushveld and Southern Tall Grassveld. The construction of aqueduct routes and access roads along steep gradients has the potential to exacerbate erosion in these areas. Without careful mitigation this will lead to veld degradation and this may ultimately impinge on the quality of the water produced by the project.

5 SUGGESTED MITIGATION

(Applicable to the impoundments)

- Conduct an EIA in which a study on the rare and endangered species of the basins will run across a number of seasons. This study should include GPS data so that rescue operations can be conducted despite dormancy of the plants concerned. It should also include an assessment of the parochial occurrence of the species above the flood lines.

- Include in an EIA a study of habitat requirements, breeding systems and germination aspects of the respective endangered species. When more information is available some rare and threatened plants will have to be rescued, transplanted and propagated.

- (Impact 4 and 5 applicable to Mielietuin and Jana) Commission a study on the autecology of *Vitelariopsis dispar* (both); *Ledebouria* sp. *nov* (Jana)*; Aloe* sp. nr. *zebrina* (Jana)*; Euphorbia pseudocactus* (Jana), below the impoundments. This study must:
  - (i) provide GPS data of existing populations
  - (ii) provide information on the occurrence of age classes within populations (to assess recruitment before damming),
  - (iii) provide data on breeding systems,
  - (iv) provide data on germination requirements,
  - (v) model suitable habitat.

- (Also applicable to the aqueduct routes) An active weed control program must be initiated to circumvent major problems which result from ecological disturbance associated with the construction of the aqueducts, dam walls and access roads. This project must include:
  - (i) an assessment of the current status of weed populations through aerial survey and ground truthing. GPS data must be provided.
  - (ii) an assessment of the dynamics of the weed population following the initiation of the project to gauge increases or decreases in existing stands
  - (iii) an investigation of mechanisms by which weeds are spreading within the system
  - (iv) a long term management proposal for weed control.

- Plant species of medicinal and craft importance. The parochial value of this resource should be quantified. An attempt should be made to predict the effect of increased harvesting from adjacent areas following the inundation of the dam basins. An ethnobotanical study should be initiated to monitor the impact of new harvesting on the adjacent vegetation, following the loss of the basin resource.

6 FURTHER INVESTIGATIONS REQUIRED

Further investigation on the taxonomy, conservation status and phytogeography of the following need to be addressed:

Ledebouria sp. nov.
Aloe sp. nr. *zebrina*
Euphorbia pseudocactus

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8 CREDENTIALS

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BSc. Natal University, 1983.
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PhD. Botany, Natal University, 1997 (Awarded the Captain Scott Medal for the top PhD in South Africa).

Research interests:
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Reports:

(i) Riparian vegetation of the Mpofana River and the potential impact of increased stream flow. SK&R for Umgeni Water Board.

(ii) Riparian vegetation of the Umkomazi River and the instream flow requirements. Umgeni Water Board.

(iii) The impact of the Mohale Dam on the availability of indigenous medicinal plants. Loxton, Venn and Associates.

C.R. Scott-Shaw
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Principal research interests:
(i) Population demography of rare and threatened plants.
(ii) Taxonomy of the KwaZulu-Natal flora, in particular the Euphorbiaceae.
(iii) Phytogeography of the summer rainfall area of southern Africa.
(iv) Plant diversity changes in response to different management in grasslands.
(v) Compilation of status reports on threatened plants.
(vi) Compilation of a "Red Data Book" for KwaZulu-Natal and the curation of this information in an electronic database.
(vii) An analysis of endemism in the KwaZulu-Natal flora.
(viii) Curation of the Killick Herbarium* including the identification of plant specimens.

* The Donald Killick Herbarium (CPF) is the KZNNCS central herbarium. It contains 23 000 specimens from the region's protected areas.

Reports:

(i) Scoping report on vegetation for Mosa Florestal - the following components in this afforestation project by SAPPI in southern Mocambique during 1995; descriptions and assessments of plant communities; compilation of species lists and species conservation status evaluations; production of vegetation map; production of a zonation map for areas of high conservation value. This was prepared for Loxton, Venn and Associates.

(ii) DWAF contract to evaluate the conservation value of the natural areas on state land in forestry areas of the former homeland forestry departments from the Northern Province to the Eastern Province. This included preparing a comparative rating system of each area's biodiversity attributes.

(iii) Botanical surveys and vegetation management plan for the Lesotho Highlands Development Authority (LHDA) projects working on the development of the two new nature reserves (National Parks) Bokong and Tsehlanyane - the botanical surveys, plant identifications and vegetation mapping; development of the management plans and drafting operational plans for fire management.

(iv) The 9 000ha afforestation project for Ho Ha Tribal Authority in the former Transkei - descriptions and assessments of plant communities; compilation of species lists and species conservation status evaluations; production of vegetation map; production of a zonation map for areas of high conservation value; proposals for management plans and Natural Heritage Sites.

(v) The botanical component of the following specialist assessments: the proposed Jana versus Klip Dam site selection.

(vi) Participant in the project: Streamlined Environmental Assessment for KZN - sections on forests; grasslands; important plant populations; important plant communities; important vegetation types. (For DWAF.)

(vii) Rare and threatened plants of KwaZulu-Natal and neighbouring regions. Published as a 200 page book.

9 GLOSSARY

Consociation - a hierarchal term of co-dominance in which one of the species displays dominant physiognomy

Decreaser species - palatable plant species which are selectively grazed and decrease under high stocking rates

Fasciation - equivalent to Braun Blanquet's 'Fascies' which is hierarchally refined to differentiate between communities with small but key differences

Hygrophilous - species which require high moisture levels during active growth

Increaser species - poorly palatable species which are avoided by most herbivores and increase under high stocking rates

Mesophytes - plants which are adapted to moderate habitats with respect to water availability

PRECIS - National Herbarium Pretoria computer information system

Pyrophytes - plant species specially adapted to survive fires, usually with the proliferation of subterranean organs

Refugium - a stable niche, little altered by the changes in the surrounding vegetation

Ruderal - pioneer species of disturbed areas

Xerophytic - plant species adapted to cope with arid environments

APPENDICES

APPENDIX 1: PLANTS OF MEDICINAL VALUE IN THE BASINS

APPENDIX 2: CRAFT PLANTS FROM THE MIELIETUIN BASIN

APPENDIX 3: SPECIES INVENTORY FOR MIELIETUIN BASIN

APPENDIX 4: SPECIES INVENTORY FOR JANA BASIN

APPENDIX 1

PLANTS OF MEDICINAL VALUE IN THE BASINS

APPENDIX 1. PLANTS OF MEDICINAL VALUE IN THE BASINS

1 *Acacia robusta*
2 *Acacia nilotica*
3 *Acacia seiberiana*
4 *Acacia tortilis*
5 *Acacia karroo*
6 *Acocanthera oppositifolia*
7 *Allophylus decipiens*
8 *Allophylus melanocarpus*
9 *Aloe spectabilis*
10 *Apodytes dimidiata*
11 *Asparagus africanus*
12 *Berchemia zeyheri*
13 *Boscia foetida* subsp. *longipedicellata*
14 *Boscia albitrunca*
15 *Buddleja saligna*
16 *Bulbine frutescens*
17 *Calpurnia aurea* subsp. *aurea*
18 *Capparis sepiaria* var. *citrifolia*
19 *Cassine transvaalensis*
20 *Cassine aethiopica*
21 *Ceratotheca triloba*
22 *Cheilanthes viridis*
23 *Chenopodium album*
24 *Chlorophytum comosum*
25 *Chlorophytum modestum*
26 *Clematis brachiata*
27 *Cleome monophylla*
28 *Clerodendrum glabrum*
29 *Clutia pulchella*
30 *Coddia rudis*
31 *Combretum erythrophyllum*
32 *Commelina africana*
33 *Corchorus asplenifolius*
34 *Cotyledon orbiculata*
35 *Crassula alba*
36 *Crassula rubicunda*
37 *Crinum macowanii*
38 *Croton gratissimus*
39 *Cyanotis speciosus*
40 *Cyperus esculentus*
41 *Cyphostemma hypoleucum*
42 *Cyphostemma natalitium*
43 *Cyrtanthus breviflorus*
44 *Cyrtanthus contractus*
45 *Dalbergia obovata*
46 *Datura stramonium*
47 *Dichrostachys cinerea*
48 *Diospyros lycioides*
49 *Diospyros whyteana*
50 *Dombeya cymosa*
51 *Drimiopsis maculata*
52 *Ehretia rigida*
53 *Elephantorrhiza elephantina*
54 *Elephantorrhiza woodii*
55 *Equisetum ramosissimum*
56 *Erianthemum dregei*
57 *Eriospermum abyssinicum*
58 *Euclea schimperi* var. *daphnoides*
59 *Euclea crispa*
60 *Eulophia ovalis*

61 *Euphorbia triangularis*
62 *Gazania linearis*
63 *Gerbera piloselloides*
64 *Grewia occidentalis* var. *occidentalis*
65 *Helichrysum oxyphyllum*
66 *Helichrysum rugulosum*
67 *Helinus integrifolius*
68 *Hibiscus aethiopicus*
69 *Hibiscus pusillus*
70 *Hippobromus pauciflorus*
71 *Huernia hystrix*
72 *Hypoxis multiceps*
73 *Hypoxis hemerocallidea*
74 *Imperata cylindrica*
75 *Indigofera velutina*
76 *Jasminum multipartitum*
77 *Kalanchoe rotundifolia*
78 *Kalanchoe crenata* subsp. *crenata*
79 *Ledebouria ovatifolia*
80 *Leonotis ocymifolia* var. *raineriana*
81 *Maytenus senegalensis*
82 *Maytenus heterophylla* ssp. *heterophylla*
83 *Maytenus undata*
84 *Mohria caffrorum*
85 *Monopsis decipiens*
86 *Mystacidium capense*
87 *Otholobium polystictum*
88 *Ozoroa paniculosa*
89 *Pappea capensis*
90 *Ptaeroxylon obliquum*
91 *Pelargonium alchemilloides*
92 *Pelargonium luridum*
93 *Pellaea calomelanos*
94 *Pleurostylia capensis*
95 *Polygala serpentaria*
96 *Polygala hottentotta*
97 *Priva cordifolia*
98 *Ptaeroxylon obliquum*
99 *Rhoicissus tridentata*
100 *Rhus chirindensis*
101 *Salvia runcinata*
102 *Sansevieria hyacinthoides*
103 *Scabiosa columbaria*
104 *Schizobasis intricata*
105 *Schotia brachypetala*
106 *Senna italica*
107 *Senna septemtrionalis*
108 *Spirostachys africana*
109 *Sutera atropurpurea*
110 *Sutera floribunda*
111 *Tapinanthus gracilis*
112 *Tapinanthus natalitius* subsp. *natalitius*
113 *Tarchonanthus camphoratus*
114 *Teucrium kraussii*
115 *Trimeria grandifolia* subsp. *grandifolia*
116 *Tritonia lineata*
117 *Vepris lanceolata*
118 *Vernonia oligocephala*
119 *Vernonia hirsuta*
120 *Viscum rotundifolium*
121 *Vitellariopsis dispar*
122 *Vitex rehmannii*

123 *Wahlenbergia grandiflora*
124 *Ziziphus mucronata*

APPENDIX 2

CRAFT PLANTS FROM THE MIELIETUIN BASIN

APPENDIX 2. CRAFT PLANTS FROM THE MIELIETUIN BASIN

1 *Acacia caffra*
2 *Acacia sieberiana*
3 *Aristida* spp.
4 *Berchemia zeyheri*
5 *Brachylaena elliptica*
6 *Buddleja saligna*
7 *Combretum apiculatum*
8 *Cussonia* sp.
9 *Dichrostachys cinerea*
10 *Dombeya cymosa*
11 *Ehretia rigida*
12 *Euclea crispa*
13 *Grewia occidentalis*
14 *Juncus kraussii*
15 *Olea europea* ssp. *africana*
16 *Pappea capensis*
17 *Ptaeroxylon obliquum*
18 *Schotia brachypetala*
19 *Spirostachys africana*
20 *Tarchonanthus camphoratus*
21 *Vepris lanceolata*
22 *Vitex rehmannii*
23 *Ziziphus mucronata*

APPENDIX 3

SPECIES INVENTORY FOR MIELIETUIN BASIN

APPENDIX 3. SPECIES INVENTORY FOR MIELIETUIN BASIN

TOTAL = 430

Abutilon grantii
Acacia ataxacantha
Acacia karroo
Acacia nilotica
Acacia robusta subsp. *robusta*
Acacia seiberiana
Acacia tortilis subsp. *heteracantha*
Acalypha glabrata var. *glabrata*
Acalypha villicaulis
Acalypha peduncularis
Acocanthera oppositifolia
Agapanthus campanulatus
Agrostis lachnantha var. *lachnantha*
Allophylus melanocarpus
Allophylus decipiens
Aloe mudenensis
Aloe ecklonis
Aloe greatheadii var. *davyana*
Aloe spectabilis
Aloe dominella
Aloe cooperi
Anthospermum pumilum
Anthospermum herbaceum
Antizoma angustifolia
Apodytes dimidiata var. *dimidiata*
Aptenia sp.
Argyrolobium molle
Argyrolobium tomentosum
Argyrolobium tuberosum
Aristida congesta
Arundinella nepalensis
Asclepias dregeana var. *calceola*
Asparagus cooperi
Asparagus suaveolens
Asparagus coddii
Asparagus virgatus
Asparagus plumosus
Asparagus africanus
Astragalus atropilosulus subsp. *burkeanus*
Barleria sp.
Barleria obtusa
Barleria greenii
Berchemia zeyheri
Berkheya erysithales
Blepharis integrifolia var. *integrifolia*
Blepharis longispica
Boscia albitrunca var. *albitrunca*
Boscia foetida subsp. *longipedicellata*
Bothriochloa insculpta
Brachylaena elliptica
Brachymenium acuminatum
Buddleja dysophylla
Buddleja saligna
Bulbine narcissifolia
Bulbine frutescens
Bulbostylis oritrephes
Bulbostylis scleropus
Calodendrum capense
Calpurnia aurea subsp. *aurea*
Canthium mundtianum
Capparis sepiaria var. *citrifolia*
Cassine aethiopica
Cassine transvaalensis
Cassinopsis ilicifolia
Cephalaria oblongifolia
Ceratotheca triloba
Ceropegia carnosa
Chaetacanthus burchellii
Chamaesyce inaequilatera
Cheilanthes viridis
Chenopodium album
Chenopodium schraderianum
Chionanthus foveolatus subsp. *foveolatus*
Chironia palustris
Chlorophytum modestum
Chlorophytum comosum
Clausena anisata
Cienfuegosia gerrardii
Clematis brachiata
Cleome monophylla
Cleome gynandra
Clerodendrum caeruleum
Clerodendrum glabrum
Clutia pulchella
Coccinia variifolia
Coddia rudis
Combretum apiculatum
Combretum erythrophyllum
Commelina africana
Commiphora harveyi
Corchorus asplenifolius
Cotyledon orbiculata
Crabbea acaulis
Crabbea hirsuta
Crassula lineolata
Crassula rubicunda
Crassula alba
Crassula lanceolata subsp. *transvaalensis*
Crassula pellucida
Crinum macowanii
Crinum bulbispermum
Crotalaria capensis
Croton gratissimus
Cuscuta campestris
Cyanotis speciosus
Cymbopogon excavatus
Cymbopogon marginatus
Cymbopogon plurinodis
Cymbopogon validus
Cynodon dactylon
Cyperus denudatus
Cyperus rubicunda
Cyperus difformis
Cyperus esculentus
Cyperus latifolius
Cyperus fastigiatus
Cyperus latifolius
Cyperus marginatus
Cyperus distans
Cyperus compactus
Cyphostemma hypoleucum
Cyphostemma humile
Cyphostemma natalitium
Cyphostemma woodii
Cyrtanthus galpinii
Cyrtanthus breviflorus
Cyrtanthus contractus
Dalbergia obovata
Dalechampia capensis
Datura stramonium
Denekia capensis
Dias coitnifolia
Dichondra repens
Dichrostachys cinerea
Dicliptera clinopodia
Digitaria eriantha
Diospyros lycioides
Diospyros whyteana
Dissotis canescens
Dombeya cymosa
Dovyalis zeyheri
Dovyalis caffra
Drimiopsis maculata
Echinochloa crusgalli
Echinochloa crus-galli
Ehretia rigida
Eleocharis dregeanus
Elephantorrhiza woodii
Elephantorrhiza elephantina
Equisetum ramosissimum
Eragrostis curvula
Eragrostis chloromelas
Erianthemum dregei
Eriocaulon abyssinicum
Eriosema lucipetalum
Eriosema kraussianum
Eriosema salignum
Eriospermum abyssinicum
Erythrina humeana
Erythroxylum pictum
Euclea crispa
Euclea schimperi var. *daphnoides*
Eulalia villosa
Eulophia ovalis
Euphorbia triangularis
Euphorbia striata var. striata
Euphorbia clavarioides var. *truncata*
Eustachys paspaloides
Felicia filifolia
Festuca caprina

Ficus sur
Ficus ingens
Ficus burtt-davyi
Fimbristylis dichotoma
Garuleum latiolium
Gazania linearis
Gerbera piloselloides
Gerbera ambigua
Gladiolus crassifolius
Gnidia meisnerianus
Gnidia caffer
Gnidia anthylloides
Grewia occidentalis var. *occidentalis*
Grewia hispida
Habenaria tridens
Heteropogon contortus
Helichrysum coriaceum
Helichrysum oxyphyllum
Helichrysum rugulosum
Helichrysum athrixiifolium
Helichrysum pallidum
Helichrysum hyphocephalum
Helichrysum lineare
Helinus integrifolius
Hemarthria altissima
Hermannia grandistipula
Hermannia parviflora
Heteromorpha arborescens var. *abyssinica*
Heteromorpha stenophylla var. *transvaalensis*
Heteropogon contortus
Hibiscus aethiopicus
Hibiscus trionum
Hibiscus pusillus
Hippobromus pauciflorus
Hoffmanseggia sandersoni
Huernia hystrix
Hyparrhenia cymbaria
Hyparrhenia filipendula
Hyparrhenia cymbaria
Hyparrhenia hirta
Hyparrhenia hirta
Hypericum aethiopicum
Hypoestes aristata
Hypoestes forskoalii
Hypoxis multiceps
Hypoxis hemerocallidea
Hypoxis rigidula
Imperata cylindrica
Indigastrum argyraeum
Indigifera torulosa
Indigofera acanthoclada
Indigofera tenuissima
Indigofera ionii
Indigofera velutina
Ipomoea crassipes
Ipomoea sinensis subsp. *blepharosepala*
Ipomoea oblongata
Ischaemum fasciculatum
Isoglossa grantii
Jasminum angulare
Jasminum multipartitum
Jasminum stenolobum
Jasminum breviflorum
Jatropha natalensis
Juncus lomatophyllus
Juncus oxycarpus
Juncus exsertus
Juncus effusus
Juncus punctorius
Justicia protracta
Kalanchoe crenata subsp. *crenata* var. *crenata*
Kalanchoe rotundifolia
Kedrostis africana
Kniphofialeariifolia
Ledebouria ovatifolia
Ledebouria asperifolia
Leonotis ocymifolia var. *raineriana*
Lepidium bonariense
Leucas martinicensis
Leucas capensis
Limosella longiflora
Limosella maior
Lippia javanica
Lycium cinereum
Maerua angolensis
Maerua caffra
Malva parviflora var. *parviflora*
Mariscus dregeanus
Mariscus congestus
Mariscus congesta
Matricaria nigellaefolia
Maytenus undata
Maytenus nemorosa
Maytenus peduncularis
Maytenus heterophylla subsp. *heterophylla*
Maytenus senegalensis
Maytenus tenuispina
Melasma scabra
Melinis nerviglumis
Melhania didyma
Melolobium microphyllum
Menodora africana
Miscanthidium capensis
Miscanthidium junceum
Miscanthus junceus
Mohria caffrorum
Monopsis decipiens
Myrsine africana
Mystacidium capense
Nolletia rarifolia
Ochna serrulata
Oenothera rosea
Olea europaea subsp. *africana*
Oligomeris dregeana
Ornithogalum sp.
Orthosiphon wilmsii
Orthosiphon suffrutescens
Orthosiphon labiatus
Osteospermum calendulaceum
Otholobium polystictum
Oxalis corniculata
Ozoroa paniculosa
Pachystigma macrocalyx
Panicum coloratum
Panicum deustum
Panicum volutans
Pappea capensis
Paspalum sp.
Pavetta cooperi
Pavetta lanceolata
Pavetta gardeniifolia var. *gardeniifolia*
Pelargonium luridum
Pelargonium alchemilloides
Pellaea calomelanos
Pennisetum thunbergii
Peristrophe cernua
Pentaschistis aurea subsp. *pilosogluma*
Persicaria serrata
Persicaria strigosum
Persicaria lapathifolium
Peucedanum caffrum
Phragmites australis
Phalaris arundinacea
Phyllanthus maderaspatensis
Phyllanthus glaucophyllus
Plectranthus hadiensis var. *tomentosus*
Plectranthus verticillatus
Plectranthus calycinus
Pleurostylia capensis
Poa binata
Pollichia campestris
Polygala gymnoclada
Polygala serpentaria
Polygala hottentotta
Premna mooiensis
Priva cordifolia
Ptaeroxylon obliquum
Pygmaeothamnus chamaedendrum var. *setulosus*
Ranunculus multifidus
Rhoicissus tridentata
Rhus dentata
Rhus pyroides
Rhus gerrardii
Rhus rehmanniana var. *rehmanniana*
Rhus chirindensis
Rhus pentheri
Rhynchosia reptabunda
Rhynchosia minima var. *prostrata*
Rhynchosia carribaea
Rhynchosia crassifolia
Rhynchosia totta
Rhynchosia confusa
Rotala sp.
Ruellia cordata

Ruellia baurii
Rumex sagittatus
Rumex lanceolatus
Salvia aurita var. *galpinii*
Salvia runcinata
Sansevieria hyacinthoides
Sarcostemma viminale
Scabiosa columbaria
Schizobasis intricata
Schizoglossum bidens
Schizoglossum decipiens
Schizostephium griseum
Schizostylis coccinea
Schkuhria pinnata
Schoenoplectus muricinux
Schotia brachypetala
Scirpus paludicola
Scirpus falsus
Scutia myrtina
Sebaea longicaulis
Secamone filiformis
Senecio glaberrimus
Senecio scoparius
Senecio digitalifolius
Senecio deltoideus
Senecio affinis
Senecio rhomboideus
Senna septemtrionalis
Senna italica
Sesbania punicea
Sida rhombifolia
Sideroxylon inerme
Silene pilosellifolia
Smodingium argutum
Solanum coccineum
Solanum incanum
Solanum tomentosum
Sorghum versicolor
Sphaerostylis sp.
Sporobolus capensis,
Sporobolus festivus
Sporobolus fimbriatus
Sporobolus pyrimidalis
Stachys natalensis var. *galpinii*
Stachys natalensis var. *natalensis*
Streptocarpus pentherianus
Streptocarpus cooksonii
Striga elegans
Suregada africana
Sutera noodsbergensis
Sutera floribunda
Sutera atropurpurea
Tapinanthus gracilis
Tapinanthus natalitius subsp. *natalitius*
Tarchonanthus camphoratus
Teramnus labialis subsp. *labialis*
Teucrium kraussii
Themeda triandra
Thesium cytisoides
Thunbergia neglecta
Thuranthos basuticum
Tortula muralis
Trachyandra saltii var. *saltii*
Trachyandra asperata var. *nataglencoensis*
Tragus racemosus
Trichoneura grandiglumis
Trimeria grandifolia subsp. *grandifolia*
Trimeria trinervis
Tritonia lineata var. *lineata*
Typha capensis
Vepris lanceolata
Verbena bonariensis
Verbena tenuisecta
Vernonia oligocephala
Vernonia hirsuta
Viscum rotundifolium
Vitellariopsis dispar
Vitex rehmannii
Vitex harveyana
Wahlenbergia paucidentata
Wahlenbergia grandiflora
Walafrida densiflora
Ximenia caffra
Xyris capensis
Zaluzianskya glareosa
Ziziphus mucronata

APPENDIX 4

SPECIES INVENTORY FOR JANA BASIN

APPENDIX 4. PROVISIONAL LIST OF WOODY PLANTS RECORDED FOR THE JANA DAM SITE BY R. SCOTT-SHAW 1999

Aloe arborescens 028.1 ALOACEAE 1026
Krantz Aloe; Kransaalwyn; iNhlaba-encane
Aloe spectabalis / marlothii 029.5 ALOACEAE 1026
Aloe; aalwyn; iNlaba
Aloe rupestris 030.3 ALOACEAE 1026
Bottlebrush Aloe; inKalane
Salix mucronata subsp. woodii 036.3 SALICACEAE 1873
Willow; umNyezane, umZekana
Celtis africana 039 ULMACEAE 1890
White stinkwood; Witstinkhout; umVumvu
Trema orientalis ULMACEAE
Ficus glumosa 064 MORACEAE 1961
African rock Fig; Afrikaanse rotsvy; iNkokhokho
Ficus ingens 055 MORACEAE 1961
Red-leaved rock Fig; Rooiblaarrotsvy; umDende, umDende-obomvu, isiGondwane, iNkokhokho
Ficus sur 050 MORACEAE 1961
Cape Fig; Kaapsevy; umKhwikwane
Ficus thonningii 048 MORACEAE 1961
Common Wild Fig; umThombi
Obetia tenax 071 URTICACEAE 1979
Tree nettle; Bergbrandnetel; uluZi, umDadi-omkhulu, imBokozembe
Pouzolzia mixta 070 URTICACEAE 1992
Soap nettle; Seepnetel; uDekane
Ximenia caffra 103 OLACACEAE 2136
Large sourplum; Groot suurprium; umThunduluka-omncane, umKholotshwana
Cryptocarya woodii 116 LAURACEAE 2813
Cape laurel; Kaapse kweper; umThongwane, umNgqabe, iNqayi-emnyama, isiLindangulube
Osrydicarpos schimperianus
Erianthemum dregei
Boscia albitrunca var. albitrunca 122 CAPPARACEAE 3106
Sheperd's Tree; Witgat; umVithi, isiNama
Boscia foetida subsp. rehmanniana 125 CAPPARACEAE 3106
Stink Shepherd's Tree; Stinkwitgat; umVithi
Capparis sepiaria CAPPARACEAE 3106
Maerua angolensis 132 CAPPARACEAE 3112
Bead-bean Tree; Knoppiesboontjieboom;; umEnwayo; umGodithi
Maerua cafra 133 CAPPARACEAE 3112
Common Bush-cherry; Gewone Witbos;; unTswantwsane
Maerua rosmarinoides CAPPARACEAE 3112

Acacia ataxacantha 160 MIMOSACEAE 3446
Flame Acacia; Vlamdoring; uThathawe, uBobhe
Acacia caffra 162 MIMOSACEAE 3446
Common Hook Thorn; Gewone Haakdoring; umTholo
Acacia karoo 172 MIMOSACEAE 3446
Sweet Thorn; Soetdoring; umuNga
Acacia nilotica 179 MIMOSACEAE 3446
Scented Thorn; Lekkerruikpeul; umNqawe
Acacia robusta 183 MIMOSACEAE 3446
Splendid Acacia, Ankle Thorn; Enkeldoring;; umNgamanzi
Acacia schweinfurthii 184.1 MIMUSACEAE 3446
River Climbing Thorn; Rivierrankdoring; uThathawe, uBophe
Acacia sieberiana var. woodii 187 MIMOSACEAE 3446
Paperbark Acacia; Papierbasdoring; umKhamba
Acacia tortilis ssp. heteracantha 188 MIMOSACEAE 3446
Umbrella Thorn, Haak-en-Steek; umSasane, umThwethwe, isiShoba
Dichrostachys cinerea 190 MIMOSACEAE 3452
Sickle Bush. Sekelbos; uGagane
Schotia brachypetala 202 CAESALPINIACEAE 3506
Tree Fuchsia, Weeping boer-bean; Huilboerboom; umGxamu, uVovovo, iHluze
Calpurnia aurea 219 FABACEAE 3607
Natal Laburnum; isiKhiphampethu, iNtsiphane-enkhulu, umHlahlambedu, umLalandlovana

Crotalaria capensis 224.1 FABACEAE 3669
Cape Rattle-pod; Kaapse Klapperpeul; uBukheshezane
Erythrina humeana 243.1 FABACEAE 3870
Dwarf Coral Tree; Kleinkoraalboom; umSinsana, iKati
Erythroxylum emarginatum 249 ERYTHROXYLACEAE 3956
Common coca Tree; Gewone kokaboom; iKhandalempakha, uBambematsheni, uPhaphane
Zanthoxylum capense 253 RUTACEAE 3991
Small Knobwood; Kleinperdepram; umNungwane,umNungumabele
Vepris lanceolata 261 RUTACEAE 4076
White ironwood, Witysterhout; uMozane, umZane, iSutha
Vepris reflexa 260 RUTACEAE 4076
Bastard white ironwood, Basterwitysterhout; uMozane
Clausena anisata 265 RUTACEAE 4091
Horsewood; Perdepis; umSanga, umNukambiba, isiFudu
Commiphora harveyi 277 BERSERACEAE 4151
Bronze paper Commiphora; Rooistamkannidood; umNyala, iHlunguthi, umBumbungane
Commiphora woodii 291 BERSERACEAE 4151
Forest Commiphora; Boskanniedood; umDe-wehlathi
Ptaeroxylon obliquum 292 PTAEROXYLACEAE 4157
Sneezewood; Nieshout; umThathe, uBhaqa
Ekebergia capensis 298 MELIACEAE 4193
Cape Ash; Essenhout; umNyamathi, umGwenya-wezinja, uVungu, uMathunzini-ye-zintaba
Croton gratissimus 328 EUPHORBIACEAE 4348
Lavender croton; Laventelkoorsbessie; umaHlabakufeni, uHubeshane
Acalypha glabrata 335.1 EUPHORBIACEAE 4407
Forest False-nettle; Bosvalsnetel; uThobothi
Clutia pulchella EUPHORBIACEA 4448
Warty-friuted Lightning Bush; Gewone Bliksembos; umEmbesa
Surega africana 338 EUPHORBIACEAE
Spirostachys africana 341 EUPHORBIACEAE 4478
Tamboti; Tambotie; umThombothi
Jatropha hirsuta
Jatropha natalensis
Jatropha sp.
Euphorbia evansii 348 EUPHORBIACEAE 4498
Small-toothed Euphorbia; isiPhapha; uHlonhlo
Euphorbia ingens 351 EUPHORBIACEAE 4498
Candelabra Tree; Gewone naboom; umHlonhlo, uMahetheni
Euphorbia pseudocactus EUPHORBIACEAE 4498
Euphorbia tirucalli 355 EUPHORBIACEAE 4498
Pencil euphorbia; umDuze, umSululu, umDe-wehlathi, uMunde
Euphorbia triangularis 356 EUPHORBIACEAE 4498
River euphorbia; Driehoekmelkbos;
Sclerocarya birrea subsp. caffra 360 ANACARDIACEAE 4558
Marula; Maroela; umGanu
Ozoroa paniculosa 375 ANACARDIACEAE 4589
Common Resin Tree; Gewone haarpuisboom; isiFice
Rhus chirindensis 380 ANACARDIACEAE 4594
Red Currant; Bostaaibos; iNhlokoshiyane-enkulu, iKhathabane
Rhus dentata 381.1 ANACARDIACEAE 4594
Nana berry. Nanabessie; umHlalamvubu
Rhus gerrardii 384.1 ANACARDIACEAE 4594
River currant; riviertaaibos;
Rhus lucida 388.1 ANACARDIACEAE 4594
Glossy currant; Blinktaaibos;
Rhus pentheri 391 ANACARDIACEAE 4594
Common crow-berry; Gewone kraaibessie; iNhlokoshiyane
Rhus pyroides 392 ANACARDIACEAE 4594
Common wild currant; Gewone taaibos; iNhlokoshiyane
Rhus rehmanniana 393.1 ANACARDIACEAE 4594
Blunt-leaved taaibos; Stompblaartaaibos;
Rhus rigida ANACARDIACEAE 4594

Gymnosporia buxifolia [=Maytenus heterophylla] 399 CELASTRACEAE 4625
Common spike-thorn; Gewone pendoring; uSolo, iNgqwangane, isiBhubhu, isiHlangu
Gymnosporia macrocarpa ined. [=Maytenus nemorosa] 399.3 CELASTRACEAE 4625
Gymnosporia nemorosa [=Maytenus nemorosa] 399.3 CELASTRACEAE 4625
White forest spike-thorn; Witbospendoring; iNgqwangane
Maytenus acuminata 398 CELASTRACEAE 4625

Silky-bark; Sybas; isiNama
Maytenus peduncularis 401 CELASTRACEAE 4625
Blackwood; Swarthout; umNqayi
Maytenus undata 403 CELASTRACEAE 4625
Koko Tree; Kokoboom; iDohame, iNqayi-elibomvu

Cassine eucleiformis [=>Robsonodendron eucleiformis] 413 CELASTRACEAE 4641
White silky bark; Witsybas;
Cassine transvaalensis [=>Eleodendron transvaalensis] 416 CELASTRACEAE 4641
Transvaal saffronwood; Transvaalsaffraan; iNgwavuma, iNqotha
Mystroxylon aethiopicum [=Cassine aethiopica] 410 CELASTRACEAE 4641
Kooboo-berry; Koeboebessie; umNqayi, umGunguluzampunzi
Pleurostylia capensis 419 CELASTRACEAE 4641
Coffee Hardpear
Apodytes dimidiata 422 ICACINACEAE 4686
White Pear; Witpeer; umDakane
Allophylus africanus 425 SAPINDACEAE 4734
African allophylus; umHlohlela
Pappea capensis 433 SAPINDACEAE 4784
Dopprium; Dopprium; umQhokwane
Hippobromus pauciflorus 438 SAPINDACEAE 4836
Basterperdepis; uQhume, isiPhahluka
Ziziphus mucronata 447 RHAMNACEAE 4861
Buffalo-thorn; Blinkblaar-wag-'n-bietjie; umPhafa, umLahlankosi
Berchemia zeyheri 450 RHAMNACEAE 4868
Red ivory; Rooi-ivoor; umNeyi, umNcaka, umNini
Scutia myrtina 451 RHAMNACEAE 4874
Cat-thorn; Katdoring; uSondela, isiBinda
Heteropyxis natalensis HETEROPYXIDACEAE
Rhoicissus tridentata
Grewia hispida 458? TILIACEAE 4966
Grewia flava 459.1 TILIACEAE 4966
Brandy bush
Grewia occidentalis 463 TILIACEAE 4966
Cross-berry; Kruisbessie; iLalanyathi, iManhlele, iKlolo
Dombeya cymosa 469 STERCULIACEAE 5053
Natal Dombeya; Nataldrolpeer; iBunda
Dombeya rotundifolia 471 STERCULIACEAE 5053
Wild pear; Gewone drolpeer, Dikbas; iNhlinziyo-enkulu
Scolopia zeyheri 498 FLACOURTIACEAE 5296
Thorn pear; Doringpeer; iDungamuzi-lehlati
Trimeria grandifolia 503 FLACOURTIACEAE 5315
Wild Mulberry; Wildermoerbei; iDebelendlovu
Dais cotinifolia 521 THYMELIACEAE 5465
Pompon Tree; Basboom; inTozwane-emnyama
Combretum erythrophyllum 536 COMBRETACEAE 5538
River Bush-willow; Vaderlandswilg; umBondwe, umDubu
Combretum kraussii 540 COMBRETACEAE 5538
Red-leaf Bush Willow. Rooiblaar; umDubu-wehlathi
Cussonia spicata 564 ARALIACEAE 5872
Cabbage Tree; Gewone kiepersol; umSenge
Heteromorpha trifoliata 568 APIACEAE 5992
Parsely Tree; Wildepieterseliebos; umBhangandlala
Vitellariopsis dispar 589 SAPOTACEAE 6386
Tugela milkwood; Tugelabastermelkhout;
Diospyros lycioides ssp. guerkei 605.2 EBENACEAE 6404
Bluebush; Bloubos; umNqandane
Diospyros whyteana 611 EBENACEAE 6404
Bladder-nut, Black bark; Bostolbos, Swartbos; uManzimane, umNqandane
Euclea crispa 594 EBENACEAE 6404
Bush Gwarri, Bloughwarrie; iShekisane, iDungamuzi, isiZimane, umNqandane
Euclea racemosa ssp. zuluense [= E. schimperi] 600 EBENACEAE 6404
Bush guarri; Bosgwarrie; iChitamuzi
Olea europaea ssp. africana 617 OLEACEAE 6434
Wild Olive; Swartolienhout; umSinsi, umNqumo
Chionanthus foveolatus
Jasminum multipartitum
Jasminum breviflorum
Jasminum stenolobium

Nuxia oppositifolia 635 OLEACEAE 6469
River nuxia; Watervlier; iNkhweza
Buddleja saligna 636 OLEACEAE 6473
Witolienhout; iGqeba-elimhlope
Acokanthera oppositifolia 639 APOCYNACEAE 6558
Common poison-bush; Gewone gifboom; inHlungunyembe
Ehretia rigida 657 BORAGINACEAE 7043
Puzzle Bush; Deurmekaarbos; umHlele, iSalanyathi
Premna mooiensis 658 VERBENACEAE 7185
Skunkbush; Muishondbos; umTshetshembane
Vitex rehmannii 664 VERBENACEAE 7186
Pipe-stem Tree; Pypsteelboom; umLuthu, umDuli, umBhendula
Clerodendrum glabrum 667 VERBENACEAE 7191
White cat's whiskers; Haarpuisblaar; iFamu, umNukalembeba
Coddia rudis 689.1 RUBIACEAE 8283
Small bone-apple. Kleinbeenappel; umDondwane, umGogwane
Canthium mundianum 710 RUBIACEAE 8352
Rock alder; Klipels; umNgalambele
Pavetta gardeniifolia 716 RUBIACEAE 8383
Common Bride's Bush; Gewone bruidsbos;
Brachylaena elliptica 725 COMPOSITAE 8936
Bitter leaf; Bitterblaar;
Tarchonanthus camphoratus 733 COMPOSITAE 8937
Camphor Bush; Kanferbos; iGqeba-elimhlope

REVIEW

Peer Review

on

Thukela Water Project Feasibility Study: Plant Biodiversity Baseline Study

Introduction

From the ***Background document and Environmental Issues Report*** it is clear that the feasibility study in the brief from DWAF, was to identify and define all pertinent issues affecting the project, indicate nature of solutions, but not to actually solve the problems. The outcome of the Feasibility Study should provide DWAF with information required to make strategic selection between the TWP and other development options. However uncertainties would make it impossible to conclude the Feasibility Study with definite development proposals. This study should then provide a framework of development options within which a decision can be made once uncertainties are cleared up.

The Plant Biodiversity Baseline study should identify and evaluate the consequences of embarking on implementation of the project on environmental issues, specifically on the plant biodiversity on landscape, plant community and species levels. It is understood that this is a Feasibility Study, not intended to be an EIA, though that the findings of the Feasibility Study should provide guidelines to the decision makers with regard to the vegetation and plant diversity in the area concerned.

Some important issues were not explicitly mentioned in the TOR, e.g. access roads, service link roads, construction camps (with associated facilities), realignment of roads.

Review Report

I studied the report in terms of the criteria provided by the Institute of Natural Resources. Following these criteria, this review includes the following issues:

Compliance with Terms of Reference

Compliance with the TOR is evaluated for the three sites separately (Jana, Mielietuin and Conveyance Route). The evaluation is summarised Tables 1-3. The structure and content of the report was also evaluated in terms of the TOR and the evaluation is summarised in Table 4.

Table 1: An evaluation of Compliance to TOR for the proposed Jana Dam site

1. Jana Dam	Assessed	Comment
• Describe Terrestrial Environment		Basically described though see comments below
Landscape level	Yes	Too little information given on plant biodiversity – e.g. • no list of PRECIS given for this area • 200 species recorded (grasses excluded) – though no list given • no landscape map - which landscapes are present, which are important in terms of plant diversity
Community Level	Yes	• Map provided – though mapped vegetation types not listed or discussed. • Table 4.3 neither explained nor discussed • Little information on plant diversity on this level
Species Level	Yes	Adequate
• Priority, keystone, indicator, dominant species and populations	Yes	Given at species level only
• Conservation importance species areas		 Not adequately or clearly stated, though some comments hidden in the text (p7) Hotspot areas were identified
• Rare, threatened and	Yes	Adequate

endemic species		
• Species of significant traditional importance to man	Yes	Adequate
• Habitats and ecological processes required for population maintenance	No	Nothing is reported on processes, e.g. flooding, erosion, changes in runoff etc
• Description and evaluation of **impacts** on terrestrial biodiversity (Criteria and Terminology Table 1 Landscape level Community Level Species Level	Yes	General Impacts for the two basins and conveyance routes combined – this is considered as inadequate – Impacts should be **more specific** and given **separately** for the two dams and the conveyance routes Impacts were listed and Tabled No Impacts were listed and Tabled
• Mitigation measures	Yes	Totally inadequate
• Further investigations	Yes	Also listed under mitigation
• Guidelines for pre- and post dam monitoring	No	Not provided

Table 2: An evaluation of Compliance to TOR for the proposed Mielietuin Dam site

2. Mielietuin Dam	Compliance	Comment
• Describe Terrestrial Environment		Basically described though see comments below
Landscape level	Yes	Too little information given on plant biodiversity • no landscape map - which landscapes are present, which are important in terms of plant diversity • list of PRECIS is given for this (Mielietuin) area
Community Level	Yes	• No Map provided • Communities discussed from literature - adequate • Some information on plant diversity on this level given
Species Level	Yes	Adequate PRECIS list provided
• Priority, keystone, indicator, dominant species and populations	No	No information given
• Conservation importance species areas	No	No information given
• Rare, threatened and	Yes	Discussed under paragraph 4.4; move to 4.1

endemic species		
• Species of significant traditional importance to man	Yes	Adequate
• Habitats and ecological processes required for population maintenance	No	Nothing is reported on processes, e.g. flooding, erosion, changes in runoff etc
• Description and evaluation of impacts on terrestrial biodiversity (Criteria and Terminology Table 1 Landscape level Community Level Species Level	Yes	General Impacts for the two basins and conveyance routes combined – this is considered as inadequate – Impacts should be more **specific** and given **separately** for the two dams and the conveyance routes Impacts were listed and Tabled No Impacts were listed and Tabled
• Mitigation measures	Yes	Totally inadequate
• Further investigations	Yes	Also listed under mitigation
• Guidelines for pre- and post dam monitoring	No	Not provided

Table 3: An evaluation of Compliance to TOR for the proposed Conveyance Routes

3. Conveyance Routes	Compliance	Comment
• Describe Terrestrial Environment		Basically described under paragraph 4.5 A map indicating the routes on Acocks or Low & Rebelo maps would be useful
Landscape level	Yes	• No landscape map - which landscapes are present, which are important in terms of plant diversity • Several lists of PRECIS are given for the route – this is well addressed and adequate
Community Level	No	• Not discussed
Species Level • Priority, keystone, indicator, dominant species and populations	Yes	Adequate PRECIS lists provided with reference to species of conservation value
• Conservation importance species areas	Yes Yes Yes	 Given in PRECIS lists Briefly mentioned
• Rare, threatened and endemic species	Yes	Given in PRECIS lists

• Species of significant traditional importance to man	No	Not addressed for the conveyance routes
• Habitats and ecological processes required for population maintenance	No	Nothing is reported on processes, e.g. flooding, erosion, changes in runoff etc
• Description and evaluation of impacts on terrestrial biodiversity (Criteria and Terminology Table 1 Landscape level Community Level Species Level	Yes	General Impacts for the two basins and conveyance routes combined – this is considered as inadequate – Impacts should be more specific and given separately for the two dams and the conveyance routes Some impacts also loosely given on p15 Impacts were listed and Tabled, Some impacts also loosely given on p15 No Impacts were listed and Tabled
• Mitigation measures	Yes	Totally inadequate
• Further investigations	Yes	Also listed under mitigation
• Guidelines for pre- and post dam monitoring	No	Not provided

Further Comments

In my opinion the report is balanced, impartial and unbiased, and it does contain most of the information needed for decision making – It is, however, not adequately comprehensive in terms of the TOR. Although the reporters attempted to give an interpretation of the vegetation of the three sites, the report is not structured well, there is a lack of logical train of thought, and the message to the decision makers becomes unclear.

More photographs to illustrate certain viewpoints, landscapes, vegetation types, riverine vegetation, pristine communities, degraded communities, hotspots, beautiful areas e.g. cliffs, would be very useful (compare Animal Report).

The three sites should be assessed **<u>independently</u> with regard to all aspects** mentioned in the TOR.

The following comments may assist in improving the structure of the report:

For <u>each</u> site give the following:

Landscape level

- Give maps of geology, land type and landscape types (etc.), all available in digital form in e.g. EMPAT, to indicate the diversity (especially in topography, geology and soils, as determinants of vegetation types and species distribution) as given in paragraph 6.1.5 of the *Background Report and Environmental Issues Report*. Indicate the locality of the relevant site, and also the conveyance route alternatives. Also indicate conservation areas and the Biosphere Reserve. Present these maps, even if there is no apparent variation, (e.g. in geology), as this provides the background to the reader and is also valuable information for the decision making process.
- Then follows the description of the vegetation, from literature and supplemented by (limited) field work on the landscape level, as already given:
    - for the Jana Basin under point 4.2.1 (p7-8) - this is **adequate** in the report;
    - for the Mielietuin Basin under point 4.1 (p4) - this is **not adequate** in the report;
    - for Conveyance area under point 4.5 (p15 & 30) – this could be **improved** in the report.

- Then give the PRECIS list (for the relevant site – each site independently) to illustrate species diversity for the particular landscapes represented in the relevant grid:
    - not given for the Jana Basin;
    - given for the Mielietuin Basin under Appendix 3;
    - given for the Conveyance area p16-29).

Community Level

- Then give a literature overview of plant communities described -
    - for the Jana Basin under point 4.2.1 (p9-10) - this is **inadequate** in the report, improve and supplement Table 4.3 and cross reference to the vegetation map provided;
    - for the Mielietuin Basin under point 4.1 (p4-7) - this is **adequate** in the report;
    - **inadequate** for the Conveyance Area.

Species Level

Here provide the information on total species richness (from PRECIS + field observation) and include the data on Red Data Species, Hotspot, Noteworthy Species, Endemics, etc.

- The information for Jana Basin (point 4.2.3, p10-12) is **adequate**
- for Mielietuin **inadequate,** extract information from Appendix 3 and provide as for Jana;
- for the Conveyance Area – **adequate**.

Give a **conclusion** for each of the sites don't leave this for the decision makers –they may make a wrong interpretation!

The **Impacts, Alternatives, Mitigation and Further Investigation** were not presented well, even acknowledging the fact that this study is on the Feasibility Level, and not Impact Assessment Level. Surely all possible impacts were not addressed. If the impact will destroy the vegetation (in the case of the dams) then say so! What will impacts be during construction (with roads, construction camps, accommodation with toilets, washing facilities kitchen etc). The impacts of development on the vegetation and plant species at the two dam sites are basically similar and can be grouped. The impacts of the conveyance area will be quite different, and it will be different for the various options (canal or pipeline or both) will also be different. These should be addressed in much more detail.

Under **mitigation**, suggest mitigation actions for **each** impact identified. Under point 6 (Mitigation p34) two of the three paragraphs should be placed under point 7 (Further Investigations p34). If no mitigation measures are possible, due to what-ever constraints, then say so! Express an opinion that (when more information is available) certain plant rare and threatened plant species will have to be rescued, transplanted, removed to other sites, research done on reproduction and mass production (tissue culture) etc.

Under Species with traditional significance to man – (point 4.3 p 12) refer to Appendix 1&2, or include the species lists under this paragraph.

Ecological Processes were not addressed e.g.

- some notes on the importance of e.g. periodic **flooding** to maintain certain riverine plant communities,
- how would some impacts cause **erosion** and how would this influence ecological processes (e.g. succession) and the quality of grazing (this was mentioned briefly, but not under the correct heading).

The structure and content of the report was also evaluated in terms of the TOR and the evaluation is summarised in Table 4.

Table 4. Reporting

Category	Given in Report	Comments
Summary	Yes	Not well structured
Purpose of document	Yes	Does not cover all aspects requested in Terms of Reference
Approach and Methods	Yes	Adequate – though not so well structured
Description of Current situation	Yes	Adequate
Sensitivity of Affected Environment	Partly	Inadequate
Aspects that will influence environment	Partly	Inadequate
Impact Assessment	Yes	Inadequate
Summary Assessment Table	Yes	Based on Inadequate assessment of possible impacts
Mitigatory Actions	Yes	Inadequate
List of References	Yes	Adequate
List of Tables, Figures and Appendices	No	Not given

Conclusion

Although most of the information needed is given, some parts are inadequate. The structure of the report is the biggest problem. I suggest that the report be restructured before it is accepted.

21/3/2000

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KZN NATUURBEWARINGSDIENS

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To The Project Coordinator
Institute of Natural Resources

13 July 2000

Dear Sir

Re: Thukela Water Project Flora Specialist Study - Response to reviewers report

I confirm that the all recommendations made by the reviewer Prof. G. Bredencamp that pertain to my sections of the final report were taken up and the report duly amended and improved upon.

Yours sincerely

Rob Scott-Shaw
Plant Ecologist

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Pietermaritzburg

Faculty of Science
Department of Botany

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3.7.2000.

Dear Jenny

Thanks for the reviewer's comments, in many instances they have helped focus our report. I have implemented most of the suggestions. I list the main issues that I was not able, or prepared, to ammend:

1) It is not possible to augment the data on the biodiversity of the canal routes without a considerably larger budget with respect to time (in the appropriate season).

2) I have not addressed the question of 'Ecological Processes' within the flooded area as, clearly, these will no longer be functional.

3) With respect to mitigation against decimation of rare species we have made initial suggestions. Clearly this is a huge item which will need extensive investigation, well beyond the brief of this report. The suggestion, by the reviewer, that tissue culture be utilized is rejected, as this is an expensive technique which targets clonal propagation. The interests of genetic conservation are much better served by the relocation of as many individuals as possible, in order to best represent allelic diversity.

4) The 'hotspot' data is only appropriate if groups of rare species occur in close proximity. This is the case at Jana where the vegetation has not been extensively exploited. At Mielietuin the vegetation has been utilized for a considerable time and identifiable 'hotspots' were not apparent.

Please feel free to contact me if any of the above points need clarification.

Your sincerely

[signature] Edwards

REVIEW

Peer Review

on

Thukela Water Project Feasibility Study: Animal Biodiversity Baseline Study

Introduction

From the ***Background document and Environmental Issues Report*** it is clear that the feasibility study in the brief from DWAF, was to identify and define all pertinent issues affecting the project, indicate nature of solutions, but not to actually solve the problems. The outcome of the Feasibility Study should provide DWAF with information required to make strategic selection between the TWP and other development options. However uncertainties would make it impossible to conclude the Feasibility Study with definite development proposals. This study should then provide a framework of development options within which a decision can be made once uncertainties are cleared up.

The Animal Biodiversity Baseline study should identify and evaluate the consequences of embarking on implementation of the project on environmental issues, specifically on the animal biodiversity on landscape, plant community and species levels. It is understood that this is a Feasibility Study, not intended to be an EIA, though that the findings of the Feasibility Study should provide guidelines to the decision makers with regard to the animal diversity in the area concerned.

Review Report

I studied the report in terms of the criteria provided by the Institute of Natural Resources. Following these criteria, this review includes the following issues:

Compliance with Terms of Reference

Compliance with the TOR is evaluated for Jana and Mielietuin combined and is summarised Table 1. The Conveyance Route was not adequately addressed due to time constraints.

The structure and content of the report was also evaluated in terms of the TOR and the evaluation is summarised in Table 3.

Table 1: An evaluation of Compliance to TOR for the proposed Jana and Mielietuin Dam sites

1. Jana and Mielietuin Sites	Assessed	Comment
• Describe Terrestrial Environment		Basically described though see comments below
Landscape level	Yes	• Paragraph 4.1
Community Level	No	• Not Applicable for animals
Species Level	Yes	Adequate
• Priority, keystone, indicator, dominant species and populations	Yes	Adequate
• Conservation importance	Yes	
species		Adequate
areas		Adequate
• Rare, threatened and endemic species	Yes	Adequate
• Species of significant traditional importance to man	No	But see p7-9 and p44-45 where the issues are addressed
• Habitats and ecological processes required for population maintenance	Yes	Adequate

• Description and evaluation of **impacts** on terrestrial biodiversity (Criteria and Terminology Table 1	Yes	Adequate
Landscape level		Impacts were listed and Tabled in various smaller tables
Community Level		No not applicable
Species Level		Impacts were listed and Tabled
• Mitigation measures	Yes	Adequate
• Further investigations	Yes	Adequate
• Guidelines for pre- and post dam monitoring	No	Not provided

Further Comments

In my opinion the report is balanced, impartial and unbiased. However, the comments quoted from Costanza et al. 1997 is unnecessary as this creates the impression of partiality and bias.

It seems that the report covers the two dam sites adequately, and the structure of the report suggests that separate reports for the two sites are not necessary. However, the conclusion given on p 27 creates the impression that the two sites were indeed compared, (and in the methods it is stated that they were indeed visited separately) and that the Mielietuin site was found to be "far less important". A paragraph to emphasise and motivate this conclusion, linked with the data presented in Table 5.1, would clarify this issue. Give a clear **conclusion** for each of the sites don't leave this for the decision makers –they may make a wrong interpretation!

The Conveyance Area was not assessed adequately and the report on this part of the TOR is inadequate. The authors do, however, explain why this issue was not addressed.

In general, however, the report contains sufficient information that may be used in the decision making process. There is a logical train of thought throughout, and the results are clear. Complex issues received attention and treatment in the report.

The photographs provided are of great use and assistance for the reader to interpret the landscape and the area.

The structure and content of the report was also evaluated in terms of the TOR and the evaluation is summarised in Table 4.

Table 4. Reporting

Category	Given in Report	Comments
Summary	Yes	Adequate
Purpose of document	Yes	Adequate
Approach and Methods	Yes	Adequate
Description of Current situation	Yes	Adequate
Sensitivity of Affected Environment	Yes	Adequate
Aspects that will influence environment	Yes	Adequate
Impact Assessment	Yes	Adequate
Summary Assessment Table	Yes	Various small tables which address various aspects and various species
Mitigatory Actions	Yes	Adequate
List of References	Yes	Adequate
List of Tables, Figures and Appendices	Yes	Adequate

Conclusion

This report is considered as adequate, and suggestions on only minor issues are made. I suggest that the report be accepted.

TO: J MANDER
INR
PB X01 SCOTTSVILLE
3200

FROM: O. BOURQUIN
SPECIES SURVEYS
PO BOX 1083 HILTON
3245

30 March 2000.

Dear Jennifer,

FINAL REPORT: FAUNAL SURVEY - TUGELA.

Thank you for review by Professor Bredenkamp, which I received yesterday.

1. Comment re. Costanza (1997) reference.

The quote from Costanza (1997) was specifically included following the first review remarks. These left me the impression that the reviewer was perhaps not fully aware of the concept and value of biodiversity in its full sense. I believe the quote to be a valid part of the report as it underlines the fundamental importance and value of our natural heritage, expressed by biodiversity, to all South Africans. I have simply quoted an appropriate reference, and hope that I do not, by doing so, display " partiality and bias". Professor Bredenkamp has, in any event, kindly indicated that the report is impartial, balanced and unbiased.

2. On page 1 please insert, at the end of 1., the following:
My professional opinion is that a dam should not be built on the Jana site, unless further surveys indicate that the impacts outlined in the report would not be as severe as indicated.

3. On page 1 please insert, at the end of 2., the following:
My professional opinion is that a dam could be built on the Mielietuin site without serious adverse effects to the animal biodiversity. However I would specifically recommend a survey of millipedes and earthworms in areas adjoining the proposed full capacity levels of the dam to confirm the presence of the new, or probably new species there.

4. I have noted errors and changes to the text on the hard copy on the following pages: Cover page, p.ii, 22, 27, 31, 43, 48, 49, 56, 57, 83, 84 an 109. Many of the changes result from a confirmation (by Dr. G. Bronner) that the golden mole is indeed Marley's golden mole. On page 49 the following reference needs to be included:

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1977. The value of the world's ecosystem services and natural capital. Nature, 387 : 253-260.

Thank you,

O.Bourquin

THUKELA WATER PROJECT FEASIBILITY STUDY

ANIMAL DIVERSITY BASELINE STUDY

Prepared by

O. BOURQUIN, SPECIES SURVEYS

Contributions from

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SUMMARY

The findings were as follows:

1. Within the little time available to do the investigation, it appears from the results that the Jana site has some important biological characteristics and species. These include:
   (i) an area of the KwaZulu-Natal (KZN) endemic veld-type, the northern form of Valley Bushveld, of which less than one-third of the original area is left, and of which a relatively large portion appears to be in good condition in the dam site. The impacts of a dam at Jana would be high, with some impacts on an international level, and with little apparent mitigation possible.
   (ii) representatives of animals which appear to have become "captured" in the middle Thukela Basin by the changing KZN landscape during the last few million years, and have either formed endemic species, or isolated populations of more widely spread species.
   (iii) at least 42 species important to conservation (5 mammals, 10 birds, 4 reptiles, 9 molluscs, 9 millipedes, 2 dragonflies and 3 butterflies) with the strong possibility of further important species being found.

   My professional opinion is that a dam should not be built on the Jana site, unless further surveys indicate that the impacts outlined in the report would not be as severe as indicated.

2. The Mielietuin site was considered to be less important biologically - it is smaller, has more disturbed habitats and contains species which are more than likely conserved in the adjoining Weenen Game Reserve. Even so it has representatives of at least 30 species important to conservation (3 mammals, 4 birds, 3 reptiles, 1 earthworm, 9 molluscs, 6 millipedes, 1 dragonfly and 3 butterflies).

   My professional opinion is that a dam could be built on the Mielietuin site without adverse effects to the animal biodiversity. However, I would specifically recommend a survey of millipedes and earthworms in areas adjoining the proposed full capacity levels of the dam to confirm the presence of the new, or probably new species there.

3. It is recommended that further surveys are conducted to find out if
   (i) there are other important species at Jana, in particular the more sedentary species;

(ii) what the distribution of those species is in terms of the dam site and of the surrounding areas, so that a better judgement can be made of the effects of flooding the area.

4. The theory that the middle Thukela Basin is a site representing a centre of speciation for some groups resulting from geological and landscape processes, thereby deserving conservation as demonstrating an ecological and evolutionary principle, as well as having endemic species, needs to be studied.

5. A major limitation of the investigation was the lack of time given to do the job. Many species are seasonal, or are strongly influenced by rainfall and temperature patterns. To obtain good results for a faunal study, sampling during at least two seasonal cycles would probably be necessary.

6. For some work it is necessary to stay on site for up to a week to get best results. Basic facilities (electricity, water, roofed accommodation and security) are required for this.

1 PURPOSE OF DOCUMENT AND TERMS OF REFERENCE

For the proposed Jana and Mieleietuin dam basin areas, below final water level line.

- Describe the mammals, birds, reptiles, amphibia, and selected invertebrate groups under the following parameters:
    - priority, keystone and, indicator and dominant species and populations
    - conservation importance
    - conservation status
    - importance to man
    - habitats and ecoprocesses required for population maintenance.
- Describe and evaluate the impact that the completed dams will have on the listed animal populations and communities within the dam basins (Table 1.1).
- Indicate any mitigatory actions which could be used to counteract undesirable ecological effects following completion of dams.
- Indicate requirements for further investigations in the area.

Although it was required that the aqueduct routes should be examined the time available, (1/11 - 31/12/99) was simply not long enough to do this. However, comments on the routes are made under Section 5, Descriptions of Impacts.

Table 1.1: Conventions for definitions and terminology used in the description, evaluation and assessment of environmental impacts

Category	Description or Definition
Type	A brief written statement, conveying what environmental aspect is impacted by a particular project activity or action, or policy or statutory provision.
Magnitude and Intensity · very high · high · moderate · low · no effect · unknown	The severity of the impact - Complete disruption of process; death of all affected organisms; total demographic disruption - Substantial process disruption, death of many affected organisms; substantial social disruption - Real, measurable impact, which does not alter process or demography - Small change, often only just measurable - No measurable or observable effect - Insufficient information available on which to base a judgement
Extent / Spatial Scales · international · national · regional · local	The geographical extent or area over which the direct effects of the impact are discernable, i.e. the area within which natural systems or humans directly endure the effects of the impact. - Southern Africa - South Africa - KwaZulu-Natal and the Thukela catchment, the uThukela region - dam basin, conveyance servitude, river reach, specific site locality
Duration · short term · medium term · long term	The term or time period over which the impact is expressed, **not** the time until the impact is expressed. Where necessary the latter must be specified separately. - up to 5 years (or construction phase only) - 5 to 15 years 9 (or early commissioning and operational phases) - > 15 years (or operational life)
Sign · positive (+) · negative (-)	Denotes the perceived effect of the impact on the affected area beneficial impacts impacts which are deleterious
Certainty · improbable · probable · definite	A measure of how sure, in the professional judgement of the assessor, that the impact will occur or that mitigatory activity will be effective - low likelihood of the impact actually occurring - distinct possibility that the impact may occur - impact will occur regardless of prevention measures
Significance · high · medium · low	An integration (i.e. opinion) of the type, magnitude, scale and duration of the impact. Judgements as to what constitutes a significant impact require consideration of both context and intensity. It is the assessor's best judgement of whether the impact is important or not within the broad context in which its direct effects are felt. (see Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823) - Could (or should) block the project/policy; totally irreversible (-ve impact) or provides substantial and sustained benefits (+ve impact) - Impact requires detailed analysis and assessment, and often needs substantial mitigatory actions. - Impact is real but not sufficient to alter the approach used. Probably no mitigation action necessary.

Some Explanations and Definitions

1 Environmental impact - An environmental change caused by some human act. (DEA 1992. *The Integrated Environmental Procedure*. Vol 5).

2 Environmental impact - Degree of change in an environment resulting from the effect of an activity on the environment whether discernable or undesirable. Impacts may be the direct consequence of an organisation's activities or may be indirectly caused by them. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

3 Affected environment - Those parts of the socio-economic and bio-physical environment impacted on by the development. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

4 Environmental issue - A concern felt by one or more parties about some existing, potential or perceived environmental impact. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

5 Environment - means the surroundings within which humans exist and that are made up of:

- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of (i) and (ii) and the interrelationships among and between them;
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being. (National Environmental Management Act No 107 of 1998).

6 Significance - (See Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823. Also in, DEA 1992. *The Integrated Environmental Procedure*. Vol 4).

7 Significance - "The definition of significance with regard to environmental effects is a key issue in EIA. It may relate *inter alia* to scale of the development. To sensitivity of location and to the nature of adverse effects." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 13).

8 Significance - "Once impacts have been predicted, there is a need to assess their relative significance. Criteria for significance include the magnitude and likelihood of the impact and its spatial and temporal extent, the likely degree of recovery of the affected environment, the value of the affected environment, the level of public concern, and political repercussions." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 124).

9 Significance -" The question of significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective - technical, conceptual or philosophical - the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant." (Beanlands, G. 1983. *An ecological Framework for Environmental Impact Assessments in Canada*. Institute for Resource and Environmental studies. Dalhausie University. Sections 7: 43).

10 Environment - Surroundings in which an organisation operates, including air, water, natural resources, flora, fauna, humans and their interrelation. (ISO 14001. 1996). Note - Surroundings in this context extend from within an organisation to the global system.

11 Environmental aspect - Element of an organisation's activities, products or services that can interact with the environment. (ISO 14001. 1996). Note - A significant environmental aspect is an environmental aspect that has a or can have a significant environmental impact.

12 Environmental impact - Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services. (ISO 14001. 1996).

2 METHODS

2.1 Background information

Relevant publications and reports were consulted to establish what information was already available in terms of species presence, ecological requirements, habits and habitats of species, conservation importance, usefulness to man and any other relevant information. Local people were approached for information - particularly on species presence and their usefulness.

2.2 New information

Since relatively little published information was available on the terrestrial fauna in the area, the gathering of sight records and museum specimens was carried out. Specimens were collected if they were required for positive identification, or as voucher specimens for a new locality record. Where necessary photographs were taken to assist in the confirmation of sight records. No birds, large mammals, tortoises, pythons, or any other protected or clearly recognisable species were collected, unless such were found dead or badly injured and which could prove useful for taxonomic or other purposes.

Preserved and labelled specimens were deposited in appropriate National Museum collections, either directly or via the KwaZulu-Natal Nature Conservation Service.

2.3 Sample sites

The sample areas chosen were the farms Ganna Hoek 1817 and Ramak 13696 in the Jana site, and the Farm Groote Mielietuin 1027 in the Mielietuin site. These were considered to contain representative habitats, and therefore also to contain populations of the main representative animal species which occur in the Jana and Mielietuin Dam sites.

The Jana site was visited on five occasions:

1. 4/11/99 Familiarisation visit.
2. 11-14/11/99 Field trip (Self, Field Assistant, Mr J. Craigie) based at the Ganna Hoek homestead. Information and specimens on mammals, reptiles, amphibians, molluscs, dragonflies, fruit chafer beetles and scorpions were collected. Conditions very hot and dry.
3. 19-22/11/99 As for 2, with some butterflies also being collected.
4. 28-29/11/99 Field trip with Dr Johnson and Mr Quickelberge to gather information on birds and butterflies and to look for species not found during previous trips. A collection of earthworms was started. Rainstorm from ca 16h00- 02h00.
5. 5-6/12/99 As for 4. Conditions partly overcast.

The Mielietuin site was visited on four occasions:

1. 4/11/99 Familiarisation visit.
2. 9-11/12/99 Field trip (full team, except John Craigie, bat-work rained out). Information collected on as many species as possible. One hot day, the nights and remaining days wet.
3. 15-17/12/99 Field trip, self plus two field assistants. One partly sunny day, otherwise wet.
4. 29/12/99 Field trip, John Craigie, bat recordings.

2.4 Sampling procedures and collecting methods

Collecting and observation was carried out using standard live- and snap-trapping techniques for rodents, with 1010 trap-nights completed; hand-netting for amphibians and flying invertebrates; various trapping techniques for beetles and butterflies; trapnetting for bats, and hand-collecting for reptiles, amphibians, and other invertebrates. Owl pellets were collected for identifiable remains of small mammals.

Hand collecting involved searching likely habitats (e.g. under rocks, loose tree-bark, dead fallen aloes and logs; edges of water-bodies; on flowering plants and in disused termitaria). Searches at night using vehicle lights and hand-held torches were also carried out for mammals, amphibians and reptiles.

Species' presence were also obtained by identifying tracks (e.g. water mongoose), faeces (e.g. porcupine, cane rat, baboon, dassie) skeletal remains and signs of burrowing (e.g.aardvark), feeding signs (e.g. porcupine), calls (e.g. birds, bats) and free-ranging or handheld individuals. Other information on species occurrence was obtained by questioning local people and Water Affairs staff.

2.5 Identifications

Methods of identification of species are given in the relevant texts.

2.6 Text abbreviations

In the text sight records, animal signs, collected but released animals, collected specimens not lodged in formal collections, call identifications, and photographs, are indicated with an S, while collected specimens are shown with a C. A literature record is shown by L, and an unpublished database record is shown by D.

Those animals included in the South African Red Data Books are indicated with RDB, followed by the category. The categories are endangered (species in danger of extinction if causal factors continue operating), vulnerable (likely to move into the endangered category if causal factors keep operating), rare (species with small populations which are at risk of becoming rare or endangered) and indeterminate (species insufficiently known, but possibly falling into one of the above categories).

WGR throughout the text means Weenen Game Reserve, and KZN means KwaZulu-Natal.

Photographs have been included fairly extensively in Chapter 3, as they illustrate habitats and landscapes far better than can words.

3 DESCRIPTION OF AFFECTED ENVIRONMENT

3.1 General

Both sites lie in Physiographic Region 20 (the Middle Thukela Valley), and Climatic Region 5 (Interior Thukela Valley) of Thorrington-Smith, 1960. Altitudes of the dam sites are 700-860 or to 890m asl for Jana (depending on the final dam wall height), and 965-1040asl for Mieliefontein. Within the sites the valley slopes range from flat (restricted areas) to precipitous, with most areas being moderate to steep. Some of the valley bottom flatlands and floodplains have been totally or partially transformed by ploughing and grazing.

Mean annual rainfall varies between 610-760mm per annum, falling mainly during summer. The area has high maximum temperatures (mean highest monthly temperatures of 35°C) and mean daily minimum temperatures (June and July) of 0-3°C. Light frosts can be expected between May and September, and severe frosts between June and July where the topography is conducive.

The basic geological formations belong to the Ecca-Beaufort series (sandstones, mudstones and shales), with dolerite intrusions. Descriptions of the soils are given in Van der Eyk *et al.* (1969).

Both major permanent river systems are characterised by discoloured water, especially during the rainy season, and have boulder and bed-rock beds, and mud substrates. The water-flow may be nil in temporary still pools, to fast in flowing rapids. Aquatic vegetation is often temporary due to the flash-flooding nature of the river related to disturbed catchments. The river banks are usually disturbed, except where these are rocky or relatively inaccessible to man and his stock.

Figure 3.1: 6/12/99 Ganna Hoek. Looking upstream, Thukela River, from below Mushroom Rock. The Ganna Hoek floodplain is in the left background. Most of the rocky pools and beds are inundated after rain, and the river is brown with silt.

Most, if not all, the feeder streams in the sites are temporary and are characterised by summer flows and dry winter beds. Pools in these beds may exist throughout the winter but normally dry up during extended dry periods. Vegetation in the stream beds vary from being non-existent to consisting of good grass, herb and shrub cover.

Figure 3.2: 22/11/99 Ganna Hoek. Stream valley with semi-permanent pool - home of terrapins and five species of frogs and toads. Human influence is indicated by a discarded tyre and a calf.

Figure 3.3: 22/11/99 Ramak. A highway of worn sandstone - streambed with semiclosed bushveld on the edges and steep slopes. The small temporary pools attract birds, dragonflies and other insects.

The natural vegetation is Valley Bushveld, consisting of a northern form transitional to lowveld This is an endemic veld type to KwaZulu-Natal and is grossly underrepresented in formally conserved reserves (Scott-Shaw *et al.*, 1996). Descriptions of the vegetation complexes may be found in Acocks (1975), Edwards (1967) and Scott-Shaw & Edwards (1999).

3.1.1 Effect of man

These comments are made from observations on the farms Ganna Hoek and Ramak (Jana site) and Groote Mielietuin (Mielietuin site) only.

Cultivation and grazing by cattle and goats on the floodplains has reduced most of these to short-grass, sparsely wooded areas or to croplands. Riverine vegetation, except where this is inaccessible to stock, is generally heavily grazed and browsed where cattle are allowed to free-range. This was seen on both sides of the Thukela River for the last 11.5km of river valley before the proposed Jana wall site. Off the floodplain there is much evidence of widely ranging foraging stock, certainly on Ganna Hoek, the stock entering deep into kloofs and well up moderate to steep slopes.

There was widespread evidence of wood-cutting, bark gathering, burning of whole *Aloe marlothii* (presumably for making snuff), and removal of green *Aloe* leaves. Sites were found where honey had been harvested using fire to control or kill the bees, snares set for large mammals were found, and small-bird trapping using a small wire walk-in trap was witnessed and a large home-made rat-trap was also recovered. Almost daily, people were seen fishing in the Thukela River, using handlines.

Figure 3.4: 22/1/99 Ramak. *Aloe marlothii* leaves stripped and piled to dry, apparently for medicinal purposes.

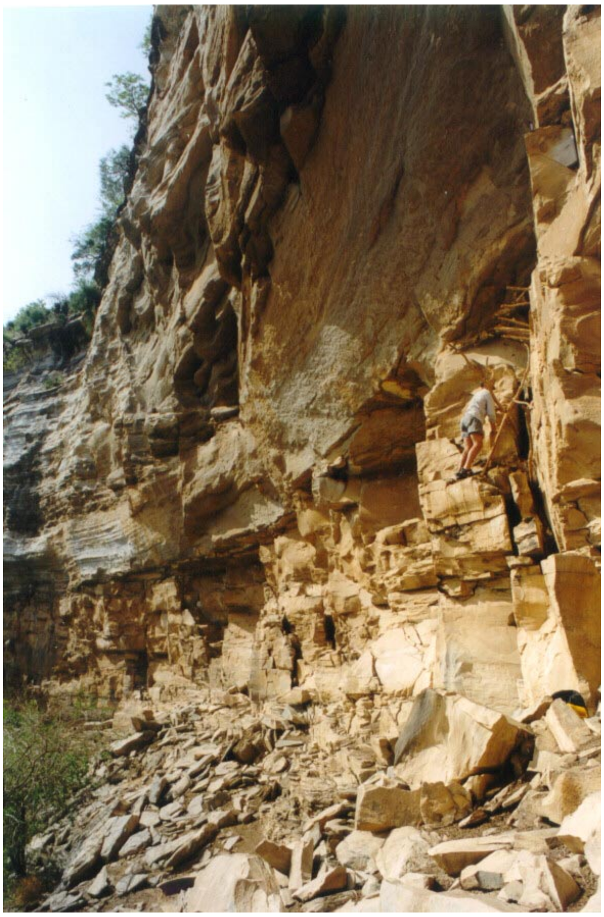

Figure 3.5: 22/11/99 Ramak. A site where honey was gathered from hives near the cliff base. Note branches wedged into crevices to enable easy access to honey. Fire was used to keep the bees at bay. In this case the bees have deserted the site.

Figure 3.6: 22/11/99 Ganna Hoek. Bark-stripping of doppruim (*Pappea capensis*). This species is particularly heavily used in the area.

Another effect of man is in the presence of invasive alien plants, some, such as prickly pear (*Opuntia* sp.) and syringa (*Melia azedarach*), occurring in the area, others such as red sesbania (*Sesbania punicea*), common lantana (*Lantana camara*), and poplars (*Populus* sp.) being mostly confined to river banks or in damper areas.

The floodplain between the Thukela River and the Ganna Hoek homestead has been cleared and turned into fields, as have most other larger floodplains within the dam sites. Some of these are still under use, others are abandoned. There is evidence of past stock-density mismanagement in the shape of a large eroded area adjacent to the Ganna Hoek homestead and an eroded area on Groote Mielietuin. Although these appear to be old, there is still active erosion at the donga heads and walls.

The building of roads and tracks in the dam sites has lead to some limited local erosion - not great because of the stony nature of the terrain, while stock and human footpaths are found in virtually all areas looked at.

Consistent, uncontrolled and probably increasing use of the resources will lead to impoverishment of the biodiversity in the area. By far the most damaging activities are those which deplete ground cover and other vegetation components as these form the basis on which the faunal components exist.

Figure 3.7: 23/11/99 Ganna Hoek. *Aloe marlothii* burnt, apparently to obtain snuff from the ash of the leaves.

3.2 Mielietuin

The main drainage system is the Bushman's River. When floods occur, particularly in the narrower valleys, scouring of the river floor and floodplain vegetation occurs, normally, apparently, as flash flooding. The river beds are generally bouldery or rocky, with some areas of mud and sand, while the floodplains seen were of black, hygrophilous soils or of red soils derived from dolerite. The river in most of its passage through the upper reaches of the dam meanders through flat to moderately sloping landscape. It is only towards the dam wall that deep gorges have been incised for about 1,5km. The upper reaches of the dam site are largely transformed by ploughing. The area to be inundated covers some 1458ha.

Man has influenced the area to a large extent through ploughing, the use of fire and grazing practises - more so than at the Jana site.

Habitats represented.
Habitats are places in which plants and animals live. General descriptions such as the following simply describe different kinds of places which are occupied by a range of species. Sometimes a plant or animal is confined to a specific habitat (such as crevices in sandstone cliffs), otherwise it may be widespread or occupying a general habitat type (such as grasslands between 500-1800m asl.)

Some of the habitats in the dam site are illustrated below:

Figure 3.8: 16/12/99 Groote Mielietuin. The Bushman's River valley, looking upstream, a few hundred metres upstream from the proposed Mielietuin Dam wall. The slopes are steep to precipitous, very rocky, and generally have a cover of open woodland with scattered bushclumps. Red veld rats (*Aethomys* sp.) are common here. The river provides habitat for otters and water-mongooses.

Figure 3.9: 9/12/99 Groote Mielietuin. iGujwana stream at the high-water level of the proposed Mielietuin Dam (ca. 1040m). The stream has boulder beds with isolated pools, tends to have a seasonal flow and has dense to fairly dense bank vegetation patchily distributed along its lower course. Streambeds such as these form highways for species which need denser vegetation in damper surroundings as habitats.

Figure 3.10: 16/12/99 Groote Mielietuin. The Bushman's River valley looking upstream (SW). Most of the floodplains have been ploughed and planted. For the most part, until about 1.5km from the proposed dam wall site, the river has low banks. Crops in the fields attract birds such as spurwing and Egyptian geese. Bushpig, kudu and grey duiker are among the many species using these lowlands. They sometimes cause crop damage, especially the bushpigs.

Figure 3.11: 10/12/99 Groote Mielietuin. Flat to gently sloping, open to semi-open bushveld typical of the Bushman's River flatlands. Exposed dolerite boulders are often a feature here. Four species of small mammals were found here, although cover was poor, and there was high earthworm activity.

Figure 3.12: 9/12/99 Groote Mielietuin. Eroded Bushman's River flatlands, indicating heavy grazing pressures. Bushman's River on left, the view is looking north, Weenen Game Reserve in the right background.

3.3 Jana

The main drainage system is the Thukela River. As at Mielietuin, scouring of the river-bed and edges occurs during flooding events. The floodplains seen were of sandy, pallid soils derived from sandstone. Although the large Ganna Hoek floodplain is obviously very old, it is still subject to erosion and deposition along its riverine edges, including very recent times. This can be seen by the layers of plastic shreds and other debris generated by humans in exposed bank faces. There are far more cliffs and steep rocky slopes contained within the Jana site than at Mielietuin, in fact these occur virtually along the total length of river to be inundated. There are also many more feeder streams running through sheltered valleys. The area to be inundated covers some 3880ha at supply level of 890m above sea level (asl) (Dept. Water Affairs & Forestry, South Africa, 1999).

On Ganna Hoek the landowner has abandoned the property, apparently because the theft, uncontrolled stock grazing and other unauthorised and, apparently, uncontrollable uses made of the property by neighbouring communities, as well as security problems, made farming in the area untenable.

Although, as at the Mielietuin site, most of the larger floodplains and other flatlands have been ploughed or heavily grazed, resulting in vegetation changes, much of the adjoining vegetation is in relatively pristine condition. Some habitats represented there are shown below.

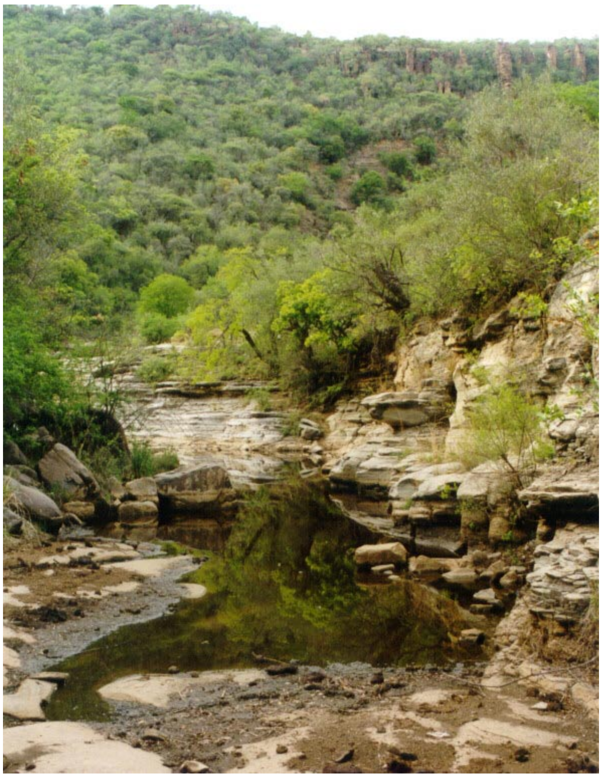

Figure 3.13: 22/11/99 Ganna Hoek. Streambed carved through sandstone bedrock, with semi-permanent pool - habitat for two amphibian species, a foraging area of water-mongoose and other small predators, and a drinking place for a variety of invertebrates and vertebrates.

Figure 3.14: 4/11/99 Ramak. Just above site of proposed Jana Dam wall. The Thukela bed is of bed-rock, and the valley sides are steep to precipitous and very rocky. Soils are generally shallow. At such sites it is difficult for burrowing species to move up-river. With a dam wall it would be impossible.

Figure 3.15: 22/11/99 Ganna Hoek. Thukela River, looking downstream after good rain. The river bed is of bedrock and boulder rubble, with some mud trapped in backwaters and larger pools. Mushroom Rock, a weathered sandstone pedestal capped with a flat sandstone slab, is in the centre of the picture. The slopes are moderate to steep except for the floodplains, and smaller plateaus above and below some cliffs, for example. This general area is the habitat of a number of important animal species such as Natal hinged tortoise and pythons.

Figure 3.16: Ganna Hoek. Steep rocky slopes with red sandstone cliffs and weathered sandstone pedestals. Habitat for Wahlberg's velvet gecko, striped skinks, southern tree agama, red rock rats, Egyptian sheath-tailed bats, duiker and bushbuck - and a host of other species.

Figure 3.17: Ramak. Cliff, scree slope and steep, rocky wooded slope - typical of the sheltered stream valleys flowing into the Thukela River. Snares set for bushbuck and duiker were found here, as well as the remains of a hunted duiker. Dassies used to occupy this cliff, but appear to have moved off, while lanner falcons were seen frequently on the top of the cliff, and a Wahlberg's eagle was nesting in the valley.

Figure 3.18: Ganna Hoek. Cliffs, carved over thousands of years by a small temporary stream. Pied crows and hadeda ibises were nesting on the face and top of the cliff.

Figure 3.19: Ganna Hoek. The transformed floodplain below Ganna Hoek homestead with ten bald ibis, a pied crow and a number of cattle feeding. The floodplain is heavily grazed by cattle and goats on an uncontrolled basis. The landowner no longer lives on the farm because of security and other problems.

4 DESCRIPTION OF SPECIES

4.1 Species recorded

Annotated checklists of the species involved are given in Appendix 1. Records of 629 species of vertebrates and selected invertebrates were gathered following field and literature searches. Forty-nine were considered of conservation importance (See Table 4.1).

Table 4.1: Species diversity and important species

	Group & Total	Jana							Mielietuin						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mammals	70	63	43	11	7	2	5	1	66	39	14	10	3	3	2
Birds	247	247	247				10*		226	226				4*	4
Reptiles	46	40	30	6	4		4		37	31	5	1		3	
Amphibians	12	12	12						12	12					
Earthworms	4	3	3						3	3				1	
Molluscs	18	18	12	6			9		18	10	7	1		9	
Millipedes	18	17	4	10	3		9	2	17	7	4	4	2	6	5
Dragonflies	44	43	21	17	4	1	2		43	14	22	7		1	1
Cetonids	33	32	23	4	5				31	21	6	4			
Butterflies	132	121	117	3	1		3	2	123	119	3	1		3	2
Scorpions	6	6	3	1					5	4	1				
	630	602	515	60	24	3	42	5	581	486	62	28	7	30	14

Key: 1 = Total species present ; 2 = definite ; 3 = probable ; 4 = possible ; 5 = uncertain ; 6 & 7 = important species, where 6 = definite + probable, 7 = possible + uncertain
* = excluding 8 Red Data species not considered to become affected by dams

4.2 Species of conservation importance

Mammals

Of the 70 mammal species recorded for the two dam sites (63 for Jana, 66 for Mielietuin), there are 6 which are considered of conservation importance.

Marley's golden mole (*Amblysomus marleyi*)
Peak-saddle horseshoe bat (*Rhinolopus blasii*)
Least dwarf shrew (*Suncus infinitesimus*)
Serval (*Felis serval serval*)
Aardwolf (*Proteles cristatus*)
Aardvark (*Orycteropus afer*)

Although another species, Kuhl's pipistrelle (*Pipistrellus kuhli*) recorded from the sites is listed in the SARDB as indeterminate, it is now considered to be fairly common, and is not regarded as an important species for conservation.

Birds

Of the 247 bird species listed, all may be expected at the Jana site, and 226 at Mielietuin. There are 9 species considered of conservation importance. Red Data species that occur peripherally or occasionally, but will hardly be affected by the proposed dams are *Sagittarius serpentarius*, secretarybird (Near-threatened), *Gyps coprotheres*, Cape vulture (Vulnerable), *Stephanoetus coronatus*, crowned eagle (Near-threatened), *Falco biarmicus*, lanner falcon (Near-threatened), *Eupodotis cafra*, whitebellied korhaan (Vulnerable), *Eupodotis melanogaster*, blackbellied korhaan (Near-threatened), *Mirafra cheniana*, melodious lark (Vulnerable) and *Lioptilus nigricapillus*, bush blackcap (Near-threatened).

Ground hornbill *Bucorvus leadbeateri*
Bald ibis *Geronticus calvus*
Black stork *Ciconia nigra*
Martial eagle *Polemaetus bellicosus*
Tawny eagle *Aquila rapax*
Peregrine falcon *Falco peregrinus*
Whitebacked night heron *Gorsachius leuconotus*
African finfoot *Podica senegalensis*
Halfcollared kingfisher *Alcedo semitorquata*

Note that Jana is much the more important site for these Red Data species. It is vital for the ground hornbill, bald ibis, black stork, peregrine falcon, whitebacked night heron, African finfoot and halfcollared kingfisher; Mielietuin is not. Jana also makes the bigger contribution to the tawny and martial eagles.

Reptiles

Of the 46 reptiles recorded (40 at Jana, 37 at Mielietuin), four are considered of conservation importance.

Natal hinged tortoise (*Kinixys natalensis*)
African rock python (*Python sebae natalensis*)
Striped harlequin snake (*Homoroselaps dorsalis*)
Wahlberg's velvety gecko (*Homopholis wahlbergii*)

Molluscs

Of the at least 18 species of molluscs recorded for both the sites, 9 are considered of conservation importance. There are no Red Data Books for molluscs in South Africa, and before this can be produced a great deal more work is required on their distribution and taxonomy.

Archachatina simplex
Eduoardia maritzburgensis
Gullela orientalis
Gullela mfongosiensis
G. barbarae
G. subframesi
G. leucocion
G. contingens and
G. crassidens jonesi

Earthworms

Of the 4 species recorded (3 at each site), one is considered important. There are no Red Data books for millipedes in South Africa.

Proandricus sp. nov.

Millipedes

Of the 18 millipede species recorded from the areas (17 at each site), 13 are considered to be important to conservation. There are no Red Data Books for millipedes in South Africa. Due to a grave lack of distributional data, and a number of taxonomic uncertainties, some of the species listed may turn out to be common ones. However, on the basis of present information, all 13 must be included.

Camaricoproctus torquidens
Doratogonus subpartitus
Doratogonus sp.
Orthoporoides sp. (cf. *pyrocephalus* ?)
Zinophora laminata
Harpagophora sp.
Chaleponcus discalceatus
Patinatius attemsi
Patinatius rusticus
Spinotarsus malleolus
Spinotarsus tubulosus
Spinotarsus tugela
Centrolobus cf. *albitarsus*

Figure 4.1: Ganna Hoek. The rare Natal hinged tortoise (*Kinixys natalensis*) here showing a male pursuing a female (top), and the same animals turned upside down temporarily to show the colour patterns of the plastron. Like finger-prints, each individual has its own pattern, and can thus be recognised again.

Figure 4.2: Ganna Hoek. A young python (*Python sebae natalensis*), classed as vulnerable in the South African Red Data book and, therefore, an important species. Caught at the homestead, this youngster was released in a small, wild valley on Ramak.

Figure 4.3: Ganna Hoek. From top left, clockwise : the millipedes *Doratoganus subpartitus* - a cluster found sheltering under a rock, note the differences in juvenile (pale) to adult (black) colour patterns; *Orthoporoides* cf *pyrocephala* a red-headed millipede and possibly a new species; and *Harpegophora* sp., a new species showing two colour morphs. These species were found at both sites.

Dragonflies

Of the 44 species recorded from the areas (33 from each site), two are regarded as important to conservation. There is no Red Data Book for dragonflies in South Africa, but conservation values for KZN are given in Samways (1994).

Paragomphus elpidius
Trithemis donaldsoni

Butterflies

Of the 132 species of butterflies recorded for the sites (121 at Jana, 123 at Mielietuin), five are considered to be of conservation importance. Although only one of these appears as South African Red Data species (Henning and Henning, 1989), it is believed that a revision of the present situation would lead to inclusion of at least some of the other species. Certainly for KZN they must all be regarded in, at least, the rare category.

Saffron saphire (*Iolaus athene*)
Potchefstroom blue (*Lepidochrysops procera*)
Natal yellow-banded sapphire (*Iolaus diametra natalica*)
Millar's hairtail (*Anthene millari*)
Tinktinkie blue (*Brephidium metophis*)

4.3 Keystone, indicator and dominant species

Mammals

Keystone species

There does not appear to be any individual keystone species. However, the small mammals (particularly rodents, shrews, elephant shrews and moles) support, as a food source, a wide array of carnivorous birds, mammals and reptiles, including a number of important conservation species. If these small mammals were to be removed from the ecosystems, there would be a drastic reduction to their predators, and there would be other impacts of varying degrees on plants and invertebrates in the area.

Indicator species

There are no known specific mammalian indicator species. The presence of a relic population of Marley's golden mole is an indicator of a former biological connection with north-eastern Zululand. The other small mammal species so far found fall into typical "southern woodland" grouping of Taylor (1998b), with a high abundance of the commoner species.

Dominant species

In terms of numbers, the red veld rats (*Aethomys* spp.) appear to dominate at both sites, while the rock elephant shrew (*Elephantulus rupestris*) is particularly common at Jana. As far as impact on the grasses is concerned, cattle appear to be having a great effect on portions of Jana, and probably influence grassveld production on Mielietuin.

Birds

Keystone species

There are no keystone species, in the sense of a bird that makes a substantial and unique contribution to the ecosystem. Almost by definition a rare species is incapable of fulfilling this role, and a common "keystone" species will, again by definition, not be threatened by losing a small part of its ecospace. The bird that contributes most to habitat functioning is *Pycnonotus barbatus*, blackeyed bulbul, by being the almost universal disperser of seeds of trees and bushes. It eats almost every species, and is equally at home in dense thickets and sparse open woodland.

Indicator species

No bird species is unique to Valley Bushveld, but the following are very typical and, in KZN, have their stronghold there;

Francolinus natalensis Natal francolin
Cuculus gularis African cuckoo
Tricholaema leucomelas Pied barbet
Turdoides jardineii Arrowmarked babbler
Cossypha humeralis Whitethroated robin
Parisoma subcaeruleum Titbabbler
Amadina erythrocephala Redheaded finch
Serinus atrogularis Blackthroated canary

However, none would be seriously affected, on a province-wide scale, by the loss of either or both dam sites.

Dominant species

None. The diversity of the avifauna precludes this.

Reptiles

Keystone species

There do not appear to be any keystone species of reptiles in the sites.

Indicator species

With the discovery of a population of Wahlberg's velvet gecko in the Jana site, a combination of this species, Natal hinged tortoise and dusky-bellied water-snake would characterise the area to the exclusion of any other in KZN.

Dominant species

The dominant reptile species on both sites is the very common variable skink *(Mabuya varia varia*) while Wahlberg's snake-eyed skink (*Panaspis wahlbergii*) appears to be the second most common.

Amphibians

Keystone species

There are no keystone species known in the areas.

Indicator species

No indicator species are known from the sites.

Dominant species

The dominant amphibian species in both sites is the Bushveld rain-frog (*Breviceps adspersus*).

Invertebrates

It is not possible to indicate keystone, indicator or dominant species for the invertebrates. The areas have not been thoroughly surveyed. Seasonal (and other) variations which influence population fluctuations (increases, decreases and apparent disappearances) which bring on these changes have not been recorded. These can make significant differences to real or perceived presence, dominance and importance values of invertebrates.

As a group, invertebrates are enormously important ecologically. Some (dragonflies, damselflies, scorpions) are predators on other invertebrates and some small vertebrates. Others form important food sources for a variety of birds, mammals, reptiles, amphibians and other invertebrates. Important functions of invertebrates include pollination (e.g. by butterflies and cetonid beetles), which ensures continuing plant resources.

Of note on both sites are harvester termites (*Hodotermes mossambicus*) which have the capability of seriously degrading grass-cover, especially under circumstances of man's mismanagement. They are also avidly fed on by a very wide range of vertebrates and invertebrates, and they assist with soil formation by breaking down plant material, enabling organic and inorganic components to be incorporated into the soil base. This function is also carried out by a number of other termite species seen on the sites and these, together with earthworms and millipedes, are very important in soil formation processes.

Earthworms enrich the soil by bringing subsoil to the surface and mixing it with topsoil. An earthworm can ingest its own weight in soil every 24 hours. It does so to obtain food in the form of decayed organic matter, bits of leaves and other vegetation, refuse and animal matter. When burrowing in soft soil the earthworm burrows by pushing soil particles aside - in firmer soil it burrows by literally eating its way through the soil. Earthworms are thus extremely important in ecosystems as soil enrichers. They also are prey to a large range of predators, from small mammals, birds and amphibians to other invertebrates. Alien earthworms indicate the effects of man on the soil, while the presence of indigenous species indicates relatively pristine soil conditions.

Millipedes play an important part in the formation of humus. They feed upon litter made of leaves, seeds, twigs and branches that have fallen to the ground, and their faeces then add rich manure to the soil. Millipedes were seen to occur in high numbers, particularly evident after rain on Ganna Hoek, in the Valley Bushveld, and they are likely to be contributing tons of manure per hectare to the area. Millipedes are prey items of some small mammals, birds, reptiles, amphibians and invertebrates.

Most of the groups of flying invertebrates contain species which are fairly widely distributed, and few species important to conservation are found. However, those groups of animals which cannot move fast or far (millipedes, molluscs) seem to have developed endemic species in the Thukela Basin, indicating that they have been isolated there for a long time.

Figure 4.4: Mielietuin. Termite (*Macrotermes* sp. ?) "nest" enveloping the trunk of *Aloe marlothii*, the termites breaking down dead leaves, assisting with the process of soil formation.

Figure 4.5: Groote Mielietuin. Natal Mistletoe (*Tapinanthus natalitius*), a parasite on *Acacia* and *Combretum* spp., and a food plant for some of the lycaenid butterflies which are well represented at both dam sites. The fruit of the mistletoe is used to make bird-lime, a sticky substance smeared on twigs to catch small birds.

5 DESCRIPTION OF IMPACTS

It is important that the concepts and facts relating to ecosystem use and value are understood, otherwise there is no basis for evaluating the assessment and/or for informed decision-making. To try and clarify the approach to describe the impacts of the proposed dams, the following extracts from Costanza *et al.* (1997) are given. Their paper needs to be read in toto for the supporting arguments and statements:

"The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support systems. They contribute to human welfare, both directly and indirectly and, therefore, represent part of the total economic value of the planet ....For the entire biosphere, the value....is estimated.....an average of US$33 trillion per year.

Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits derived from ecosystem functions , either directly or indirectly, by human populations.

In general, natural capital is considered to be a stock of materials or information that exists at a point in time. Each form of capital stock generates, either autonomously or in conjunction with services from other capital stocks, a flow of service that may be used to transform materials, or the spatial configuration of materials, to enhance the welfare of human beings. The human use of this flow of services may or may not leave the original capital stock intact. Capital stock takes different identifiable forms, most notably in physical forms including natural capital, such as trees, minerals, ecosystems, the atmosphere and so on; manufactured capital such as machines and buildings; and the human capital of physical bodies. In addition, capital stocks can take intangible forms, especially as information stored in computers or individual human brains, as well as that stored in species and ecosystems.

Ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare..... one additional way to think about the value of ecosystem services is to determine what it would cost to replicate them in a technologically produced, artificial biosphere........this is an exceedingly complex and expensive proposition. ....the earth is a very efficient, least-cost provider of human services."

The more that functioning natural ecosystems are destroyed, the more it will cost to maintain human standards of living, or indeed human life. Wild animal and plant species are indicators of ecosystem condition, and the more the pre-historical (pre-man) original species are present in an ecosystem, the better its condition, functioning and long-term value. The animal and plant species contain combinations of chemicals, perpetuated by their genetic characteristics, which have been used in the past, and are still being used extensively by man. Even very small species have the potential to influence human lives positively (and, of course, negatively). Penicillin, an anti-biotic agent obtained by culturing a fungus which causes bread mould, has saved millions of lives. What if someone had decided that bread-mould had to be eradicated, before its value was discovered, so that bread could have a longer shelf-life?

If any species of plant or animal becomes extinct at the hand of man before its values in terms of ecosystem maintenance or direct benefit to human beings have been examined, such loss might well affect all human beings. In that sense, each species has a real or potential value of international importance. Before any natural area (an area containing most or a fair proportion of its species, and operational in its basic ecosystem functions) is consigned to irreversible change, or destruction, the people making the decision are morally and legally obliged to consider the aspects mentioned above.

These duties are expressed by Act 108 of 1996 (The Constitution of the Republic of South Africa) which states in Section 24: Everyone has the right-

1. to an environment that is not harmful to their health or well-being; and
2. to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that-
   (i) prevent pollution and ecological degradation;
   (ii) promote conservation; and
   (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

The Constitution also indicates (Section 231(5)) that the Republic is bound by international agreements which were binding on the Republic when the Constitution took effect. One such agreement, the Convention on Biological Diversity, was ratified on 2 November 1995. Its objectives are *inter alia* the conservation of biological diversity and the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. This document needs to be read by decision-makers dealing with environmental transformations.

On the basis of the above, and in my professional opinion, the Jana site is considered of international importance in terms of its potential for species loss, and of national importance for the veld type and the ecological processes linked to the area, while the Mielietuin site is far less important from these viewpoints. Impacts of the proposed dams would, therefore, be generally high to very high in the Jana site, and moderate to uncertain at Mielietuin.

The revised conventions for definitions and terminology specified for this task contains definitions which raise problems.

1. The definition of "international" is given as "Southern Africa". This means that even though an impact may be considered truly international (affecting all nations) by me, I am prevented from expressing this. The definition can therefore understate the level of importance an impact might have. "International" is hereafter used in the accepted sense of the word as being "pertinent to all nations".

2. The definition for "regional" is not clear. For the sake of clarity, "regional" will be regarded as meaning KwaZulu-Natal, and "sub-regional" as the Thukela catchment.

3. "Duration - long term" is defined as "greater than 15 years (or operational life)". It is assumed that "operational life" means the time during which the dam will be useful. What is this time? An absolute maximum of 100 years? The implication is that to the decision makers 15-100 years is regarded as long term.

   The definition greatly underplays the impact on some of the ecological issues. The effect of building the dams is that natural systems, formed over millions of years, will be destroyed - not just for 15 or 100 years, but forever. Where "long term" is used in the text below, it means indefinitely (forever).

5.1 Ecosystem loss : Valley Bushveld - Northern Form

The present ecosystems are based on the evolution of landscapes, climate, soils, plants and animals over many millions of years. In the last few thousand years, man has also exerted his influence - these influences becoming greatly accelerated over the last few hundred years.

Indigenous species of plants and animals are maintained in, and are an integral part of, the ecosystems in which they evolved and developed. If an ecosystem is destroyed, so are the species living as part of it. The ecosystems are an important part of our heritage - generally man's heritage, and specifically that of the province, and **are non-renewable resources**. They cannot be recreated or duplicated.

Specific work describing all the components of the ecosystems represented in the dam sites has not been done. However, the condition of natural vegetation can give an excellent indication of the ecosystem importance and health. The vegetation found in the dam sites was classified by Acocks (1975) as Valley Bushveld, more specifically as the northern form, which is endemic to (only occurring in) KwaZulu-Natal. The largest area (over 50%) is in the Thukela Basin, smaller to very small patches are present in the Umgeni, Umkomaas, Illovo and Umlaas River basins. **The veld type is thus a very important provincial and national natural heritage feature in its own right.**

By the mid-1970's, 54,7% (419 931ha) of this veld type had been destroyed by use and developments of various kinds (Bourquin, 1996). If one accepts that the great majority of this damage started with the beginning of commercial agriculture in the province, from about 1850, then the average annual rate of destruction of Valley Bushveld from 1850 to 1975 is 3 360ha per annum. If this rate of destruction has continued over the last 24 years, then another 80 640ha has been lost, bringing the total lost to 500 571ha, or 65.2% of the original veld type. That this has been lost, and probably more, is indicated by the recent statement, “Valley Bushveld is under intense pressure from subsistence farming” (Scott-Shaw *et al.*, 1996).

The amount of this veld under formal conservation is 3 710ha - a mere 0.48% of the original area. To conserve representative biodiversity of any ecosystem, it is generally accepted that at least 10% of representative parts of the ecosystems should be conserved, that is to say managed to allow the system to operate with least interference by man, to ameliorate man’s effects, and to maintain the natural biological diversity. Clearly, to reach a target of 10% will require considerable deliberate conservation input, as just over 73 000ha more will be needed.

If the dams are built to greatest full supply levels, KwaZulu-Natal faces the loss of an endemic, non-renewable resource to the tune of another 5 338ha, or 2%, of the remaining veld type. While this does not sound like much it is an accelerating factor to the continuing destruction of the remaining veld type as a whole, which will then be less than one-third of its original extent. It will also spell the loss of an important example of the northern form of Valley Bushveld, making it more difficult to find good contiguous areas for conservation purposes if this became a priority in the future.

It is not only the total area lost that is important, but the quality of the area and its functions. While the Mielietuin site is near the edge of the Valley Bushveld, the Jana site is situated near the centre of the middle Thukela catchment which contains the greatest contiguous area of the northern form of Valley Bushveld. Here we expect the greatest variety of plants and animals characterising Valley Bushveld, that is, the best representative of the expected biological diversity. It is the valleys of this veld type which are of greatest importance, not the higher areas which appear to have a more generalist, wide-spread fauna and flora.

The greater the reduction of area and thus of the population sizes of plants and animals, the greater the possibility of ecosystem disruption, genetic impoverishment and species extinction.

Impact Ecosystem Loss	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Confidence	Significance
Jana	High	National	Long term	Negative	Definite	High
Mielietuin	Low	National	Long term	Negative	Definite	Low

5.2 Species loss

On the basis of present information, it is quite possible that actual extinctions of some plant and animal species may happen. The number of Thukela Basin endemics, and the three, maybe four, new species found in the dam sites, shows that there is a distinct possibility that other poorly known groups will also contain new species, endemics and rarities which could be seriously affected by the dams. There is also the possibility that the flooding of the dam sites could cause extinction of a species before it has been discovered.

It would be unwise to take the risk of destroying not only the new species, but also stocks of known species which have not yet been examined in terms of present human needs. It is a wise long-term investment to maintain all wild species stocks as carriers of genetic aids to future problems, solvable with the help of new or developing technology.

The building of the Jana Dam will create a barrier between some populations of species surviving upstream and downstream of the dam. For those animals which are aquatic or which can swim easily, this will not cause a long-term problem, provided they are able to move around the dam wall. Fragmentation of previously contiguous populations into separated island populations, by flooding a core area, could lead to genetic weakening of populations. This contributes to the further possibility of long-term species loss. If the isolated populations are small, they are more vulnerable to adverse effects of climate, predation and disease, this again contributing to species loss.

There is no doubt that some species will become locally extinct if the Jana Dam is built. For example, the cliffs and other steep rocky places at the Jana site are home to a newly discovered population of Wahlberg’s velvet gecko. With flooding of the area to 860m asl, the gecko’s habitats will be virtually destroyed in the Thukela Basin above the dam wall, as it does not normally occur above 900m above sea level. The population would, in my opinion, be wiped out above the dam wall, but populations will probably be found in the Thukela Valley below the Jana site.

The effect of the Mielietuin Dam will be far less dramatic, with most species occupying areas around the area to be flooded, especially in the adjacent Weenen Game Reserve.

The loss or possible loss of a species is considered to be of international importance, because it represents a reduction to world biodiversity and the loss of genetic material of potential or realised value to humans. In all cases, the species are endemic (= only occurring in) KwaZulu-Natal, and are therefore of great importance to the region.

The new species, and possible new species are:

Earthworm *Proandricus* sp.
So far found only at Mielietuin. The rating is valid if the species occurs only within the Mielietuin Dam site.

Millipede a. *Doratogonus* sp.
This species, as yet undescribed, is known only from the Jana site. The ratings are valid if the species only occurs in the Jana Dam site.

Millipede b. *Centrolobus* sp.
Found only at Mielietuin, and the only locality known if it is a new species. Its relationship with *C. albitarsus* needs confirmation. The rating are valid if the species is new and occurs only at Mielietuin.

Millipede c. *Harpagophora* sp.
This species has been found only at Jana and Mielietuin Dam sites, and is thus a Thukela Basin endemic. It is likely to occur in the intervening habitats. The ratings are valid if the species occurs only in the two dam sites.

Ratings for each of the four species are:

Impact Species Loss	**Magnitude/ Intensity**	**Extent/ Spatial**	**Duration**	**Sign**	**Certainty**	**Significance**
	Very high	International	Long term	Negative	Definite	High

Marley's golden mole.
This species was not included in the SARDB as its status as a full species was only recognised in 1995, after publication of the SARDB. However, it is considered to be vulnerable in terms of SARDB ratings. It is known from but two localities in northern Maputaland, making it a very rare KZN endemic (found nowhere else in the world), and is KZN's only endemic mammal.

The building of the dam may wipe out the population, which at this stage is estimated to represent one-third of the populations, based on the distribution records. The ratings are valid if the species occurs only at Jana in the Thukela Basin.

Impact Species Loss	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	High	International	Long term	Negative	Definite	Medium

5.3 Overall species population shrinkage

If the dams are built, there are a number of indigenous species whose distribution ranges will be curtailed in amount by the area flooded. For the larger, mobile terrestrial species (of birds, mammals and reptiles), escape from drowning will be possible provided the dam is not filled rapidly. However, this may not be controllable. Many of these animals may then be forced into unsuitable habitats, or habitats already occupied by the same species. In such cases, minimal survival of the displaced numbers can be expected, and escape from drowning will be a short-term escape. For most of the smaller, sedentary terrestrial animal species death by drowning following the filling of the dam will result in loss of the majority (estimated over 90%) of the involved populations in the dam sites.

Wet-grassland dwellers, and river/river margin users (including otter, water mongoose, cane rat and vlei rat, water monitor, various frogs and toads and a host of invertebrates such as dragonflies and damselflies) will be initially detrimentally affected by loss of floodplains - and the long-term effects on their populations will be determined by the species involved, the nature of the new shoreline, fluctuation of water levels and degrees of disturbance. Some will be better off, others not.

For such animals which do not naturally occupy higher altitudes than those at the full water levels, the building of the dams will result in a shrinkage of the outer limits of their distribution range. Because the Thukela Basin is so poorly known in terms of many of its animal components, it is not possible to determine what percentage of the distribution ranges of most of the species will be lost.

Dr D. Johnson says about the birds:

(i) "At site. Nearly all species would suffer 100% loss. Inundation would not kill them directly, but it is a mistake to assume that birds will survive by shuffling to higher ground. Firstly, the habitat may not be identical, and the greater the shift the more likely the habitat will change. Secondly, and more importantly, the new habitat will already be saturated with its own birds. While nobody will die of conflict or starvation, birds lacking territories, i.e. the immigrants, will never breed.

A few species would benefit, but mainly common species, and then only species not typical of Valley Bushveld - most water birds. With only one exception, such birds are found in almost every vegetation type where substantial water bodies exist. The spurwinged and Egyptian geese, for example, have multiplied enormously because of the proliferation of dam-building, to the point where they are sometimes considered agricultural pests."

(ii) "In Valley Bushveld as a whole. No species will be eliminated altogether from Valley Bushveld by the building of the dams. The Valley Bushveld "specials" will lose whatever proportion of their population corresponds to the area lost under the dams. Other species will generally lose less."

5.3.1 Thukela Basin endemics (known only from this area)

These species are of high importance to KwaZulu-Natal as they are known only from the confined area of the Thukela Basin. Their survival is determined by the maintenance of a relatively pristine habitat. The ratings are valid if they are confined to the Thukela Basin.

Snails:

Archachatina simplex

This species is an endemic to the central Thukela River catchment in KZN, having been found in Muden, Weenen, Ladysmith and Nqutu. It has been found in both dam sites and appears to be confined to Valley Bushveld.

Gulella orientalis

A species known only from a small number of localities (less than 10) in the Thukela catchment. It has been found at Jana, and probably occurs in Mielietuin.

G. mfongosiensis, C.barberae, G. subframesi, G. contingens, G. crassidens jonesi

These species are all central Thukela catchment endemics which will definitely be found in one or both catchments. They may represent speciation events within the central Thukela catchment, indicating isolation of the populations for many thousands of years.

Millipedes:

Camaricoproctus torquidens

A Thukela Valley endemic so far found only at Jamesons Drift. Probable at Jana, possible at Mielietuin.

Doratogonus subpartitus

A Thukela Valley endemic found at both sites.

Orthoporoides sp. (cf. *pyrocephalus* ?)

Possibly a new species, taxonomic revision of the genus required. Found at both sites.

Chalceponcus discalceatus

An apparently rare localised endemic, previously known only from Ladysmith, KZN. Found on Mielietuin, probably not at Jana.

Patinateus attemsi

An apparently rare localised endemic, known only from the Thukela River at Kranskop. Probable at Jana, possible at Mielietuin.

Patinateus rusticus

An apparently rare endemic known only from Slievrye, Estcourt. Possibly at Mielietuin.

Spinotarsus malleolus

Apparently rare endemic known only from Weenen. Definitely at Mielietuin, possibly at Jana.

Spinotarsus tubulosus

An apparently rare endemic known only from Middeldrift, Thukela River. Probable at Jana.

Spinotarsus tugela

An apparently rare localised endemic, known only from the Thukela River at Kranskop. Probable at Jana.

Centrolobus cf. *albitarsus*

Either a new species, or one which was previously known only from Lochliel in Mpumalanga. Found at Mielietuin, possibly at Jana.

Impact Population Reduction	**Magnitude/ Intensity**	**Extent/ Spatial**	**Duration**	**Sign**	**Certainty**	**Significance**
	Moderate**	National	Long term	Negative	Definite	Medium*

* Requires further field work and assessment

** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

5.3.2 KwaZulu-Natal endemics

These species are of importance to KwaZulu-Natal as they are known only from the province. Their survival is determined mainly by the maintenance of their habitats. The ratings are valid if they are confined to the province.

Earthworms:
Microchaetes parvus
Found in midlands and coastal areas from the Thukela Basin south. Found at both sites.
Tritogenia zuluensis
Known previously only from Mfongosi area, the species has been found at both dam sites.

Snails:
Eduoardia maritzburgensis
Found primarily in Valley Bushveld and Thornveld habitats in the central Thukela and Umgeni systems. It has been found at both sites.

Millipedes:
Zinophora laminata
So far found only at Hluhluwe Game Reserve and Jamesons Drift. Probable at Jana, possible at Mielietuin.

Rating for each of the species:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Low**	Regional	Long term	Negative	Definite	Low*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

5.3.3 Red Data species

Mammals:
Aardvark.
The aardvark is rated as vulnerable in the SARDB, and occurs in both dam sites, but does not appear to be common in either. The species is in high demand for traditional medicine, and for its meat. Flooding, particularly of the Jana site, will cause a reduction in the regional population. The density of aardvark is not known for the region. Areas suitable for aardvark surrounding the dam sites will already have the full complement of the species as modified by the degree of utilisation of this species by the local human populations. Although widely distributed, the species is considered rare outside game reserves.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	National	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Aardwolf.
The aardwolf is rated as rare (SARDB) in South Africa. It is considered to be a very useful species to farmers as its main food consists of snouted harvester termites, of which they may eat about 300 000 per night. It is considered to definitely occur at Mielietuin, and possibly at Jana. Numbers are believed to be low.

Least dwarf shrew.
This species is infrequently collected, and is listed as indeterminate in the SARDB. Although it is fairly widely distributed, it does not appear to be common in any area. It has been collected from the Weenen Game Reserve (adjacent to the Mielietuin site) and is considered to definitely occur in both dam sites.

Serval.
Rated as rare in the SARDB, the serval is as much the victim of man, who wrongfully has considered it to be a “problem species”, as it is from habitat disturbance (also man-caused). It is considered to possibly occur at Mielietuin, and definitely at Jana. If it occurs, it will probably be in low numbers.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Low	Regional	Long term	Negative	Definite	Low*

* Requires further field work and assessment

Peak-saddle horseshoe bat.
Rated as indeterminate in the SARDB, the species is known from three localities in KZN, including the Ngubevu Gold Mine in the Thukela Valley. It is known to roost in sandstone caves and in other caves and mine adits, and is considered to definitely occur at the Jana site, and possibly at the Mielietuin site. It is at its southernmost range extension in KZN.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Low	Sub-regional	Long term	Negative	Definite	Low*

* Requires further field work and assessment

Birds:

Ground hornbill.

Rated as vulnerable in the SARDB, the naturally low density - one family group per 100km^2 - at which the species occurs in KZN means that even the largest reserves cannot support viable populations on their own. Indeed few are big enough to contain even a single group territory. If the species is to survive it must do so on unprotected land. However, it has already disappeared from several parts of the historical range through habitat alteration. The incredibly leisurely breeding rate of the ground hornbill is another cause for concern. In historic times it was sufficient to balance mortality, but any new threats that accelerate mortality could easily cause extinction within a few generations. Even the unnecessary loss of a single adult could be serious. A family group of three forages on Ganna Hoek almost daily. The nest site is not yet located, but undoubtedly is present in rock jumble caves near the base of the cliffs fringing the Thukela. Both the nest site and most foraging habitat would be lost after inundation.

The ground hornbill is revered by nearly all rural communities, usually in connection with the species' supposed influence on rainfall. In most societies the attitude is "hands-off"; interference will induce endless drought, or floods, depending upon who is interviewed. In effect, ground hornbills enjoy traditional protection, the only reason that they survive at all, given the painfully slow recruitment rate. Unfortunately, there is an increasing trend to regard it as powerful muti that must have some use in rain-making ceremonies. Now there is no "slack" in its demography, making the loss of even a single adult a critical event.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	High	National	Long term	Negative	Definite	Medium*

* Requires further field work and assessment

Bald ibis.

This is a South African endemic (SARDB - vulnerable) of exceptional interest. It is a relict species, whose only relative, the Waldrapp *Geronticus eremitus*, is found in Morocco. DNA studies indicate a separation of 1.5 million years. Obviously there was a single, united population during a cold episode, making the bald ibis an important element in prehistoric climatology. Although a Red Data species, it is one of the few undergoing a modest increase in population. However, this is no cause for complacency when limiting factors are unknown. The northeastern quarter of KZN is the heart of its range. It nests colonially on cliff ledges, foraging on flat open ground. A small colony - two nests - is present on the Thukela on Ramak. This colony is well below the projected high water mark for the dam. Every day 8-10 ibises, including a fledged juvenile from the 1999 season, foraged on the floodplain at Ganna Hoek. The proximity of nesting cliffs to the feeding grounds makes this ideal habitat.

Black stork.
Although wide-ranging throughout the cooler, more mountainous parts of Africa, the black stork (SARDB - near threatened) is nowhere common. Currently the population appears stable. It nests on mountain ledges, and forages on the flats below. The Thukela Valley is ideal habitat. Most of the suitable nesting ledges are above the projected water level, but all foraging habitat would be submerged. A recently-fledged juvenile was seen on the floodplain at Ganna Hoek, indication of nesting nearby.

Martial eagle.
RDB status - vulnerable. Ranges Africa-wide, and more flexible in habitat than most other large birds, but constrained by its enormous space requirements. It has both a low population density and a very low recruitment rate. Typically a pair has a territory of $100km^2$. Developed land, lacking suitable prey, is excluded from consideration. An essential feature of the territory is a wooded area including trees tall enough to provide a secure nest site. Riverine woodland along the Thukela is a good example. Wild country, where there is little or no agriculture and its associated agrochemicals is essential for the martial eagle. This species is present, and almost certainly nests at both sites.

Tawny eagle.
RDB status - vulnerable. This is another fairly wide-ranging eagle, formerly quite common in subtropical woodlands, but now in retreat. The Thukela Basin represents the southern edge of its range. Its semi-scavenging habits, and the prevalent use of poison in many farming areas has greatly reduced numbers. Wild, undeveloped areas, such as the Thukela Valley, and especially sites such as Ganna Hoek are essential sanctuaries. The nest site was not found but undoubtedly exists there. Quite probably Mielietuin also has a permanent territory and nest site.

Peregrine falcon.
RDB status - near threatened. Two populations exist in KZN. Both are rare. One is migrant and does not breed; the other, consisting of probably 10-20 pairs, is resident. The limiting factors

are not well understood, but peregrines seem confined to heavily wooded or forested valleys with bare rocky cliffs upon which they nest. The Thukela Valley is good habitat, and peregrines have been recorded at Ganna Hoek, probably nesting there. Although the nest site might not be affected by inundation, all foraging space will be lost. Mielietuin is less suitable, smaller cliffs and more open vegetation.

Whitebacked night heron.
This is a very sparsely scattered species that is declining in KZN. Its RDB status is vulnerable. It depends upon dense vegetation adjacent to or even overhanging permanent water, usually a quiet river. Slower-flowing water is preferred, so that this section of the Thukela is not ideal. Nevertheless, conditions at Jana make it possible for the species to occur there. This is the only rare bird that might benefit from building the dams. It especially likes dense vegetation overhanging water. For example, a pair now nests at Spioenkop Dam, in a position that could never be used without the dam. Of course, successful establishment of extra pairs at Jana or Mielietuin would depend upon constancy of dam level: it is in practice a condition never likely to be achieved for long enough.

African finfoot.
Although widely distributed in the subtropical parts of KZN this is a rare habitat specialist, with a RDB status of vulnerable. It must have permanent flowing water, either of considerable extent, or with good cover and lack of disturbance. Dense waterside vegetation, or overhanging banks, both of which are present along parts of the Jana site, provides suitable cover. It is declining everywhere, a function of river degradation, and all remaining suitable sites deserve conservation.

Halfcollared kingfisher.
RDB status - near threatened. This is a species liking flowing water where fringes of dense vegetation line the banks. It needs waterside perches, especially liking tree roots exposed on gradually eroding banks. The Thukela at Jana looks especially suitable, with possibly a territory every two kilometres or so. Although not yet rare, this species is declining in KZN because of river degradation.

The ratings for each of the above eight species are:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	National	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Reptiles:
Natal hinged tortoise.
This species is rated as rare in the SARDB, mainly because of sylviculture, agriculture, shifting cultivation and other habitat destruction. Over 50% of its natural range falls in KZN, with populations also occurring in eastern Swaziland and south-eastern Mpumalanga. It is present in both dam sites.

African rock-python.
Rated as vulnerable in the SARDB, the python is the largest South African snake, and is subject to being killed by humans for a number of reasons, including for the rural medicinal trade. It has become locally extinct through habitat destruction, and was exterminated in historical times in the Eastern Cape. It occurs in both sites, more commonly at Jana.

The ratings for the two above species are:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	Regional	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Striped harlequin snake.
The SARDB rating is rare. This is a poorly known species recorded from a number of widely scattered localities. Much of its former habitat is now in areas of extensive unsuitable agricultural usage. It should be found in both dam sites.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	National	Long term	Negative	Definite	Low*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Butterflies:
Natal yellow-banded sapphire.
Found plentifully nearly 100 years ago along the Thukela River, it is now rated in the SARDB as rare.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	Regional	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Other important species:
Reptiles:
Wahlberg's velvet gecko.
This large species was previously known only from the Umfolozi Basin and to the north. It is fairly common in the right habitats in those areas. The unexpected occurrence in the Thukela Basin (Jana site) in what is probably an isolated population indicates ecological events, probably based on geomorphological changes in KZN, which appears to be supported by the presence of other apparently isolated populations of animals. It is thus an important indicator of evolutionary processes in the Province.

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	Regional	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Dragonflies:

Paragomphus elpidius
An extremely localised and rare species, previously recorded from Ladysmith and M'Fongosi in KZN. Found at Jana, probably at Mielietuin.
Trithemis donaldsoni
A highly localised species in South Africa, and only two previous records from KZN. It lives at and near moderately flowing rivers and streams.

The ratings for both species are:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	Regional	Long term	Negative	Definite	Low*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Butterflies:
(All information from C. Quickelberge, personal correspondence, 1999.)

Saffron saphire (*Iolaus athene*)
Nearly 100 years ago a man called George H. Burns, who lived in Weenen, used to collect butterflies for a living and he traded with museums all over the world. His diary (passed on to me by F.Stevens of Scottburgh) contains lists of his daily catches (species and numbers). His catches of *Iolaus pallene* and *diametra* were almost daily occurrences for months on end. *Iolaus pallene* is today easily one of the rarest butterflies of Natal, second only to *Bowkeria phosphor*. The three specimens I recorded at the Jana Dam site are the first I have seen of this species after over 20 years of collecting in KZN.

Potchefstroom blue (*Lepidochrysops procera*)
This species was first caught at Mielietuin in 1893, which remained the only Natal locality until I found a colony at Itala (Game Reserve) in November 1990. Although it is known from a very few localities in the Transvaal, it is considered a rare species.

The ratings for both species are:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Moderate**	National	Long term	Negative	Definite	Medium*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

Millar's hairtail (*Anthene millari*)
Although scarce and seldom caught, it is more widespread over KZN than the previous three species.

Tinktinkie blue (*Brephidium metophis*)
An arid country species of the Karoo etc., its occurrence in KZN is interesting and very limited. It was recently found in good numbers within the Weenen Game Reserve.

The ratings for both species are:

Impact Population Reduction	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
	Low**	Regional	Long term	Negative	Definite	Low*

* Requires further field work and assessment
** Could be high if species distribution is very localised, and if populations in other localities have been adversely affected by habitat change

5.4 Ecological processes

The river acts as a species highway, by which, for example, animals normally occupying low-lying coastal areas can increase their distribution inland. Burrowing species (moles, earthworms, some lizards) rely almost entirely on floodplains and the soft or damp substrates under riverine woodland in which to live. Species, both terrestrial and arboreal, which live in moist coastal forests can also use the woodland belt, and the well-wooded feeder streams in kloofs along the Thukela River as highways and habitats.

The following statement made by Dr D. Herbert can be applied to many groups of plants and animals in the Thukela Valley:
"From the perspective of terrestrial molluscan conservation the most important consideration is to maintain contiguous undisturbed land within the system. Any development that results in the loss or fragmentation of relatively pristine habitat is likely to detrimentally affect mollusc populations. Dams will not only eliminate terrestrial molluscs in the areas to be flooded and transform the habitat in the immediate neighbourhood, but they could also result in the formation of an in-valley barrier, separating upstream and downstream populations - depending on the width of the valley and the height of the dam wall. This would obviously impact upon gene flow and population dynamics in low vagility invertebrates such as molluscs. The most important vegetation types with regard to the endemic molluscs appear to be the bushveld of the valley floor and savanna-woodland mosaic. The molluscs occurring in wooded/forested koppies in the region are generally more widespread."

The area in all probability presents a unique representative of an ecological process, that of recent species isolation, and the possibility that it has formed a centre of endemism for some plant and animal groups, especially those which are somewhat sedentary and which are susceptible to local environmental, and other changes. This is an important part of our historical and scientific heritage.

From the results of recent surveys, albeit short and localised, it is apparent that the Thukela Valley holds some unexpected biological treasures. During the Miocene (20-5mya) the Province was very much flatter and less deeply incised than it is now, and the rivers had wide meandering courses. It was thus easy for tropical and subtropical plant and animal species to filter south and to move up the warmer, lower-lying river valleys. During the end of the Pliocene (ca. 2-1mya) there was uplifting to 2700m of the northern Drakensberg and the adjacent highveld, and the rivers proceeded to gouge through the old planations to form new, deep gorges.

Although the coastal plain effectively widened in the north by sea-bed uplift, it remained narrow and incised south of Mtunzini. During the last glacial period (ca. 18000 years ago), the sea level was more than 100m below its present levels. With a warming of the earth, this rose again to its present levels. The changes to the coastline and the deep incisions made by activated rivers, together with relatively rapid changes in altitude and therefore to temperatures, could have trapped many tropical and subtropical species in valley pockets, from which they could not escape.

The above theory is not based on any but extremely superficial knowledge of geomorphological processes, and needs to be examined by better qualified people.

The discovery of a population of the big (up to 23cm long) Wahlberg's velvety gecko, which had previously been unknown south of the Umfolozi catchment, is a case in point. There is no evidence that the Thukela population has any connection with those to the east and north of it. Because its upper altitudinal limit is about 900m asl, the flooding of the Jana Dam site will destroy the population above the dam wall in its entirety. We are fairly sure, however, that populations occur below the dam wall site, but this needs to be substantiated.

The finding of skulls of a very rare, KwaZulu-Natal endemic golden mole in owl pellets in the Jana site indicates another island population confined to the Jana Dam basin - this needs to be confirmed. The nearest, and only, other known population of the species is in northern Tongaland.

Impact Loss of Speciation Process	**Magnitude/ Intensity**	**Extent/ Spatial**	**Duration**	**Sign**	**Certainty**	**Significance**
Jana	High	International	Long term	Negative	Definite	High
Mielietuin	Low	International	Long term	Negative	Improbable	Low
Loss of Genetic Variability						
Jana	High	National	Long term	Negative	Definite	High
Mielietuin	Low	National	Long term	Negative	Improbable	Low

5.5 Potential nature-based incomes and values

The areas have real incomes based on stock grazing and limited agriculture. These will be totally negated. Other forms of use include the following:

- Actual
  - subsistence fishing, hunting (including honey gathering) and plant food gathering;
  - plant and plant-parts gathering for local and regional magico-medicinal purposes;
  - animal and animal-part gathering for local and regional magico-medicinal purposes;
  - fuel gathering;
  - building, equipment and tool material gathering;
  - sport hunting and fishing;
  - non-extractive nature-appreciation activities;
  - home establishment.

All these will be negated, except that subsistence and sport fishing will probably be enhanced if the dams are built. The additional pressures which will be brought to bear on resources, which are presently available in the dam sites and which will disappear if the dams are built, will have a negative impact in other areas. As populations grow, more and more natural resources are sought in South Africa. As sources of these decline, greater pressures on the remaining resources will take place. An escalating reduction of indigenous plants, animals and their habitats has generally taken place to a great degree over the last few hundred years, and shows no sign of declining.

- Potential
  - extended general eco-tourism activities including general scenic and nature trails;
  - specialist "science trails" including those for general ecology, birds, invertebrates and botany;
  - controlled harvesting of biota (plants and animals) for the hobby market, including plants (e.g. aloes and other succulents), butterflies, cetonid beetles and reptiles;
  - controlled harvesting of biota for long-term provision of magico-medicinal products;
  - controlled harvesting (mainly plants) for building, tools and equipment materials;
  - controlled harvesting of biota for decorative and ornamental products.

- Cultural, teaching and scientific values
    - field teaching and awareness programmes dealing with ecology and ecological principles;
    - research opportunities for taxonomy, evolutionary theory, species distributions, and other ecological/biological subjects;
    - discovery opportunities for natural products discoveries;
    - spiritual satisfaction for people in natural, peaceful surroundings; maintenance of evolutionary and ecological heritage.

However, the main problems facing land-owners and occupiers in the areas (a lack of law and order, lack of respect for the rights and needs of others, and general poverty among the black people) need to be addressed as a matter of urgency. It is unlikely that any wise land-use will be able to be practised effectively, whether the dams are built or not, unless these problems are addressed in the region. Aims of management of the areas must include work provision for the local black people and their incorporation into land-use decisions, under the umbrella of maintaining the life-supporting ecological processes, and maintaining the regional biodiversity.

Impact Natural Resource-based Value Loss	Magnitude/ Intensity	Extent/ Spatial	Duration	Sign	Certainty	Significance
Jana	High	Regional	Long term	Negative	Definite	High
Mielietuin	Moderate	Local	Long term	Negative	Definite	Low

5.6 Impacts of the aqueduct route

It is unlikely that a pipeline, or the process of its laying, will affect fauna except very locally and in the short term. Although a 30m fenced construction servitude is envisaged, this would be replaced by an unfenced 20m servitude once construction was completed. No service roads will be required, although tracks will be necessary.

The construction of a canal-type aqueduct would incorporate a permanent 5m wide service road, permanent servitudes of 40-80m, and with the canal itself (width not given in the background document supplied, but given by the reviewer of this report as ca 10m wide and probably at least 2.6m deep), would present a barrier to faunal movement as well as a death-trap to many vertebrates and invertebrates. There is no indication that the design will incorporate features allowing small animals falling into the canal to escape. Even though the walls of the canal are sloped, the slope may not be sufficient to allow escape by many animals and unless the concrete sides are considerably roughened with horizontal lines. Any design would need to be tested, unless such a design has already proven successful.

The 202km of open canal, which is part of the water carrier from Grootfontein to Omatako Dam (Namibia), has a maximum width of 3.7m and a maximum depth of 1.65m. It has 1:1 sloped sides. Over 150 sampling days (June 1985- August 1986) , 3445 vertebrates of over 100 species were removed from the canal. Forty-six percent of these were dead. Because of predation and sampling factors, it is considered that less than 35% of the animals actually falling into the canal were recorded (Griffin *et al.*, 1987).

6 MITIGATORY ACTIONS

There are few mitigatory actions which can be undertaken. For the most part, those animals living in the dam site will be lost, either by drowning or because of habitat lack or competition and predation outside the dam area.

6.1 Mammals

No mitigatory actions for most small mammals are possible. If the dam is to be built, inspection tunnels or other artificial caves or tunnels should not be blocked off with mesh, but with parallel bars placed horizontally. This will allow bats to use these sites as roosting and breeding areas. The placement of security, and other lights, can be detrimental to bat populations, and before these are placed, a specialist should be consulted.

Special efforts should be made to capture Marley's golden moles and to establish one or more populations in suitable areas.

Large mammals such as kudu, impala, bushbuck and duiker can be captured and relocated if the adjoining areas to their habitats are already occupied by populations of the same species. This would be an expensive undertaking given the generally rugged nature of the terrain. If the open canal system is adopted for water conveyance, canal design must incorporate escape features for animals falling into the canal.

6.2 Birds

No mitigatory actions are possible.

6.3 Reptiles

Tortoises should be searched for and removed from the areas to be flooded, and relocated to adjoining suitable habitats. A prior search should be made to identify such areas.

6.4 Amphibians

No mitigatory actions are believed necessary.

6.5 Invertebrates

The only mitigatory actions for those invertebrate groups looked at are to capture any species so far known to be endemic to the dam sites and to translocate these to suitable areas. These would include mainly millipedes at this stage, but would also include any new species which may yet be found in the sites.

6.6 Aqueduct routes

To mitigate against the effects of barrier and trap represented by a open canal system, I believe a buried pipeline would be by far the best option to adopt.

7 REQUIREMENTS FOR FURTHER INVESTIGATION

The following are investigations which should be carried out, none of which should take longer than two years to provide needed information, except number 7.5:

7.1 Establishment of the present distribution of contiguous and island distribution of Valley Bushveld (Acocks' 23a), its rate of destruction and the best sites for establishment of representative areas in which to conserve the natural ecosystems, biota and characteristics. The aim should be to attain at least 10% of the original veld type as conserved areas.

7.2 Examination of the possibility that the middle Thukela Basin is a site of speciation following isolation of sub-tropical and tropical animals and plants in the area as a result of geomorphic and climatic changes.

7.3 Establishment of the presence and distribution of terrestrial burrowing, non-flying and other poorly-mobile species of animals known from the dam site should be established to see if they occur above, below or alongside the dam sites. The following groups and species should be involved: Marley's golden mole; Wahlberg's velvet gecko; burrowing lizards; Natal hinged tortoise and leopard tortoise; molluscs; earthworms; spiders, pseudoscorpions and mites - mainly the litter and soil dwellers; isopods; millipedes; litter and soil dwelling centipedes; thysanurans; termites; wingless beetles, and litter and soil dwelling species; ants; fauna of sheltered kloofs, fauna of floodplains and riverine cliffs.

The importance of this information would be realised in terms of better taxonomy, distribution patterns, biodiversity status, and would form a platform for future decisions based on ecosystems.

7.4 If it is decided that one or both dams are to be built, it would be of great value to survey the sites, and collect series of every species (excluding birds) found in the area. This would constitute a biological "library" by which the fauna and flora of the general, and specific, areas would be thoroughly known. In turn, this would assist in future assessments of areas in Valley Bushveld. This recommendation is an extension of 7.3 above.

7.5 If the dams are built : ascertain the biodiversity adjacent to the dams to see if any species have been lost, if island populations have been formed, and if the dams are barriers to species movements.

7.6 An elucidation of the options, problems and solutions facing land-use for the Jana site, which would include the dam as an option.

7.7 If an open canal is used for the aqueduct, a design incorporating features allowing escape by animals must be tested and proven successful prior to canal construction.

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APPENDICES

APPENDIX 1: ANNOTATED CHECKLISTS OF ANIMAL SPECIES

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MAMMALS

The initial list of expected species was derived from Taylor (1998), Skinner and Smithers (1990), Rowe-Rowe (1992, 1994), Bourquin and Mathias (1995) and Armstrong *et al.* (1998). Confirmation of occurrence was obtained from field surveys and by questioning local inhabitants (see Methods). Taxonomic arrangement follows Skinner and Smithers (1990), as does nomenclature as amended by Taylor (1998). Conservation importance values (CIV) follow Rowe-Rowe (1991, 1992) and Bourquin (1988). These values have maxima of 50 for the conservation issues, and 10 for importance to humans. Values of 21 or more, and/or 3 or more, respectively, indicate that the species is important.

Order INSECTIVORA
Family SORICIDAE

Myosorex varius Forest shrew L
Nearest record 2830CA. Occurrence: Probable for both sites.
Conservation status: nil. CIV: 7,1. Impact: low, negative. Mitigation: nil.

Crocidura flavescens Greater musk-shrew C, L
Occurrence: One skull was found in an owl pellet, Ramak, November 1999. Definite for Mielietuin.
Conservation status: nil. CIV: 3,2. Impact: low, negative. Mitigation: nil

Crocidura hirta Lesser red musk shrew L
Nearest record 2829DA. Occurrence: Possible for both sites.
Conservation status: nil. CIV: 12, 0. Impact: low, negative. Mitigation: nil.

Crocidura cyanea Reddish-grey musk shrew L
Nearest record 2829AD. Occurrence: Probable for both sites.
Conservation status: nil. CIV: 4, 1. Impact: low, negative. Mitigation: nil.

Suncus varilla Lesser dwarf shrew L
Nearest record: WGR. Occurrence: Definite at Mielietuin, probable at Jana.
Conservation status: Nil. CIV: 14, 0. Impact: low, negative. Mitigation: nil.

Suncus infinitesimus Least dwarf shrew L
Nearest record: WGR. Occurrence: Definite at Mieleietuin, probable at Jana.
Conservation status: SARDB - I . CIV: 22, 0. Impact: low, negative. Mitigation: nil.

Family CHRYSOCHLORIDAE

Amblysomus hottentotus Hottentot golden mole L
Nearest record: 2829BD. Occurrence: Probable at Mielietuin, possible at Jana. A few mole "heaps" were seen near the edge of the Thukela River on floodplain of deep sand, 13/11/99, below Ganna Hoek homestead. The species making these heaps was not identified, but could

have been Hottentot golden mole. A report by Taylor (1999) indicates that another species, Marley's golden mole, may be responsible for these heaps (see following species).
Conservation status: nil. CIV: 4, 2. Impact: low, negative. Mitigation: nil.

Amblysomus marleyi Marley's golden mole C
Occurrence: Marley's golden mole is known only from northern KwaZulu-Natal. Skulls of this mole found in owl pellets on Ramak indicate that the species occurs in the Jana Dam site (Taylor, 1999). It has already been suggested that this species be afforded RDB status of vulnerable, as it is endemic to Maputaland and its habitats are threatened. If its presence is verified in the Jana Dam site it would make the site an important one for maintaining the species. Mole activity was noted only on the Thukela River floodplain, and it is likely that the floodplain is the only good habitat (because of deep soils) for the species.
Conservation status: Considered vulnerable, but not in Smithers, 1986. No CIV was given by Bourquin (1988) but following his method the rating would be 41,0. Impact: high, negative. Mitigation: nil.

Order MACROSCELIDAE
Family MACROSCELIDIDA

Elephantulus myurus Rock elephant shrew C
Occurrence: Jana - One specimen collected 12/11/99, at 800m asl on steep, rocky, NE facing slope in woodland (Ramak), one seen on large dolerite boulders on banks of Thukela River, 12/11/99, at 760m asl, and several caught in very rocky sandstone areas on Ganna Hoek. Common in the area in very rocky or bouldery habitats - but not a cliff dweller. Mielietuin - definite occurrence.
Conservation status: nil. CIV: 14, 0. Impact: low, negative. Mitigation: nil.

Order CHIROPTERA
Family PTEROPODIDAE

Epomophorus wahlbergi Wahlberg's epauletted fruit bat L
Nearest record: 2830CCA. Occurrence: Possible at both sites, but not as permanent residents.
Conservation status: nil. CIV: 8, 2. Impact: low, negative. Mitigation: nil.

Family NYCTERIDAE
Nycteris thebaica Egyptian slit-faced bat L, S
Nearest record: WGR. Occurrence: Definite at Jana, flight sonar recorded at Mielietuin.
Conservation status: nil. CIV: 11, 1. Impact: low, negative. Mitigation: nil.

Family RHINOLOPHIDAE
Rhinolophus clivosus Geoffroy's horseshoe bat S
Occurrence: Flight sonar recorded during November at Ganna Hoek. Definite at Mielietuin.
Conservation status: nil. CIV: 11, 1. Impact: low, negative. Mitigation: nil.

Rhinolophus blasii Peak-saddle horseshoe bat L
Nearest record: 2830DAD. Occurrence: Probable at both sites.
Conservation status: SARDB: I. CIV: 23, 1. Impact: low, negative. Mitigation: nil.

Rhinolophus simulator Bushveld horseshoe bat
Nearest record: 2830DBD. Occurrence: Probable at both sites.
Conservation status: nil. CIV: 14, 1. Impact: low, negative. Mitigation: nil.

Family HIPPOSIDERIDAE
Hipposideros caffer Sundevall's leaf-nosed bat L
Nearest record: 2830DBC. Occurrence: Probable at both sites.
Conservation status: nil. CIV: 9, 1. Impact: low, negative. Mitigation: nil.

Family VESPERTILIONIDAE
Miniopterus fraterculus Lesser long-fingered bat L
Nearest record: 2830DAB. Occurrence: Probable at both sites.
Conservation status: nil. CIV: 16, 1. Impact: low, negative. Mitigation: nil.

Miniopterus schreibersii Schreiber's long-fingered bat L
Nearest record 2929BBC. Occurrence: Probable at both sites.
Conservation status: nil. CIV: 9, 1. Impact: low, negative. Mitigation: nil.

Pipistrellus kuhlii Kuhl's pipistrelle S
Occurrence: Flight sonar call recorded on Ganna Hoek, November,1999. Probable at Mielietuin.
Conservation status: SARDB: I; CIV: 19, 1. Impact: low, negative. Mitigation: nil.

Myotis tricolor Temminck's hairy bat L, S
Nearest record: 2830DAD. Occurrence: Flight sonar recorded at Jana., probable at Mielietuin.
Conservation status: nil. CIV: 15, 1. Impact: low, negative. Mitigation: nil.

Eptesicus capensis Cape serotine bat S
Nearest record: WGR. Occurrence: Flight sonar recorded at both sites.
Conservation status: nil. CIV: 6, 1. Impact: low, negative. Mitigation: nil.

Scotophilus dinganii Yellow house bat S
Occurrence: Flight sonar recorded at Ganna Hoek and at Mielietuin.
Conservation status: nil. CIV: 9, 1. Impact: low, negative. Mitigation: nil.

Family: MOLOSSIDAE
Tadarida aegyptiaca Egyptian free-tailed bat S
Occurrence: Flight sonar recorded at both sites, and heard in sandstone crevice during the day, during November 1999, Ganna Hoek.
Conservation status: nil. CIV: 15, 1. Impact: low, negative. Mitigation: nil.

Chaerephon pumila Little free-tailed bat S
Flight sonar recorded November,1999 at Ganna Hoek, and possibly at Mielietuin (sonar needs interpretation).
Conservation status: nil. CIV: 11, 2. Impact: low, negative. Mitigation: nil.

Order PRIMATES
Family LORISIDAE

Otolemur crassicaudatus Thick-tailed bushbaby L
Nearest record: 2930BBD. Occurrence: Some local people at Ganna Hoek were shown pictures of the species but did not know the Zulu name or recognised the animal. Possible at both sites. Conservation status: nil. CIV: 7, 1. Impact: low, negative. Mitigation: nil.

Papio hamadras ursinus Chacma baboon S
Occurrence: Baboons were heard calling on the evening s of 11, 12, and 13/11/99, on high cliffs above Ganna Hoek homestead. Baboons were also seen near the prposed Jana dam site wall on 22/11/99. The animals appear to be permanent residents in the general area, as Water Affairs staff say they have seen and heard the baboons regularly during the last year. At least 10 individuals are present (J.Craigie, 13/11/99). Not at Mielietuin.
Conservation status: nil. CIV: 5, 6. Impact: low, negative. Mitigation: nil.

Chlorocebus aethiops pygerythrus Vervet monkey S
Occurrence: Vervet monkeys were reported as being present in the area (local people, 23/11/99).No calls were heard and no sightings made during 11-14 and 20-23/11/99 on Ganna Hoek, and the species is not at Mielietuin.
Conservation status: nil. CIV: 4, 6. Impact: low, negative. Mitigation: nil.

Order LAGOMORPHA

Family LEPORIDAE
Lepus saxatilis Scrub hare S
Occurrence: A scrub hare was seen on Ganna Hoek at the edge of floodplain near the house, on 21/11/99. Definite at Mielietuin.
Conservation status: nil. CIV: 2, 2. Impact: low, negative. Mitigation: nil.

Pronolagus rupestris Smith's red rock rabbit S
Nearest record: 2829DBCC. Rock rabbits were reported as being present in the area (local people, 23/11/99). Probable at Mielietuin.
Conservation status: nil. CIV: 18, 0. Impact: low, negative. Mitigation: nil.

Order RODENTIA

Family HYSTRICIDAE
Hystrix africaeaustralis Porcupine S
Occurrence: Quills, dung and bark gnawing of porcupines were seen in a number of areas (11-14/11/99) on Ganna Hoek, and on Mielietuin (9-11/12/99), indicating a widespread distribution in the areas.
Conservation status: nil. CIV: 7, 6. Impact: low, negative. Mitigation: nil.

Family GLIRIDAE
Graphiurus murinus Woodland dormouse L
Nearest record: 2829DBC, 2830CCA. Occurrence: Definite at both areas.

Conservation status: nil. CIV: 4, 1. Impact: low, negative. Mitigation: nil.

Family THRYONOMYIDAE

Thryonomys swinderianus Greater cane rat S

Occurrence: Dung pellets of cane-rat were found along the Thukela River bank at Ganna Hoek. Local people confirmed the presence of this animal in the area. It would appear that the population is not very large. Probable at Mielietuin.

Conservation status: nil. CIV: 9, 5. Impact: low, negative. Mitigation: nil.

Family MURIDAE

Otomys angoniensis Angoni vlei rat C, L

Occurrence: Identified from 19 skulls from owl pellets from Ramak and Ganna Hoek. Definite at Mielietuin.

Conservation status: nil. CIV: 14, 0. Impact: low, negative. Mitigation: nil.

Steatomys pratensis Fat mouse L

Nearest record: 2830DBC. Occurrence: probable for both areas.

Conservation status: nil. CIV: 18, 0. Impact: low, negative. Mitigation: nil.

Lemniscomys rosalia Single-striped mouse C

Occurrence: One specimen was collected on 12/11/99, Ganna Hoek, and on 10/12/99 at Mielietuin, both from open woodland.

Conservation status: nil. CIV: 8, 0. Impact: low, negative. Mitigation: nil.

Grammomys dolichurus Woodland mouse

Occurrence: A skull was found in an owl pellet on Ramak, November, 1999. Possible in Mielietuin.

Conservation status: nil. CIV: 14, 0. Impact: low, negative. Mitigation: nil.

Grammomys cometes Mocambique woodland mouse C

Occurrence: Found in closed canopy streambank forest at Mielietuin, 11/12/99. This specimen is the first collected from the Thukela basin, and provides a valuable distributional link explaining the presence of an outlying record from the Royal Natal National Park with populations in northern Zululand (Taylor 1998). Definite on Jana.

Conservation status: Nil. CIV: 16, 0 (revised from Bourquin, 1988). Impact : Low on Mielietuin, moderate on Jana. Mitigation: nil.

Mus minutoides Pygmy mouse L

Nearest record: WGR. Occurrence: Definite in both areas.

Conservation status: nil. CIV: 3, 0. Impact: low, negative. Mitigation: nil.

Mastomys natalensis Natal multimammate mouse C, L

Occurrence: Skull remains were identified from owl pellets from both Ramak and Ganna Hoek, and from collected specimens on Ganna Hoek. Definite at Mielietuin.

Conservation status: nil. CIV: 2, 3. Impact: low, negative. Mitigation: nil.

Mastomys coucha Multimammate mouse
Nearest record: WGR. Occurrence: Definite at both sites.
Conservation status: nil. No CIV available. Impact: low, negative. Mitigation: nil.

Thallomys paedulcus Tree rat C
Occurrence: Definite at both sites.
Conservation status: nil. CIV: 12, 0. Impact: low, negative. Mitigation: nil.

Aethomys chrysophilus Red veld rat L
Nearest record: WGR. Occurrence: Possible at both sites. Previous identifications from Weenen Game Reserve may however be erroneous - the taxonomy of the genus has been changed and the species likely in the areas are those recorded below.
Conservation status: nil. CIV: Because of taxonomic rearrangements, no CIV available. Impact: low, negative. Mitigation: nil.

Aethomys ineptus Red veld rat C, L
Occurrence: Skulls found in owl pellets at Jana, and specimens collected from both sites..
Conservation status: nil. CIV: Because of taxonomic rearrangements, no CIV available Impact: low, negative. Mitigation: nil.

Aethomys namaquensis Namaqua rock mouse C
Occurrence: Identified from skull remains found in owl pellets and from a collected specimen, Jana. Definite at Mielietuin.
Conservation status: nil. CIV: Because of taxonomic rearrangements, no CIV available Impact: low, negative. Mitigation: nil.

Saccostomus campestris Pouched mouse C
Occurrence: Found at Mielietuin in open woodland, 11/12/99, and skulls found in owl pellets on Ramak, November 1999.
Conservation status: nil. CIV: 9, 0. Impact: low, negative. Mitigation: nil.

Dendromus melanotis Grey climbing mouse L
Nearest record: 2830CDA. Occurrence: Probable at both areas.
Conservation status: nil. CIV: 12, 0. Impact: low, negative. Mitigation: nil.

Family PROTELIDAE
Proteles cristatus Aardwolf
Nearest record: WGR. Occurrence: Definite at Mielietuin, possible at Jana.
Conservation status: SARDB: R.. CIV: 22, 2. Impact: low, negative. Mitigation: nil.

Family HYAENIDAE
Crocuta crocuta Spotted hyaena L
Nearest record: WGR. Occurrence: Uncertain. If present at either area, then in very low numbers as temporary wanderers.
Conservation status: nil. CIV: 13, 4. Impact: low, negative. Mitigation: nil.

Family FELIDAE

Felis caracal Caracal S

Occurrence: Caracal were reported as being present in the Ganna Hoek area (local people, 23/11/99). Possible at Mielietuin.
Conservation status: nil. CIV: 6, 5. Impact: low, negative. Mitigation: nil.

Felis serval Serval L

Nearest record: WGR. Occurrence: Possible at Mielietuin, uncertain at Jana.
Conservation status: SARDB: R. CIV: 24, 4. Impact: low, negative. Mitigation: nil.

Family CANIDAE

Vulpes chama Cape fox L

Nearest record: 2829DBB. Not at Jana, uncertain at Mielietuin.
Conservation status: nil. CIV: 17, 1. Impact: low, negative. Mitigation: nil.

Canis mesomelas Black-backed jackal S

Black-backed jackal were reported as being present in the Ganna Hoek area (local people, 23/11/99). Definite at Mielietuin.
Conservation status: nil. CV: 1, 5. Impact: low, negative. Mitigation: nil.

Canis familiaris Dog S

Numbers of dogs were seen in the Ganna Hoek area, and dog spoor was fairly commonly found. The remains of a dead individual was found in a dry stream bed on Ganna Hoek, 13/11/99. Dog spoor was seen on Mielietuin.

Family MUSTELIDAE

Aonyx capensis Cape clawless otter L

Nearest record: WGR. Occurrence: Definite at Jana, and definite at Mielietuin according to the land-owner.
Conservation status: nil. CIV:17, 2. Impact: low, negative. Mitigation: nil.

Ictonyx striatus Striped polecat S, L

Nearest record: 2829DBD. Occurrence: The remains of a striped polecat were found at Mielietuin, 16/12/99, not present at Jana.
Conservation status: nil. CIV: 14, 1. Impact: low, negative. Mitigation: nil.

Family VIVERRIDAE

Genetta genetta Small-spotted genet L

Nearest record: 2829CCB. Occurrence: Possible at Mielietuin, not at Jana.
Conservation status: nil. CIV: not given by Rowe-Rowe, 1992. Impact: low, negative. Mitigation: nil.

Genetta tigrina Large-spotted genet S

Occurrence: Large-spotted genet were reported as being present in the Ganna Hoek area (local people, 23/11/99). Definite at both sites.
Conservation status: nil. CIV: 1, 5. Impact: low, negative. Mitigation: nil.

Cynictis penicillata Yellow mongoose L
Nearest record: WGR. Occurrence: Definite at Mielietuin, not at Jana.
Conservation status: nil. CIV: 12, 0. Impact: low, negative. Mitigation: nil.

Galerella sanguinea Slender mongoose S
Occurrence: An individual was seen near the Ganna Hoek homestead, 6/12/99, and at Mielietuin, 16/12/99.
Conservation status: nil. CIV: 6, 2. Impact: low, negative. Mitigation: nil.

Ichneumia albicauda White-tailed mongoose L
Nearest record: 2829DDB. Occurrence: Definite at both sites.
Conservation status: nil. CIV: 7, 1. Impact: low, negative. Mitigation: nil.

Atilax paludinosus Water mongoose S
Occurrence: Spoor of water-mongoose was found along the Thukela River and along several water-courses, 11-14/11/99, Ganna Hoek. Definite at Mielietuin.
Conservation status: nil. CIV: 9, 1. Impact: medium, positive. Mitigation: nil.

Order TUBULIDENTATA
Family ORYCTEROPODIDAE
Orycteropus afer (Pallas 1766) Aardvark S
Occurrence: A fresh aardvark dig was found on red sand flats above a stream on Ganna Hoek, and other digging signs were found scattered in the area. The species appears to be rare in the area, judging from the paucity of diggings. Similarly, digging signs were seen at Mielietuin during 9-11/12/99.
Conservation status: SARDB: V. CIV: Not available. Impact: low, negative. Mitigation: Filling of dam should be done as slowly as possible.

Order: HYRACOIDEA
Family: PROCAVIIDAE
Procavia capensis Rock dassie S
Nearest record: WGR. Occurrence: Water Affairs staff stated that they had seen dassie at Ganna Hoek, but that these were few in number. Accumulations of dassie dung were found at the lower reaches and base of a sandstone cliff on Ramak, but no dassies were seen or heard there. Most of the dung looked old. One dassie was seen near the wall-site of the proposed Jana dam, 5/11/99. Definite at Mielietuin.
Conservation status: nil. CIV: 7, 5. Impact: low, negative. Mitigation: nil.

Order ARTIODACTYLA
Family SUIDAE
Potamochoerus porcus Bushpig S
Occurrence: Bushpig were reported as being present in the Ganna Hoek area, but not in great numbers (local people, 23/11/99), while numbers of bushpig skulls were seen of animals which had been killed on Mielietuin where they had been raiding the bottomland crops.
Conservation status: nil. CIV: 6,5. Impact: low, negative. Mitigation: nil.

Phacochoerus aethiopicus Warthog D,L
Nearest record: WGR, Colenso Conservancy. Occurrence: Although introduced to areas adjoining the dam sites, it appears that warthogs have only rarely entered the dam sites.
Conservation status: nil. CIV: 16, 4. Introduced species. Impact: low, negative. Mitigation: nil.

Family BOVIDAE
Sylvicapra grimmia Common duiker S
Occurrence: A total of four grey duiker were seen on Ganna Hoek, and fresh remains of a grey duiker were found on Ramak on 22/11/99. Several duiker were seen on Mielietuin.
Conservation status: nil. CIV: 1, 5. Impact: low, negative. Mitigation: nil.

Raphicerus campestris Steenbok S
Nearest record: WGR. Occurrence: Steenbok were reported as being present in the area (local people, 23/11/99).Definite at Mielietuin, with one seen above the dam site, and the landowner confirming their presence on the farm.
Conservation status: nil. CIV: 15, 1. Impact: low, negative. Mitigation: nil.

Ourebia orebi Oribi S
Occurrence: No oribi occur on Jana, but the land-owner of Groote Mielietuin farm said that the species occurred in the dam-site. The species has not been recorded from this area before.
Conservation status:SARDB: V. CIV:16, 1. Impact: low, negative. Mitigation: nil.

Aepyceros melampus Impala S
The remains of an impala were found on Ganna Hoek. Two young rams were seen on 22/11/99, and three on 28/11/99, on Ramak. Impala were seen on Groot Mielietuin, but not in the dam site itself. It is possible that some individuals may enter the site.
Conservation status: nil. CIV: 9, 6. Impact: low, negative. Mitigation: nil.

Tragelaphus strepsiceros Kudu D, S
Occurrence: Water Affairs staff indicate that kudu are present on Ganna Hoek, while some of the local people confirmed this (23/11/98) but indicated that kudu lived on the top slopes. Kudu were seen on the Mielietuin site 9-11/12/99, and 15-16/12/99.
Conservation status: nil. CIV: 11, 4. Impact: low, negative. Mitigation: nil.

Tragelaphus scriptus Bushbuck S
Occurrence: A bushbuck was seen in dense tree cover next to the Thukela River (Ganna Hoek, 22/11/99) and were reported as being fairly common in the Ganna Hoek area (local people, 23/11/99). Definite at Mielietuin.
Conservation status: nil. CIV: 9, 6. Impact: low, negative. Mitigation: nil.

Redunca fulvorufula Mountain reedbuck S
Occurrence: Mountain reedbuck were reported as being present in the Ganna Hoek area (local people, 23/11/99). Definite at Mielietuin.
Conservation status: nil. CIV: 11, 3. Impact: low, negative. Mitigation: nil.

BIRDS

The total expected list for the system is 247. All will occur at Jana, 226 at Mielietuin. The actual numbers seen were 109 at Jana (two days of observation) and 77 at Mielietuin (one day, less than ideal conditions). This ratio of seen/day : overall expected number conforms to the seen : known relationship in well-watched nature reserves, indicating that some reliability can be placed upon the predicted totals. The difference in the species lists can be attributed to the following reasons:

1. Jana has more cliffs, and they are taller and offer more security to birds.

2. Jana is closer to the source of subtropical Zululand birds.

3. Jana is richer botanically - at least in terms of bird-friendly tree species.

4. Jana has denser riverine vegetation.

5. Jana has a more extensive floodplain.

There will be a few species that occur at Mielietuin, and not at Jana, but these will be species typical of higher altitudes that do not figure in this exercise.

Key:

J = recorded at Jana during site visits
M = recorded at Mielietuin during site visits
(J) = presumed present at Jana
(B) = presumed present at both sites

SOUTH AFRICAN ENDEMIC BIRDS

Geronticus calvus Bald Ibis
Gyps coprotheres Cape Vulture
Buteo rufofuscus Jackal Buzzard
Mirafra cheniana Melodious Lark
Lioptilus nigricapillus Bush Blackcap
Monticola rupestris Cape Rock Thrush
Cossypha dichroa Chorister Robin
Sigelus silens Fiscal Flycatcher
Stenostira scita Fairy Flycatcher
Tchagra tchagra Southern Tchagra
Nectarinia chalybea Lesser Doublecollared Sunbird
Nectarinia afra Greater Doublecollared Sunbird
Zosterops pallidus Cape White-eye
Ploceus capensis Cape Weaver
Estrilda melanotis Swee Waxbill

Order: PELECANIFORMES
Family: PHALACROCORACIDAE
Phalacrocorax carbo (Linnaeus 1758) Whitebreasted Cormorant (B)
Phalacrocorax africanus (Sparrmann 1788) Reed Cormorant (B)

Order: CICONIIFORMES
Family: ARDEIDAE
Ardea cinerea Linnaeus 1758 Grey Heron (B)
Ardea melanocephala Vigors and Children 1826 Blackheaded Heron J(B)
Bubulcus ibis (Linnaeus 1758) Cattle Egret J(B)
Gorsachius leuconotus (Wagler 1855) Whitebacked Night Heron (J)
Ixobrychus sturmii (Hartlaub 1858) Dwarf Bittern (B)

Family: SCOPIDAE
Scopus umbretta Gmelin 1789 Hamerkop J(B)

Family: CICONIIDAE
Ciconia ciconia (Linnaeus 1758) White Stork (B)
Ciconia nigra (Linnaeus 1758) Black Stork J(B)

Family: PLATALEIDAE
Threskiornis aethiopicus (Latham 1790) Sacred Ibis (B)
Geronticus calvus (Boddaert 1783) Bald Ibis J(B)
Bostrychia hagedash (Latham 1790) Hadeda Ibis JM

Order: ANSERIFORMES
Family: ANATIDAE
Alopochen aegyptiacus (Linnaeus 1766) Egyptian Goose JM
Anas undulata Dubois 1837 Yellowbilled Duck (B)
Anas sparsa Eyton 1838 African Black Duck J(B)
Plectropterus gambensis (Linnaeus 1758) Spurwinged Goose M(B)

Order: FALCONIFORMES
Family: SAGITTARIIDAE
Sagittarius serpentarius (Miller 1779) Secretary Bird (B)

Family: ACCIPITRIDAE
Gyps coprotheres (Forster 1798) Cape Vulture (B)
Milvus migrans (Daudin 1800) Black (Yellowbilled) Kite JM
Elanus caeruleus (Desfontaines 1787) Blackshouldered Kite (B)
Aviceda cuculoides Swainson 1836 Cuckoo Hawk (B)
Aquila verreauxii Lesson 1830 Black Eagle (B)
Aquila rapax (Temminck 1828 Tawny Eagle JM
Aquila wahlbergi Sundevall 1850 Wahlberg’s Eagle JM
Hieraaetus pennatus (Gmelin 1788) Booted Eagle J(B)
Lophaetus occipitalis (Daudin 1800) Longcrested Eagle M(B)

Polemaetus bellicosus (Daudin 1800) Martial Eagle (B)
Stephanoaetus coronatus (Linnaeus 1766) Crowned Eagle (J)
Circaetus cinereus Vieillot 1818 Brown Snake Eagle (B)
Buteo buteo (Linnaeus 1758) Steppe Buzzard JM
Buteo rufofuscus (Forster 1798) Jackal Buzzard J(B)
Accipiter minullus (Daudin 1800) Little Sparrowhawk J(B)
Accipiter melanoleucus Smith 1830 Black Sparrowhawk (B)
Accipiter tachiro (Daudin 1800) African Goshawk (B)
Micronisus gabar (Daudin 1800) Gabar Goshawk (B)
Polyboroides typus Smith 1829 Gymnogene JM

Family: FALCONIDAE
Falco peregrinus Tunstall 1771 Peregrine Falcon (J)
Falco biarmicus Temminck 1825 Lanner Falcon J(B)
Falco subbuteo Linnaeus 1758 Hobby Falcon (B)
Falco amurensis Radde 1863 Eastern Redfooted Kestrel (B)
Falco tinnunculus Linnaeus 1758 Rock Kestrel J(B)

Order: GALLIFORMES
Family: PHASIANIDAE
Francolinus shelleyi Ogilvie-Grant 1890 Shelley's Francolin (B)
Francolinus natalensis Smith 1834 Natal Francolin JM
Francolinus swainsonii (Smith 1836) Swainson's Francolin (B)
Coturnix coturnix (Linnaeus 1758) Common Quail (B)

Family: NUMIDIDAE
Numida meleagris (Linnaeus 1766) Helmeted Guineafowl J(B)

Order: GRUIFORMES
Family: TURNICIDAE
Turnix sylvatica (Desfontaines 1787) Kurrichane Buttonquail (B)

Family: RALLIDAE
Amaurornis flavirostris (Swainson 1837) Black Crake (B)

Family: HELIORNITHIDAE
Podica senegalensis (Viellot 1818) African Finfoot (J)

Family: OTIDIDAE
Eupodotis cafra (Lichtenstein 1793) Whitebellied Korhaan (B)
Eupodotis melanogaster (Ruppell 1837) Blackbellied Korhaan (B)

Order: CHARADRIIFORMES
Family: CHARADRIIDAE
Charadrius tricollaris Vieillot 1818 Threebanded Plover (B)
Vanellus coronatus (Boddaert 1783) Crowned Plover (B)
Vanellus armatus (Burchell 1822) Blacksmith Plover (B)

Family: SCOLOPACIDAE
Actitis hypoleucos (Linnaeus 1758) Common Sandpiper JM
Tringa glareola Linnaeus 1758 Wood Sandpiper (B)

Family: BURHINIDAE
Burhinus capensis (Lichtenstein 1823) Spotted Dikkop M(B)

Order: COLUMBIFORMES
Family: COLUMBIDAE
Columba guinea Linnaeus 1758 Rock Pigeon J(B)
Columba arquatrix Temminck 1809 Rameron Pigeon (J)
Streptopelia semitorquata (Ruppell 1837) Redeyed Dove JM
Streptopelia capicola (Sundevall 1837) Cape Turtle Dove JM
Streptopelia senegalensis (Linnaeus 1766) Laughing Dove J(B)
Oena capensis (Linnaeus 1766) Namaqua Dove (B)
Turtur chalcospilos (Wagler 1827) Greenspotted Dove JM
Turtur tympanistria (Temminck 1810) Tambourine Dove J

Order: MUSOPHAGIFORMES
Family: MUSOPHAGIDAE
Tauraco porphyreolophus (Vigors 1831) Purplecrested Lourie (J)

Order: CUCULIFORMES
Family: CUCULIDAE
Cuculus gularis Stephens 1815 African Cuckoo JM
Cuculus solitarius Stephens 1815 Redchested Cuckoo JM
Cuculus clamosus Latham 1801 Black Cuckoo JM
Clamator glandarius (Linnaeus 1758) Great Spotted Cuckoo (B)
Clamator levaillantii (Swainson 1829) Striped Cuckoo (B)
Clamator jacobinus (Boddaert 1783) Jacobin Cuckoo (B)
Chrysococcyx klaas (Stephens 1815) Klaas's Cuckoo JM
Chrysococcyx caprius (Boddaert 1783) Diederik Cuckoo JM
Centropus burchellii Swainson 1838 Burchell's Coucal (B)

Order: STRIGIFORMES
Family: TYTONIDAE
Tyto alba (Scopoli 1777) Barn Owl (B)

Family: STRIGIDAE
Bubo africanus (Temminck 1823) Spotted Eagle Owl J(B)

Order: CAPRIMULGIFORMES
Family: CAPRIMULGIDAE
Caprimulgus europaeus Linnaeus 1758 European Nightjar (B)
Caprimulgus pectoralis Cuvier 1817 Fierynecked Nightjar (B)

Order: APODIFORMES
Family: APODIDAE
Apus apus (Linnaeus 1758) European Swift J(B)
Apus barbatus (Sclater 1865) Black Swift J(B)
Apus caffer (Lichtenstein 1823) Whiterumped Swift M(B)
Apus horus (Heuglin 1869) Horus Swift JM
Apus affinis (Gray 1840) Little Swift J(B)
Apus melba (Linnaeus 1758) Alpine Swift (B)
Cypsiurus parvus (Lichtenstein 1823) Palm Swift J(B)

Order: COLIIFORMES
Family: COLIIDAE
Colius striatus Gmelin 1789 Speckled Mousebird (B)
Urocolius indicus (Latham 1790) Redfaced Mousebird J(B)

Order: ALCEDINIFORMES
Family: ALCEDINIDAE
Ceryle rudis (Linnaeus 1758) Pied Kingfisher (B)
Megaceryle maxima (Pallas 1769) Giant Kingfisher (B)
Alcedo semitorquata Swainson 1823 Halfcollared Kingfisher (B)
Alcedo cristata Pallas 1764 Malachite Kingfisher J(B)
Ispidina picta (Boddaert 1783) Pygmy Kingfisher (B)
Halcyon albiventris (Scopoli 1786) Brownhooded Kingfisher JM

Family: MEROPIDAE
Merops pusillus Statius Muller 1766 Little Bee-eater (B)
Family: CORACIIDAE
Coracias garrulus Linnaeus 1758 European Roller (B)

Family: UPUPIDAE
Upupa epops Linnaeus 1758 Hoopoe JM

Family: PHOENICULIDAE
Phoeniculus purpureus (Miller 1784) Redbilled Woodhoopoe (B)
Rhinopomastus cyanomelas (Vieillot 1819) Scimitarbilled Woodhoopoe (B)

Family: BUCEROTIDAE
Bycanistes bucinator (Temminck 1824) Trumpeter Hornbill J
Tockus alboterminatus (Buttikofer 1889) Crowned Hornbill J
Bucorvus leadbeateri (Vigors 1825) Ground Hornbill J(B)

Order: PICIFORMES
Family: LYBIIDAE
Lybius torquatus (Dumont 1816) Blackcollared Barbet JM
Tricholaema leucomelas (Boddaert 1823) Pied Barbet JM
Pogoniulus pusillus (Dumont 1816) Redfronted Tinker Barbet JM
Trachyphonus vaillantii Ranzani 1821 Crested Barbet (B)

Family: INDICATORIDAE
Indicator indicator (Sparrmann 1777) Greater Honeyguide J(B)
Indicator variegatus Lesson 1830 Scalythroated Honeyguide (J)
Indicator minor Stephens 1815 Lesser Honeyguide M(B)
Prodotiscus regulus Sundevall 1850 Sharpbilled Honeyguide M(B)

Family: PICIDAE
Campethera abingoni (Smith 1836) Goldentailed Woodpecker JM
Dendropicos fuscescens (Vieillot 1818) Cardinal Woodpecker JM
Thripias namaquus (Lichtenstein 1793) Bearded Woodpecker (J)

Family: JYNGIDAE
Jynx ruficollis Wagler 1830 Redthroated Wryneck JM

Order: PASSERIFORMES
Family: ALAUDIDAE
Mirafra cheniana Smith 1843 Melodious Lark (B)
Mirafra africana Smith 1836 Rufousnaped Lark JM
Mirafra sabota Smith 1836 Sabota Lark M(B)
Mirafra curvirostris (Hermann 1783) Longbilled Lark J(B)
Calandrella cinerea (Gmelin 1789) Redcapped Lark (B)

Family: HIRUNDINIDAE
Hirundo rustica Linnaeus 1758 European Swallow M(B)
Hirundo albigularis Strickland 1849 Whitethroated Swallow (B)
Hirundo cucullata Boddaert 1783 Greater Striped Swallow JM
Hirundo abyssinica Guerin-Meneville Lesser Striped Swallow JM
Hirundo fuligula Lichtenstein 1842 Rock Martin JM
Delichon urbica (Linnaeus 1758) House Martin (B)
Riparia riparia (Linnaeus 1758) Sand Martin (B)
Riparia paludicola (Vieillot 1817) Brownthroated Martin (B)
Psalidoprocne holomelas (Sundevall 1850) Black Sawwing Swallow (B)

Family: CAMPEPHAGIDAE
Campephaga flava Vieillot 1817 Black Cuckooshrike (B)

Family: DICRURIDAE
Dicrurus adsimilis (Bechstein 1794) Forktailed Drongo JM

Family: ORIOLIDAE
Oriolus larvatus Lichtenstein 1823 Blackheaded Oriole JM

Family: CORVIDAE
Corvus capensis Lichtenstein 1823 Black Crow M(B)
Corvus albus Statius Muller 1766 Pied Crow J(B)
Corvus albicollis Latham 1790 Whitenecked Raven J(B)

Family: PARIDAE
Parus niger Vieillot 1818 Southern Black Tit JM

Family: REMIZIDAE
Anthoscopus caroli (Sharpe 1871) Grey Penduline Tit (B)

Family: TIMALIIDAE
Turdoides jardineii (Smith 1836) Arrowmarked Babbler J(B)
Lioptilus nigricapillus (Vieillot 1818) Bush Blackcap (J)

Family: PYCNONOTIDAE
Pycnonotus barbatus (Desfontaines 1787) Blackeyed Bulbul JM
Andropadus importunus (Vieillot 1818) Sombre Bulbul JM

Family: TURDIDAE
Turdus libonyana (Smith 1836) Kurrichane Thrush (B)
Turdus olivaceus Linnaeus 1766 Olive Thrush (J)
Turdus litsitsirupa (Smith 1836) Groundscraper Thrush (B)
Monticola rupestris (Vieillot 1818) Cape Rock Thrush (B)
Cercomila familiaris (Stephens 1826) Familiar Chat J(B)
Thamnolaea cinnamomeiventris (Lafresnaye 1836) Mocking Chat J(B)
Saxicola torquata (Linnaeus 1766) Stonechat (B)
Cossypha dichroa (Gmelin 1789) Chorister Robin (J)
Cossypha caffra (Linnaeus 1771) Cape Robin JM
Cossypha humeralis (Smith 1836) Whitethroated Robin J(B)
Pogonocichla stellata (Vieillot 1818 Starred Robin (J)
Erythropygia leucophrys (Vieillot 1817) Whitebrowed Robin JM

Family: SYLVIIDAE
Sylvia borin (Boddaert 1783) Garden Warbler (B)
Parisoma subcaeruleum (Vieillot 1817) Titbabbler J(B)
Hippolais icterina Icterine (Vieillot 1817) Warbler (B)
Acrocephalus arundinaceus (Linnaeus 1758) Great Reed Warbler (B)
Acrocephalus baeticatus (Vieillot 1817) African Marsh Warbler (B)
Acrocephalus palustris (Bechstein 1798) European Marsh Warbler (B)
Acrocephalus schoenobaenus (Linnaeus 1758) European Sedge Warbler (B)
Acrocephalus gracilirostris (Hartlaub 1864) Cape Reed Warbler (B)
Phylloscopus trochilus (Linnaeus 1758) Willow Warbler M(B)
Apalis thoracica (Shaw and Nodder 1811) Barthroated Apalis J
Sylvietta rufescens (Vieillot 1817) Longbilled Crombec JM
Camaroptera brachyura (Vieillot 1820) Bleating Warbler JM
Cisticola juncidus (Rafinesque) Fantailed Cisticola JM
Cisticola chiniana (Smith 1843) Rattling Cisticola JM
Cisticola tinniens (Lichtenstein 1842) Levaillant’s Cisticola (B)
Cisticola aberrans (Smith 1843) Lazy Cisticola (B)
Cisticola fulvicapilla (Vieillot 1817) Neddicky JM
Prinia subflava (Gmelin 1789) Tawnyflanked Prinia JM

Family: MUSCICAPIDAE
Muscicapa striata (Pallas 1764) Spotted Flycatcher JM
Muscicapa adusta (Boie 1828) Dusky Flycatcher (B)
Melaenornis pammelaina (Stanley 1814) Black Flycatcher (B)
Melaenornis pallidus (Muller 1766) Pallid Flycatcher (B)
Sigelus silens (Shaw 1809) Fiscal Flycatcher JM
Batis capensis (Linnaeus 1766) Cape Batis (J)
Batis molitor (Hahn and Kuster 1850) Chinspot Batis JM
Stenostira scita (Vieillot 1818) Fairy Flycatcher (B)
Terpsiphone viridis (Statius Muller 1766) Paradise Flycatcher JM

Family: MOTACILLIDAE
Motacilla aguimp Dumont 1821 African Pied Wagtail M(B)
Motacilla capensis Linnaeus 1766 Cape Wagtail JM
Anthus cinnamomeus (Gmelin 1789) Grassveld Pipit (B)
Anthus similis Jerdon Longbilled Pipit (B)
Anthus leucophrys Vieillot 1818 Plainbacked Pipit (B)
Anthus vaalensis Shelley 1900 Buffy Pipit (B)
Anthus lineiventris Sundevall 1850 Striped Pipit (J)
Anthus caffer Sundevall 1850 Bushveld Pipit (B)
Macronyx capensis (Linnaeus 1766) Orangethroated Longclaw (B)

Family: LANIIDAE
Lanius minor Gmelin 1788 Lesser Grey Shrike (B)
Lanius collaris Linnaeus 1766 Fiscal Shrike J(B)
Lanius collurio Linnaeus 1758 Redbacked Shrike J(B)

Family: MALACONOTIDAE
Laniarius ferrugineus (Gmelin 1788) Southern Boubou JM
Dryoscopus cubla (Shaw 1809) Puffback (B)
Nilaus afer (Latham 1801) Brubru JM
Tchagra tchagra (Vieillot 1816) Southern Tchagra M(B)
Tchagra senegala (Linnaeus 1758) Blackcrowned Tchagra JM
Telophorus zeylonus (Linnaeus 1766) Bokmakierie (B)
Telophorus sulfureopectus (Lesson 1831) Orangebreasted Bush Shrike JM
Malaconotus blanchoti Stephens 1826 Greyheaded Bush Shrike J(B)

Family: STURNIDAE
Cinnyricinclus leucogaster (Boddaert 1783) Plumcoloured Starling JM
Lamprotornis nitens (Linnaeus 1758) Glossy Starling JM
Onychognathus morio (Linnaeus 1766) Redwinged Starling JM

Family: PROMEROPIDAE
Promerops gurneyi Verreaux 1871 Gurney's Sugarbird (B)

Family: NECTARINIIDAE
Nectarinia famosa (Linnaeus 1766) Malachite Sunbird (B)
Nectarinia chalybea (Linnaeus 1766) Lesser Doublecollared Sunbird (J)
Nectarinia afra (Linnaeus 1766) Greater Doublecollared Sunbird (B)
Nectarinia talatala (Smith 1836) Whitebellied Sunbird JM
Nectarinia senegalensis (Linnaeus 1766) Scarletchested Sunbird (J)
Nectarinia amethystina (Shaw 1811) Black Sunbird JM

Family: ZOSTEROPIDAE
Zosterops pallidus Swainson 1838 Cape White-eye JM

Family: PLOCEIDAE
Passer domesticus (Linnaeus 1758) House Sparrow J(B)
Passer diffusus (Vieillot 1818) Greyheaded Sparrow (B)
Petronia superciliaris (Blyth 1845) Yellowthroated Sparrow (B)
Amblyospiza albifrons (Vigors 1831) Thickbilled Weaver (B)
Ploceus ocularis Smith 1828 Spectacled Weaver JM
Ploceus cucullatus Statius Muller 1766 Spottedbacked Weaver M(B)
Ploceus capensis (Linnaeus 1766) Cape Weaver (B)
Ploceus velatus Vieillot 1819 Masked Weaver JM
Ploceus intermedius Ruppell 1837 Lesser Masked Weaver J(B)
Anomalospiza imberbis (Cabanis 1868) Cuckoo Finch (B)
Quelea quelea (Linnaeus 1758) Redbilled Quelea J(B)
Euplectes orix (Linnaeus 1758) Red Bishop J(B)
Euplectes axillaris (Smith 1838) Redshouldered Widow (B)
Euplectes albonotatus (Cassin 1848) Whitewinged Widow M(B)
Euplectes ardens (Boddaert 1783) Redcollared Widow (B)

Family: ESTRELDIDAE
Pytilia melba (Linnaeus 1758) Melba Finch (B)
Lagonosticta rubricata (Lichtenstein 1823) Bluebilled Firefinch J(B)
Lagonosticta rhodopareia (Linnaeus 1758) Redbilled Firefinch (J)
Uraeginthus angolensis (Linnaeus 1758) Blue Waxbill JM
Estrilda astrild (Linnaeus 1758) Common Waxbill (B)
Estrilda melanotis (Temminck 1823) Swee Waxbill (B)
Ortygospiza atricollis (Vieillot 1818) Quail Finch J(B)
Sporaeginthus subflavus (Vieillot 1818) Orangebreasted Waxbill (B)
Amadina erythrocephala (Linnaeus 1758) Redheaded Finch J(B)
Spermestes cucullatus Swainson 1838 Bronze Mannikin (B)
Spermestes bicolor (Freaser) Redbacked Mannikin (J)

Family: VIDUIDAE
Vidua macroura (Pallas 1764) Pintailed Whydah J(B)
Vidua funerea (de Tarragon 1847) Black Widowfinch (B)

Family: FRINGILLIDAE
Serinus mozambicus (Statius Muller 1776) Yelloweyed Canary JM
Serinus atrogularis (Smith 1836) Blackthroated Canary (B)
Serinus canicollis (Swainson 1838) Cape Canary (B)
Serinus sulphuratus (Linnaeus 1766) Bully Canary (B)
Serinus gularis (Smith 1836) Streakyheaded Canary JM
Emberiza flaviventris Stephens 1815 Goldenbreasted Bunting J(B)
Emberiza capensis Linnaeus 1766 Cape Bunting (B)
Emberiza tahapisi Smith 1836 Rock Bunting (B)

REPTILES Tortoises, terrapins, snakes, lizards, worm-lizards

The initial list was derived from a manuscript being prepared for publication (Reptiles of KwaZulu-Natal, O.Bourquin), Branch 1998 and Bourquin & Mathias, 1995.

Conservation importance values (CIV) were obtained from Bourquin, 1990, and Lambiris and Bourquin (1993). A score of 21 or more, or 3 or more respectively indicates the species as important in KwaZulu-Natal.

Tortoises and terrapins (Order: Testudines)

Family: TESTUDINIDAE

Geochelone pardalis Leopard tortoise L
Nearest records: Weenen Game Reserve (WGR) and 2830 CAC.
Occurrence: Possible in low numbers in both dam sites, not occurring on very steep terrain, or in areas with dense ground cover or very rocky areas.
Conservation rating: No RDB rating, but becoming scarce in KZN because of habitat loss, use as traditional medicine, and as food.
Impact: Low, negative. Mitigatory measures: The filling of the dam should be done as slowly as possible, allowing escape by the tortoises. The species is able to swim to some extent. Any tortoises found in areas to be flooded should be removed to the Colenso conservancy or WGR.

Kinixys natalensis Natal hinged tortoise S
Occurrence: Four individuals (2 males, 1 female and one of unknown sex) were seen on Ganna Hoek after good rain had fallen , on 29/11/99. All were found on moderate to relatively flat N to NE facing slopes in open to semi-closed woodland. Ground was stony but not excessively rocky, and ground cover was sparse, with few grasses and with scattered broad-leaved herbs and small shrubs. The species does not appear to live on very steep slopes, in areas with dense ground or tree cover or in very rocky areas.
Definite on Mielietuin.
Conservation rating: SARDB: Rare . Impact:moderate, negative. Mitigatory measures: All tortoises found in the areas to be flooded should be removed and relocated in the WGR or in suitable areas in the Colenso Conservancy. This species is not known to be able to swim.

Family: PELOMEDUSIDAE

Pelomedusa subrufa Marsh terrapin S
Occurrence:The remains of a marsh terrapin were found in a dry water course on 14/11/99, and live animals were seen in pools in two separate streambeds on Ganna Hoek. Seen at Mielietuin in a stream and in a small isolated pool, 15/12/99.
Conservation rating: Nil. Impact, high positive. The increased water area will allow populations to increase where suitable nesting and aestivation sites are present.Mitigatory measures: None needed.

Snakes and lizards (Order: Squamata)
Snakes (Suborder: Serpentes)

Family: LEPTOTYPHLOPIDAE

Leptotyphlops scutifrons scutifrons Peters’ thread snake C
Conservation rating: Nil. CIV: 4,0. Impact: Low, negative. Mitigatory measures: None needed.
Family: BOIDAE

Python sebae natalensis Smith 1840 Natal rock-python S
Occurrence: A Water Affairs staff member reports seeing a total of five pythons during the last year on and near Ganna Hoek. A juvenile was caught at the Ganna Hoek house (22/11/99) and released away from the homestead area. Reported as being at Mielietuin by the land-owner.
Conservation rating: SARDB: V. CIV:24, 8. Impact: Low, negative. Mitigatory measures: none.

Family: ATRACTASPIDIDAE

Atractaspis bibronii (Smith, 1849) Bibron’s burrowing asp D
Occurrence: Definite at both sites.
Conservation rating: Nil. CIV: 8,0. Impact: Low, negative. Mitigatory measures: None needed.

Aparallactus capensis (Smith, 1849) Cape black-headed centipede eater C
Occurrence: Found in termitaria at Mielietuin, 9-10/12/99. Definite at Jana.
Conservation rating: Nil. CIV: 5, 0. Impact: Low, negative. Mitigatory measures: None needed.

Family: COLUBRIDAE

Lycodonomorphus laevissimus (Gunther 1862) (= *L. l. laevissimus*, *L.l. natalensis* and *L.l. fitzimonsi*) Dusky-bellied water-snake L
Occurrence: Definite at both sites.
Conservation rating: Nil. CIV:Not given as a single species at the time. Impact: Low, negative. Mitigatory measures: None needed.

Lycodonomorphus rufulus Lichtenstein 1823 Common brown water-snake D
Occurrence: Definite at both sites.
Conservation rating: Nil. CIV: 6, 0. Impact: Low, negative. Mitigatory measures: None needed.

Lamprophis fuliginosus Brown house snake C
Occurrence: Two brown house snakes were found under a fallen aloe on Ganna Hoek, 5/12/99. Definite at Jana.
Conservation rating: Nil. CIV: 1,4. Impact: Low, negative. Mitigatory measures: None needed.

Lycophidion capense capense Cape wolf snake C
Occurrence: A Cape wolf snake was found under a rock in fairly dense woodland on Ganna Hoek, 21/11/99. Definite at Mielietuin.
Conservation rating: Nil. CIV: 2, 0. Impact: Low, negative. Mitigatory measures: None needed.

Mehelya capensis capensis Cape file snake D
Occurrence: Probable at both sites.
Conservation rating: Nil. CIV: 12,1. Impact: Low, negative. Mitigatory measures: None needed.

Pseudaspis cana Mole snake D
Occurrence: Probable at both sites.
Conservation rating: Nil. CIV: 4,2. Impact: Low, negative. Mitigatory measures: None needed.

Psammophis brevirostris brevirostris Short-snouted grass snake C
Occurrence: A short-snouted grass snake was found in an old termitarium on Ganna Hoek, 21/11/99. Definite at Mielietuin.
Conservation rating: Nil. CIV: 6,0. Impact: Low, negative. Mitigatory measures: None needed.

Psammophis mossambicus (= *P. phillipsii*) Olive grass snake D
Occurence: Definite at both sites.
Conservation rating: Nil. CIV: 9, 0. Impact: Low, negative. Mitigatory measures: None needed.

Philothamnus semivariegatus semivariegatus Spotted bush snake L, D, C
Occurence: Definite at Jana, found at Mielietuin 16/12/99. .
Conservation rating: Nil. CIV:7, 0. Impact: Low, negative. Mitigatory measures: None needed.

Philothamnus hoplogaster Green water snake D
Occurence: Definite at both sites.
Conservation rating: Nil. CIV: 7,0. Impact: Low, negative. Mitigatory measures: None needed.

Dasypeltis scabra Common eggeater L
Occurence: Definite at both sites.
Conservation rating: Nil. CIV: 4, 0. Impact: Low, negative. Mitigatory measures: None needed.

Crotaphopeltis hotamboeia Herald snake L,D
Occurence: Definite at both sites.
Conservation rating: Nil. CIV: 1,0.. Impact: Low, negative. Mitigatory measures: None needed.

Telescopus semiannulatus semiannulatus Eastern tiger snake L
Occurrence: Possible at Jana, not at Mielietuin.
Conservation rating: Nil. CIV: 13, 0 Impact: Low, negative. Mitigatory measures: None needed.

Dispholidus typus typus Boomslang L, D
Occurence: Definite at both sites.
Conservation rating: Nil. CIV:7, 0. Impact: Low, negative. Mitigatory measures: None needed.

Thelotornis kirtlandii capensis Vine snake L, D
Occurrence: Possible at Jana, not at Mielietuin.
Conservation rating: Nil. CIV: 10, 0. Impact: Low, negative. Mitigatory measures: None needed.

FAMILY: ELAPIDAE

Homoroselaps dorsalis Striped harlequin snake L, D
Occurrence: Possible at both sites.
Conservation rating: SARDB: R. CIV: 28, 0. Impact: Low, negative. Mitigatory measures: None needed.

Naja mossambica Mozambique spitting cobra S, L
Occurence: Three dead specimens seen (killed 1-2 weeks before) on (Schurfde Poort 1147), 4/11/99 and reported as common on Ganna Hoek by Water Affairs staff. Seen at Mielietuin, 16/12/99.
Conservation rating: Nil CIV: 8,2. Impact: Low, negative. Mitigatory measures: None required.

Dendroaspis polylepis Black mamba S
One ca.1.8m mamba was seen hunting rodents near Ganna Hoek homestead, 6/12/99. Definite at Mielietuin.
Conservation rating: Nil. CIV: 10, 3. Impact: Low negative. Mitigatory measures: None required.

FAMILY: VIPERIDAE

Causus rhombeatus Rhombic night adder L
Occurrence: Definite at both sites.
Conservation rating: Nil. CIV: 7,0. Impact: Low, negative. Mitigatory measures: None needed

Bitis arietans Puff adder S, L
Occurrence: One dead specimen seen (killed 1-2 weeks ago) on Schurfde Poort 1147, 4/11/99. Definite at both dam sites.
Conservation rating: Nil. CIV: 3, 5. Impact: Low negative. Mitigatory measures: None required.

Lizards (Suborder Sauria)

FAMILY: SCINCIDAE

Acontias plumbeus Giant legless skink D
Nearest record: 2829DBD. Occurrence: Probable at Jana, not at Mielietuin.
Conservation rating: Nil. CIV: 12, 0. Impact: Low, negative. Mitigatory measures: None needed.

Mabuya capensis Cape skink D
Occurrence: Probable at both sites.
Conservation rating: Nil. CIV: 9, 1. Impact: Low, negative. Mitigatory measures: None needed.

Mabuya striata punctatissima Speckled skink C
The speckled skink was found to be fairly well distributed in dolerite boulder areas, and on sandstone outcrop areas and around the Ganna Hoek homestead. Definite at Mielietuin.
Conservation rating: Nil. CIV: 9, 1. Impact: Low negative. Mitigatory measures: None required.

Mabuya varia varia Variable skink S
Occurrence: The variable skink is common and wide-spread in both areas.
Conservation rating: Nil. CIV: 6, 1. Impact: Low negative. Mitigatory measures: None required.

Panaspis wahlbergii Wahlberg's snake-eyed skink C
Occurrence: Seen on several occasions under fallen, dead *Aloe spectabilis* on Ganna Hoek , and also found on a dolerite ridge in burnt veld. Common on Mielietuin.
Conservation rating: Nil. CIV: 9, 0. Impact: Low negative. Mitigatory measures: None required.

FAMILY: LACERTIDAE.

Nucras ornata (= *N. taeniolatata ornata*) Ornate sandveld lizard C
Several individuals were found on Ganna Hoek, under stones on gentle, rocky slopes (21-23/11/99). Definite at Mielietuin.
Conservation rating: Nil. CIV: 15, 1. Impact: Low, negative. Mitigatory measures: None needed.

FAMILY: GERRHOSAURIDAE

Gerrhosaurus flavigularis Yellow-throated plated lizard L
Occurrence: Definite at both sites.
Conservation rating: Nil. CIV: 5, 1. Impact: Low, negative. Mitigatory measures: None needed.

Family: CORDYLIDAE

Chamaesaura macrolepis macrolepis Large-scaled grass-lizard D
Occurrence: Uncertain at both sites.
Conservation rating: Nil. CIV: 13, 0. Impact: Low, negative. Mitigatory measures: None needed.

Cordylus vittifer Transvaal girdled lizard D, L
Occurrence: Definite at Mielietuin, possible at Jana.
Conservation rating: Nil. CIV: 12, 1. Impact: Low, negative. Mitigatory measures: None needed.

FAMILY: VARANIDAE

Varanus albigularis albigularis Rock monitor C, L
One adult was seen near a dry water-course in woodland (11/11/99), and a juvenile was found at the Ganna Hoek outpost (13/11/99). Reported at Mielietuin by land-owner.
Conservation rating: Nil. CIV: 13, 2. Impact: Low negative. Mitigatory measures: None required.

Varanus niloticus niloticus Nile monitor S, L
One large adult was seen swimming in a pool in the Thukela River, 13/11/99, and one was seen on steep wooded slopes above the Thukela River, Ramak, 6/12/99. Reported at Mielietuin by land-owner.
Conservation rating: Nil. CIV: 5, 2. Impact: Low, positive. Mitigatory measures: None needed.

FAMILY: AGAMIDAE

Agama aculeata distanti Northern spiny agama C, L
Occurrence: Numbers of these ground and rock-living agamas were seen on Ganna Hoek, and two were collected (22 & 23/11/99). Definite at Mielietuin.
Conservation rating: Nil. CIV: 7, 1. Impact: Low, negative. Mitigatory measures: None needed.

Acanthocerus atricollis atricollis Southern tree agama C, S
Occurrence: A pair of tree agamas was seen on a large flowering *Maerua* sp. behind the Ganna Hoek homestead - the male was in full breeding colour, 13/11/99. One subadult was collected while it was sleeping on the sheer face of a sandstone monolith(Ganna Hoek, 12/11/99). One seen on *Aloe marlothii*, 10/12/99, Mielietuin.
Conservation rating: Nil. CIV: 7, 1. Impact: Low negative. Mitigatory measures: None required.

FAMILY: CHAMAELEONIDAE

Chamaeleo dilepis dilepis Flap-necked chameleon S
Occurrence: One individual was found at night on a steep NE facing slope in thick, low woodland, on a young *Spirostachys africana*, and two were found sleeping in *Acacia tortilis* on the edge of floodplain. Two others were seen during the day on lower slopes in *Acacia* woodland. The species appears to be quite common in the Ganna Hoek area, certainly at lower altitudes. One seen at Mielietuin in streambed vegetation, 11/12/99.
Conservation rating: Nil. CIV: 8, 1. Impact: Low negative. Mitigatory measures: None required.

FAMILY: GEKKONIDAE

Afroedura pondolia Pondo flat gecko D
Occurrence: Probable at both sites.
Conservation rating: Nil. CIV: 13, 1. Impact: Low, negative. Mitigatory measures: None needed.

Homopholis wahlbergii Wahlberg's velvet gecko C
Occurrence: Two specimens were collected from two separated localities on Ganna Hoek, establishing the unexpected presence of this big (up to 23cm long) species in the Thukela basin. Previous distributions in KwaZulu-Natal were not known south of Longitude 31degrees 15minutes east. The Ganna Hoek population is therefore at the extreme south-eastern range of the species overall distribution. Uncertain at Mielietuin.
Conservation rating: Nil. CIV: 14, 1. Impact: Moderate negative. The species does not normally occur over 900m asl. As such, the population above the proposed Jana Dam wall will probably be wiped out. It is most likely that populations occur below the Jana Dam wall. Mitigatory measures: None.

Lygodactylus capensis capensis Cape dwarf gecko S, L
Occurrence: The Cape dwarf gecko appears to be widely distributed in the Ganna Hoek area, on trees and on buildings. Definite at Mielietuin.
Conservation rating: Nil. CIV: 6, 1. Impact: Low negative. Mitigatory measures: None required.

Pachydactylus maculatus Spotted thick-toed gecko C, L
Two specimens of spotted thick-toed gecko was collected from a dead, fallen *Aloe spectabilis* on Ganna Hoek. A juvenile was found under a fallen aloe on 16/12/99, Mielietuin.
Conservation rating: Nil. CIV: 12, 0. Impact: Low negative. Mitigatory measures: None required.

Pachydactylus vansoni Van Son's thick-toed gecko D, C
Occurrence: Possible at both sites.
Conservation rating: Nil. CIV:12, 0. Impact: Low, negative. Mitigatory measures: None needed.

ORDER: CROCODYLIA
FAMILY: CROCODYLIDAE

Crocodylus niloticus Nile crocodile S
Occurrence: Water Affairs staff report the presence of a crocodile in the Thukela River at Ganna Hoek, but no positive sightings appear to be available. No breeding populations are known to occur in the Thukela Basin. Not present at Mielietuin.

AMPHIBIA   Frogs and toads

Expected distributions were obtained from Lambiris (1990) and Passmore and Carruthers (1995). Conservation importance values (CIV) were obtained from Lambiris (op.cit.). The maximum values are 50 for conservation and 10 for importance to man, with a score of 21 and 3 respectively rating an animal as important to KwaZulu-Natal. S = sight record, C = collected specimen, L = based on information in literature,

Family PIPIDAE

Xenopus laevis   Platanna   C, L
Occurrence: Numbers of tadpoles were found in a pool in a streambed, Ganna Hoek, 21/11/99. Definite at Mielietuin.
Conservation rating: Nil. CIV: 5, 4. Impact: Low, negative. Mitigatory measures: None needed.

Family BUFONIDAE

Bufo gutturalis   Guttural toad   S
Occurrence: Guttural toads were found in the Thukela River, in some of the feeder streams, and even well out in dry woodland, sheltering under rocks, on Ganna Hoek and Ramak. They were calling each night (11-13/11/99, 19-22/11/99), and clasping was seen on the night of 11/11/99. Hatchling toads were seen along the Thukela banks. Seen in open woodland on Mielietuin, 11/12/99.
Conservation rating: Nil. CIV: 3, 2. Impact: Low negative. Mitigatory measures: None required.

Bufo rangeri   Raucous toad   C
Occurrence:Two juveniles were found on the Thukela River bank, 22 & 23/11/99, and one adult was found in a streambed after good rains (29/11/99), Ganna Hoek. Numerous juveniles seen in open woodland on Mielietuin, 10/12/99 and 15-16/12/99.
Conservation rating: Nil. CIV: 7,2. Impact: Low, negative. Mitigatory measures: None needed.

Schismaderma carens   Red toad   S, L
Occurrence: Red toads were seen around the Ganna Hoek homestead and by a small rock pool in an otherwise dry streambed (11-14/11/99) and were also seen at the Thukela River's edge 21/11/99 (Ganna Hoek and Ramak). Definite at Mielietuin.
Conservation rating: Nil. CIV: 8,2. Impact: Low negative. Mitigatory measures: None required.

Family MICROHYLIDAE

Breviceps adspersus   Bushveld rain-frog   C
Occurrence: A male was found under a rock on a stony, moderate slope in well wooded veld on Ganna Hoek (21/11/99), and one under a dead fallen aloe on Ramak, 5/12/99. A male was collected at Mielietuin, 9/12/99. Very common at both sites.
Conservation rating: Nil. CIV: 7, 1. Impact: Low, negative. Mitigatory measures: None needed.

Family RANIDAE

Tomopterna cryptotis Tremelo sand-frog C, L
Occurrence: After good rain on 29/11/99, this species was found calling and clasping at 02H30-03H30 in pools in a streambed on Ganna Hoek. Definite at Mielietuin.
Conservation rating: Nil. CIV:9, 1. Impact: Low, negative. Mitigatory measures: None needed.

Tomopterna natalensis Natal sand-frog C, L
Occurrence: A number of individuals were found calling from the edge of a muddy pool in a streambed,(Ganna Hoek 20/11/99). Definite at Mielietuin.
Conservation rating: Nil. CIV: 6, 1. Impact: Low, negative. Mitigatory measures: None needed.

Ptychadena oxyrhynchus Sharp-nosed grass-frog C, L
Occurrence: One male was found calling from the edge of a muddy pool in streambed, (Ganna Hoek 20/11/99). Definite at Mielietuin.
Conservation rating: Nil. CIV:8, 1. Impact: Low, negative. Mitigatory measures: None needed.

Rana angolensis Common river frog C, S
Occurrence: Common river frogs, juveniles to adults were found in rocky, vegetated patches on the edge of the Thukela River, Ganna Hoek, 11/11/99. Seen at Mielietuin, 10/11/99 and 16/12/99.
Conservation rating: Nil. CIV: 5, 1. Impact: Low positive. Mitigatory measures: None required.

Phrynobatrachus natalensis Snoring puddle frog C, L
Occurrence: Specimens were found under a log on mud in a partially filled old dip-tank,(Ganna Hoek, 12/11/99) and in pools in water-courses (Ganna Hoek, 20 & 23/11/99). Definite at Mielietuin.
Conservation rating: Nil. CIV: 3,1. Impact: Low positive. Mitigatory measures: None required.

Cacosternum boettgeri Common caco L
Occurrence: Definite at both sites. Heard calling on Groote Mielietuin but out of dam area, 16/12/96.
Conservation rating: Nil. CIV:10, 0. Impact: Low, negative. Mitigatory measures: None needed.

Family HYPEROLIIDAE

Kassina senegalensis Bubbling kassina L, S
Occurrence: Heard calling at Mielietuin, 10/11/99. Definite at Jana.
Conservation rating: Nil. CIV:0, 1. Impact: Low, negative. Mitigatory measures: None needed.

INVERTEBRATES

Earthworms

Identifications were obtained from Dr D.G. Plisko, Private Consultant. C means that specimens were collected. No Red Data Book is available for earthworms. More collections are required from both sites.

Family MICROCHAETIDAE

Microchaetes parvus C
Occurrence: An indigenous species widespread in many habitats in Ganna Hoek, Ramak and Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Tritogenia zuluensis C
Occurrence: Widespread on Ramak, Ganna Hoek and Mielietuin. An indigenous species known previously only from Mfongosi (28 42 S 30 48 E) in the Umfolozi River catchment, some 100km to the north-east as the crow flies.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Proandricus sp. nov. C
Occurrence: So far found only at Mielietuin dam-site, but likely to occur beyond the confines of the dam-site.
The genus *Proandricus* was described by Plisko (1992), who indicates (pers. com., 1999) that specimens collected from Mielietuin represent a new species which demonstrates certain evolutionary changes within the genus.
Conservation rating: High (endemic and apparently restricted). Impact: high ?, negative. Mitigatory measures: None.

Dichogaster sp. C
An introduced species found in the bed of a small disused dam, used as a dump, above Ganna Hoek homestead.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Terrestrial Molluscs (snails and slugs)

Identifications of terrestrial snails and possible occurrences were obtained from Dr D. Herbert (Natal Museum, Pietermaritzburg), with collected specimens being retained by the Museum. Possible occurrences of slugs were derived from Herbert, 1997. No Red Data Book is available for molluscs.

Class: Gastropoda (snails, slugs, limpets)

Family: VERONICELLIDAE
Laevicaulis natalensis natalensis L
Occurrence: Wide-spread in lower-lying, eastern regions of the Province, able to survive in hotter, drier areas such as thornveld. Definitely at both sites.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Family CHLAMYDOPHORIDAE
Chlamydophorus gibbonsi C
Occurrence: A KZN-Transkei endemic found at Jana. The nearest known previous record was at Kranskop. The taxonomy of the species and subspecies of this genus is still uncertain, and more specimens are needed. Probable at Mielietuin.
Conservation rating: Regional endemic. Impact: Low, negative. Mitigatory measures: None.

Chlamydephorus sexangulus L
Occurrence: Up to 1250m asl, nearest record Middeldrif, Thukela River. Definite at Jana, possible at Mielietuin.
Conservation rating: Thukela Basin endemic. Impact: Low, negative. Mitigatory measures: None.

Family: ACHATINIDAE

Archachatina simplex C
Occurrence: Restricted to the central Thukela River catchment. Found at both sites.
Conservation rating: Thukela Basin endemic. Impact: Low, negative. Mitigatory measures: None.

Family: CERASTIDAE

Edouardia maritzburgensis C
Occurrence: Known primarily from the valley bushveld and thornveld habitats in the central Thukela and Umgeni systems. Found at both sites.
Conservation rating: KZN endemic. Impact: Low, negative. Mitigatory measures: None.

Family: POMATIASIDAE

Tropidophora ligata C
Occurrence: Very widely distributed and common in south-eastern Africa, occurring in a variety of habitats. Found at Jana, definite at Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Family: RHYTIDIDAE

Nata vernicosa C
Occurrence: A very widely distributed and common generalist. Found at Jana, definitely at Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None needed.

Family: STREPTAXIDAE

Gulella infans C
Occurrence: A widely distributed species, but taxonomically troublesome. Occurs in a wide range of habitats, but savanna-thicket mosaic is typical. Found at Jana, definitely at Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None.

Gulella orientalis C
Occurrence: To date known from less than 10 localities in the central Thukela catchment.
Conservation rating: Thukela basin endemic. Impact: Low, negative. Mitigatory measures: None.

Gullela mfongosiensis, G. barbarae, G. subframesi, G. leucocion, G. contingens, G. crassidens jonesi D
Occurrence: These taxa are all endemic to the central Thukela catchment and probably occur at both sites.
Conservation rating: Thukela basin endemics. Impact: Low, negative. Mitigatory measures: None.

Family: SUBULINIDAE

Euonyma tugelensis C
Occurrence: Ranges from KZN south coast into southern Mocambique and from the coast to the midlands. Found at Jana, definite at Mielietuin.
Conservation rating: regional endemics. Impact: Low, negative. Mitigatory measures: None.

Opeas crystallinum C
Occurrence: Widely distributed in SE Africa. Found at Jana, definitely at Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None.

Family: UROCYCLIDAE

Sheldonia poeppigii C
Occurrence: Widely distributed in SE Africa. Found at Jana, definitely at Mielietuin.
Conservation rating: Nil. Impact: Low, negative. Mitigatory measures: None.

Millipedes

Identifications were obtained from Dr. M. Hamer (University of Natal, Pietermaritzburg), and collected specimens remained in her possession. The expected species list was obtained from Hamer (1998). Only the Orders Sphaerotheriida and Spirobolida were dealt with. Because of taxonomic problems and deficiencies for some of the taxa, and because the millipedes have not been well collected in KwaZulu-Natal, it is not possible to determine conservation importance ratings.

Order Sphaerotheriida.
Family: SPHAEROTHERIIDAE
Sphaerotherium rotundatum C?
Occurrence: Probable at both sites. Pill millipedes, probably *S. rotundatum,* were collected from both sites, but could not be identified to species as only juveniles and females were present in the sample.

Order Spirobolida.
Family: PACHYBOLIDAE
Centrobolus cf. *albitarsus* C
Occurrence: Either a new species or one previously recorded only from Lochliel in Mpumalanga. Found at Mielietuin, probably occurs at Jana.

Family: SPIROSTREPTIDAE
Camaricoproctus torquidens L
Occurrence: Known only from Jamesons Drift, KZN. Probable at Jana, uncertain at Mielietuin.

Doratogonus setosus L
Occurrence: A KZN endemic known from central and southern regions. Probable at both sites.

Doratogonus subpartitus C
Occurrence: Collected at both sites, an endemic species to the Thukela Basin.

Doratogonus sp. C
Occurrence: Found on Ganna Hoek, possibly on Mielietuin. Probably a new species, not recorded from elsewhere in South Africa.

Orthoporoides cf *pyrhocephalus* C?
Occurrence: Probable at both sites. A species of Orthoporodes was collected from both sites, and this may be *O. pyrhocephalus*, or possibly a new species.

Family: HARPAGOPHORIDAE
Zinophora laminata L
Occurrence: A KZN endemic, so far found only at Hluhluwe Game Reserve and Jamesons Drift. Probable at Jana, possible at Mielietuin.

Harpagophora sp.n. C
Occurrence: Collected at both sites, almost certainly a new species. Only one species of this

genus has been found previously in KZN (at Albert Falls, Pietermaritzburg, Bothas Hill and Rietvlei).

Family: ODONTOPYGIDAE
Chaleponcus discalceatus C
Occurrence: Collected from both sites, previously known only from Ladysmith, KZN.

Chalceponcus sp. C
Occurrence: Collected from Mielietuin, probable at Jana. Specific identification not possible at present - no access to relevant literature.

Patinatius attemsi L
Occurrence: An apparently rare localised endemic, known only from the Thukela River at Kranskop.
Probable at Jana, uncertain at Mielietuin.

Patinatius rusticus L
Occurrence: An apparently rare endemic known only from Slievrye, Estcourt. Possibly at Mielietuin.

Spinotarsus malleolus L
Occurrence: An apparently rare endemic known only from Middeldrift, Thukela River. Definitely at Mielietuin, possibly at Jana.

Spinotarsus tubulosus L
Occurrence: An apparently rare endemic known only from Weenen. Probable at both sites.

Spinotarsus tugela L
Occurrence: An apparently rare localised endemic, known only from the Thukela River at Kranskop. Probable at Jana.

Spinotarsus sp. C
Occurrence: Collected at Mielietuin, but lack of access to literature prevents further identification at this stage. Possible at Jana.

Introduced species:

Family: PARADOXOSOMATIDAE
Orthomorpha gracilis L
Occurrence: Possible at both sites.

Dragonflies and Damselflies

All animals labelled "C" were collected, identifications were obtained from Prof. M. Samways and Ms G. Whiteley (University of Natal, Pietermaritzburg). The list of expected species was extracted from Samways (1994), as were the conservation importance values (CIV). Highest score attainable is 15, any species with a score of 12 or more is considered important.

Dragonflies and damselflies are predators both as terrestrial, flying adults and as aquatic nymphs. Adults feed on small flying insects such as mosquitoes and midges,while ymphs feed on a wide range of small aquatic animals - the larger species even feeding on tadpoles and small fish. In turn, the group is fed upon by a wide variety of terrestrial (mainly birds) and aquatic insectivores.

Many species are quite specific in their habitat requirements and can therefore act as indicators of habitat types and their condition.

Suborder: ZYGOPTERA

Family LESTIDAE
Lestes pallidus L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 6. Impact: low, negative. Mitigation: nil.

Lestes plagiatus L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Lestes virgatus L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Family PROTONEURIDAE
Ellatoneura glauca L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Family COENAGRIONIDAE
Ceriagrion glabrum L
Occurrence: Possible at Jana.
Conservation status: nil. CIV:0. Impact: low, negative. Mitigation: nil.

Agriocnemis pinheyi C, L
Occurrence: Apparently scarce, highly localised,one caught on river margin over grasses, herbs and near reeds, Jana. Possible at Mielietuin.
Conservation status: nil. CIV: 11. Impact: low, negative. Mitigation: nil.

Pseudagrion kersteni L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Pseudagrion massaicum L
Occurrence: Definite at both sites.
Conservation status: nil. CIV: 6 . Impact: low, negative. Mitigation: nil.

Pseudagrion salisburyense C
Occurrence: A very common species found along open grassy river banks and pools, both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Pseudagrion sublacteum C
Occurrence: Occassional in open, grassy riverine and pool banks, Jana. Probable at Mielietuin.
Conservation status: nil. CIV: 8. Impact: low, negative. Mitigation: nil.

Enallagma glaucum L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Ischnura senegalensis L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Family CHLOROCYPHIDAE
Platycypha caligata caligata C
Occurrence Common on rocky and reedy river margins - females sometimes seen in bushveld up to at least 100m away from water. Jana. Definite at Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, positive. Mitigation: nil.

Suborder: ANISOPTERA
Family GOMPHIDAE
Ceratogomphus pictus L , C
Occurrence: Found at Mielietuin, definite at Jana.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Paragomphus cognatus L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Paragomphus elpidius C
Occurrence: Not common, found at or near rivers edge, Jana, probable at Mielietuin.
Conservation status: nil. CIV; 12. Impact: high, negative. Mitigation: nil.

Paragomphus genei C
Occurrence:Apparently not common, caught on open bank of river, Jana; possible at Mielietuin.
Conservation status: nil. CIV: 6. Impact: low, negative. Mitigation: nil.

Family AESCHNIDAE

Aeshna subpupillata L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Hemianax ephippiger L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 4. Impact: low, negative. Mitigation: nil.

Anax imperator mauricianus L
Occurrence: Definite at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Anax speratus L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Family CORDULIIAE

Macromia picta C
Occurrence: A large dragonfly and difficult to capture because of its swift flight. Found at river edge, Jana. Probable at Mielietuin.
Conservation status: nil. CIV: 4. Impact: low, negative. Mitigation: nil.

Family LIBELLULIDAE

Orthetrum abbotti L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 9. Impact: low, negative. Mitigation: nil.

Orthetrum brachiale L
Occurrence: Probable at Mielietuin, uncertain at Jana.
Conservation status: nil. CIV: 4. Impact: low, negative. Mitigation: nil.

Orthetrum caffrum L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Orthetrum chrysostigma C
Occurrence: Fairly common along open grassy or rocky river edge, also seen along streams feeding into the Thukela, Jana and caught at streams at Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Orthetrum julia falsum L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Nesciothemis farinosa C
Occurrence: Common along open river banks. One was seen feeding on a winged harvester termite, Jana. Definite for Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Palpopleura jucunda L
Occurrence: Possible at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Diplacodes lefebvrei L
Occurrence: Definites at both sites.
Conservation status: nil. CIV: 2. Impact: low, negative. Mitigation: nil.

Crocothemis erythraea C
Occurrence: Only one individual seen in open grassy area on a partially inundated floodplain of the Thukela River, Jana. Definite at Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, positive. Mitigation: nil.

Crocothemis sanguinolenta L
Occurrence: Possible at both sites.
Conservation status: nil. CIV: 5. Impact: low, negative. Mitigation: nil.

Sympetrum fonscolombei L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Philonomon luminans L
Occurrence: Possible at both sites.
Conservation status: nil. CIV: 9. Impact: low, negative. Mitigation: nil.

Trithemis arteriosa C
Occurrence: Very common along the river, and along feeder streams, Jana. Definite at Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, positive. Mitigation: nil.

Trithemis donaldsoni C
Occurrence: Only one specimen of this uncommonly encountered and apparently rare (in KwaZulu-Natal) species, was found flying over a partially inundated grassy floodplain of the Thukela River, Jana. Possible at Mielietuin.
Conservation status: nil. CIV: 12. Impact: low, negative. Mitigation: nil.

Trithemis dorsalis L
Occurrence: Possible at Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Trithemis furva C
Occurrence: A common species along the river banks, Jana and Mielietuin.
Conservation status: nil. CIV: 0. Impact: low, positive. Mitigation: nil.

Trithemis kirbyi ardens C
Occurrence: Fairly common , especially in rocky areas, along the rivers and in streambeds, both sites.
Conservation status: nil. CIV: 0. Impact: low, positive. Mitigation: nil.

Trithemis stictica L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 0. Impact: low, negative. Mitigation: nil.

Zygonyx natalensis C
Occurrence: Occasionally seen hawking over the river and along open river banks. Found at both sites.
Conservation status: nil. CIV: 6. Impact: medium, negative. Mitigation: nil.

Zygonyx torridus C
Occurrence: Collected on open river bank, Jana. Probable at Mielietuin.
Conservation status: nil. CIV: 6. Impact: medium, negative. Mitigation: nil.

Pantala flavescens C
Occurrence: Widespread, often encountered far away from the river, both sites.
Conservation status: nil. CV: 0. Impact: low, positive. Mitigation: nil.

Tramea burmeisteri L
Occurrence: Probable at both sites.
Conservation status: nil. CIV: 2. Impact: low, negative. Mitigation: nil.

Fruit-Chafer Beatles (Family: Scarabaeidae, Subfamily Cetoniinae)

Expected species, identifications and nomenclature are based on Scholtz and Holm (1985), Holm and Marais (1992) and Holm and Stobbia (1995). Collected specimens, indicated by a "C", were lodged in the Natal Museum (Pietermaritzburg). The conservation importance values (CIV) are from Bourquin 1993. The highest score possible is 15, any score over 10 indicates an important species. "L" means the presence of the species was determined by literature records.

Hypselogenia geotropina L
Occurrence: Found from coast to edge of highveld in KwaZulu-Natal. Definitely at both sites.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Anisorrhina flavomaculata flavomaculata C
Occurrence: Specimens caught in a baited trap over a stream, 23/11/99 and in butterfly traps 5/12/99, Jana. Caught in baited traps, Mielietuin, 15/12/99.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Anisorrhina algoensis C, L
Occurrence: Some were found around and on a flowering marula tree, Ramak, 5/12/99. Definitely at Mielietuin.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Anisorrhina umbonata C
Occurrence: Specimens were found feeding on Scotch thistle flowers (Ganna Hoek), on the bank of the Thukela River, 13/11/99, 22/11/99. Caught in baited traps and found feeding in numbers on Scotch thistle, Mielietuin, 9/12/99 and 15-16/12/99
Conservation status: nil. CIV: 2. Impact: medium, negative. Mitigation: nil.

Plaesiorrhinella plana C
Occurrence: Numbers of specimens were caught in baited traps in flowering jacaranda trees at the Ganna Hoek homestead, and over streambeds (19-23/11/99). Found feeding on *Acacia karroo* flowers and caught in baited traps, Mielietuin, 9/12/99 and 15/12/99.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Plaesiorrhinella trivittata L
Occurrence: Very common in low-lying forest and streambank vegetation, possibly at Jana.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Anoplocheilus figuratus L
Occurrence: Possibly at Mielietuin, not at Jana.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Diplognatha gagetes silacea L
Occurrence: Widespread through KwaZulu-Natal, definitely at both areas.
Conservation status: nil. CIV: 2. Impact: medium, negative. Mitigation: nil.

Porphyronota hebreae hebreae C
Occurrence: Probably one of the commonest cetonids in the Thukela Valley, this species was captured daily in traps on Ganna Hoek and Ramak during the investigation period. It is not easy to distinguish from the next species
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Porphyronota maculatissima C
Occurrence: A number of specimens were captured, and they appeared to favour the sheltered river valleys more than open areas at both sites. Of the two species, *P. hebreae* appeared to be by far the most common.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Elaphinis irrorata L
Occurrence: Definite at Mielietuin, probable at Jana.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Xeloma tomentosa C
Occurrence: Specimens were found feeding on Scotch thistle flowers (Ganna Hoek), on the bank of the Thukela River, 13/11/99, 22/11/99. Definitely at Mielietuin.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Phoxomela umbrosa C
Occurrence: Both yellow and black and white and black varieties were found on *Acacia brevispica* flowers, Ramak, 5/12/99. Possibly at Mielietuin.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Atrichelaphinis tigrina L
Occurrence: Probably at Jana, definitely at Mielietuin.
Conservation status: nil. CIV:0. Impact: medium, negative. Mitigation: nil.

Polybaphes balteata balteata C
Occurrence: Found feeding on *Pteroxylon obliquum* flowers, Ganna Hoek, 12/11/99. Found feeding on flowers of *Maytenus* sp., Mielietuin, 15/12/99.
Conservation status: nil. CIV: 2. Impact: medium, negative. Mitigation: nil.

Polybaphes subfasciata C, L
Occurrence: A specimen was found under a dead, fallen *Aloe spectabilis*, probably where it had hatched, Ramak, 12/11/99, others were found feeding on *Dalbergia obovata* flowers, Ramak, 6/12/99. Definitely at Mielietuin.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Pachnodella impressa C
Occurrence: One specimen was caught in baited traps in flowering jacaranda trees at the Ganna Hoek homestead, (20/11/99). Found to be fairly common in Mielietuin feeding on *Acacia karroo* flowers, 9/12/99 and 15/12/99.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Rhabdotis aulica C, L
Occurrence: Found feeding on *Acacia karroo* flowers, Mielietuin, 9/12/99 and 15/12/99. Definite at Jana.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Dischista rufa C, L
Occurrence: Found feeding on flowers of *Crinum* sp., Ganna Hoek, 5/12/99. Definitely at Mielietuin. Conservation status: nil. 1. Impact: medium, negative. Mitigation: nil.

Dischista cincta C
Occurrence: Individuals were found feeding on the flowers of *Acacia* spp., Ramak (20/11/99). Common at Mielietuin on flowers of *Acacia karroo*, 9/12/99.
Conservation status: nil. 1. Impact: medium, negative. Mitigation: nil.

Pachnoda sinuata flaviventris C
Occurrence: A specimen flying under jacaranda trees at Ganna Hoek homestead was collected on 13/11/98, and one was found feeding on the flowers of *Acacia tortilis* (23/11/99). Found at Mielietuin feeding on *Acacia karroo* flowers, 9/12/99 and 15/12/99.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Tephraea simonsi L
Occurrence: Probably at both sites.
Conservation status: nil. CIV: 7. Impact: medium, negative. Mitigation: nil.

Tephraea leucomelona C, L
Occurrence: Two specimens were caught in baited traps in flowering jacaranda trees at the Ganna Hoek homestead, (20 and 22/11/99). Definitely at Mielietuin.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Tephraea dichroa C, L
Occurrence: Specimens were found feeding on Scotch thistle flowers (Ganna Hoek), on the bank of the Thukela River, 19-22/11/99. Probably at Mielietuin.
Conservation status: nil. CIV: 1. Impact: medium, negative. Mitigation: nil.

Polystalactica perroudi C
Occurrence: One specimen was caught in baited traps in flowering jacaranda trees (22/11/99), and one in a baited butterfly trap (6/12/99), Ganna Hoek homestead. Caught in baited traps and on Scotch thistle flowers on 16/12/99, Mielietuin.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Mausoleopsis amabilis C
Occurrence: A specimen was caught feeding on the flowers of *Dalbergia obovata*, Ramak, 6/12/99. Found feeding on *Acacia karroo* and Scotch thistle, 9/12/99 and 16/12/99, Mielietuin.
Conservation status: nil. CIV: 2. Impact: medium, negative. Mitigation: nil.

Cyrtothyrea marginalis C
Occurrence: Specimens were found feeding on Scotch thistle flowers (Ganna Hoek), on the bank of the Thukela River, 20-22/11/99. Found feeding on *Acacia karroo, Maytenus* sp. and Scotch thistle, Mielietuin, 9/12/99 and 16/12/99.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Leucocelis rubra C
Occurrence: A specimen was found feeding on the flowers of *Pteroxylon obliquum*, Ganna Hoek, 12/11/99, on *Dalbergia obovata* flowers (Ramak, 6/12/99), and on flowers of *Acacia brevispica*, Ramak, 5/12/99. Found feeding on a *Acacia karroo,* Mielietuin, 9/12/99.
Conservation status: nil. CIV:1. Impact: medium, negative. Mitigation: nil.

Leucocelis amethystina C
Occurrence: Numbers of individuals were found feeding on *Acaia brevspica* and *Dalbergia obovata* flowers, Ramak, 5-6/12/99. Possibly at Mielietuin.
Conservation status: nil. CIV: 3. Impact: medium, negative. Mitigation: nil.

Leucocelis haemorrhoidalis L
Occurrence: Definite at both sites.
Conservation status: nil. CIV: 0. Impact: medium, negative. Mitigation: nil.

Leucocelis aeneicollis C
Occurrence: One animal was found feeding on flowers of *Pteroxylon obliquum*, Ganna Hoek, 12/11/99, others were found on *Acacia brevispica* and *Dalbergia obovata*, Ramak, 5-6/12/99. Found on *Acacia* sp. flowers, Mielietuin, 9/12/99.
Conservation status: nil. CIV:1. Impact: medium, negative. Mitigation: nil.

Leucocelis adspersa adspersa L
Occurrence: Possibly at both sites.
Conservation status: nil. CIV:4. Impact: medium, negative. Mitigation: nil.

Discopeltis bellula L
Occurrence: Possible at Ramak, not at Mielietuin.
Conservation status: nil. CIV:8. Impact: medium, negative. Mitigation: nil.

Butterflies

Butterflies were identified by Mr C. Quickelberge, and some by the author. Lists of expected species were derived from the manuscript "Atlas of butterflies of Natal", prepared by C. Quickelberge together with the Natal Museum, Pietermaritzburg, the Museum of Natural Sciences, Durban and the Natal Parks Board (now KwaZulu-Natal Conservation Service). Collections were carried out 28-29/11/99, 5-6/12/99 (Jana), 9-10/12/99 and 15-16/12/99 (Mielietuin), with casual collecting taking place during other visits. Few butterflies were present at both sites during the surveys.
S = sighted or captured D = based on unpublished database.

Family DANAIDAE
Danaus chrysippus S
Occurrence: Fairly common in open areas in both sites..
Conservation rating: Nil. Impact: Low negative. Mitigatory measures: None required.

Amauris albimaculata albimaculata D
Occurrence: Definitely present at both sites.
Conservation rating: Nil. Impact: Low negative. Mitigatory measures: None required.

Family SATYRIDAE
Henotesia perspicua S, D
Occurrence: Rare at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Physcaeneura panda S, D
Occurrence: Moderately common at Mielietuin, definitely at Jana.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cassionympha cassius S, D
Occurrence: Moderately common at Mielietuin, not expected at Jana.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Stygionympha wichgrafi wichgrafi D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Ypthima asterope asterope S
Occurrence: Found to be moderately common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family ACRAEIDAE
Acraea neobule neobule D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Acraea eponina manjaca D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Acraea natalica natalica S
One seen near open edge of floodplain, Jana, and a few seen at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Acraea zetes acara S
Occurrence:One seen at each site.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family CHARAXIDAE
Charaxes varanes varanes S
Occurrence: Seen at both sites, but apparently scarce.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Charaxes jasius saturnus S
Occurrence:Trapped using fermenting fruit in tent trap, Jana. Probably at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Charaxes jahlusa argynnides S
Occurrence:Common, and trapped using fermenting fruit in tent trap, Jana. Definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family NYMPHALIDAE
Biblyia ilithyia D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eurytela hiarbis angustata D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Hypolimnas misippus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Catacroptera cloanthe cloanthe S, D
Occurrence: Found at Jana, but rare there, and definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Precis archesia D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Precis octavia sesamus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Junonia hierta cebrene S
Occurrence: Very common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Junonia oenone S, D
Occurrence: Found, but rare, at Jana, definitely at Mielietuin
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Junonia orithya madagascariensis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cynthia cardui S
Occurrence: Found at both sites, but not commonly.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Phalanta phalanta aethiopica D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family LYCAENIDAE
Alaena amazoula amazoula D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Durbania amakosa natalensis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Durbania limbata D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lachnocnema bibulus S, D
Occurrence: Found, but rarely, at Jana; definitely at Mielietuin
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lachnocnema durbani D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Virachloa antalus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Myrina silenus ficedula D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Stugeta bowkeri bowkeri D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Iolaus silas silas D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Iolaus pallene S, D
Occurrence: Three specimens found at Jana, possibly at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Iolaus sidus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Iolaus mimosae mimosae D
Occurrence: Definitly at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Iolaus diametra natalica D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Aphnaeus hutchinsonii D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spindasis natalensis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spindasis phanes D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spindasis ella D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Chloroselas pseudozeritis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Axiocerses tjoane S
Occurrence: Found commonly at Jana, more scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Axiocerses amanga D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Leptomyrina hirundo D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Gonatomyrina gorgias D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Aloeides taikosama S
Occurrence: Moderately common at Jana, scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Aloeides trimeni trimeni D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Aloeides aranda D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Crudaria leroma S, D
Occurrence: Scarce at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene definita definita D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene amarah amarah S, D
Occurrence: Scarce at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene butleri livida D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene millari D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene otacilia otacilia D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene constrasta constrasta D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Anthene talboti D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cacyreus lingeus lingeus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cacyreus virilis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cacyreus palemon palemon D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cacyreus marshalli D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Zintha hintza hintza D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Tuxentius calice calice D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Tuxentius melaena melaena D
Occurrence: Definitelyly at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Tarucus sybaris sybaris D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lampides boeticus S, D
Occurrence: Scarce at Mielietuin, definitely at Jana.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Leptotes pirithous D, S
Occurrence: Definitely at Jana, scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Leptotes brevidentatis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lepidochrysops ignota D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lepidochrysops procera S, D
Occurrence: One found at Mielietuin, possibly at Jana.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lepidochrysops plebeia plebeia D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lepidochrysops patricia S
Occurrence: Found fairly commonly at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Euchrysops malathana malathana D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Euchrysops dolorosa D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eicochrysops messapus mahallokoaena D, S
Occurrence: Definitely at Jana, fairly common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cupidopsis cissus cissus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Cupidopsis iobates iobates D, S
Occurrence: Definitely at Jana, rare at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Freyeria trochylus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Azanus ubaldus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Azanus jesous jesous S
Occurrence: Common at Jana, scarcer at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Azanus natalensis D, S
Occurrence: Definitely at Jana, and found at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Azanus moriqua S
Occurrence: Rare at Jana, more common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Azanus mirza D
Occurrence: Probably at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Oraidium barberae D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Zizeeria knysna S
Occurrence: Rare at Jana and at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Zizula hylax hylax D, S
Occurrence: Definitely at Jana, rare at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Actizera lucida lucia D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Lycaena clarki D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family PIERIDAE

Pinacopterix eriphia S
Occurrence: Moderately common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colias electo S
Occurrence: Rare at Jana, common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eurema brigitta brigitta D, S
Occurrence: Definitely at Jana, moderately common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eronia cleodora cleodora S, D
Occurrence: Rare at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis vesta S
Occurrence: Common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis ione D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis regina S, D
Occurrence: Rare at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis danae annae S, D
Occurrence: Common at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis auxo auxo S, D
Occurrence: Common at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis antevippe gavisa D, S
Occurrence: Definitely at Jana, scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis evippe omphale S
Occurrence: Moderately common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis pallene S
Occurrence: Found at Mielietuin, probably at Jana.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis evagore antigone S
Occurrence: Common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Colotis eris eris S
Occurrence: Common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Belenois aurota aurota S
Occurrence: Moderately common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Belenois creone severina S
Occurrence: Moderately common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Belenois gidica D, S
Occurrence: Definitely at Jana, moderately common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Dixeia charina charina D, S
Occurrence: Definitely at Jana, moderately common at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Pontia helice helice D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Mylothris agathina D, S
Occurrence: Not at Jana, scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family PAPILIONIDAE
Papilio constantinus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Papilio demodocus demodocus S
Occurrence: Common at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Papilio nireus lyaeus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Graphium leonidas leonidas D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Family HESPERIDAE

Coeliades forestan D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eretis djaelaelae D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Eretis umbra umbra D, S
Occurrence: Definitely at Jana, scarce at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Sarangesa phidyle S, D
Occurrence: Rare at Jana, definitely at Mielietuin.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Sarangesa seineri durbana D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Netrobalane canopus D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spialia depauperata australis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spialia diomus ferax D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Spialia spio D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Gomalia elma elma D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Kedestes nerva D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Kedestes macomo D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Kedestes callicles D
Occurrence: Probably at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Zenonia zeno D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Pelopidas mathias mathias D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Gegenes pumilo gambica D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Gegenes niso niso D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Caprona pillaana D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Brephidium metophis D
Occurrence: Definitely at both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Scorpions

The potential species list was derived from Lamoral & Reynders (1975). Specimens were lodged with the Natal Museum, Pietermaritzburg.

Scorpions are predators of other invertebrates (and sometimes small vertebrates), and may be divided roughly into four groups : rock-dwellers, soil-burrowers, tree-dwellers and surface litter dwellers. Representatives of the the first two groups are present, while *Uroplectes* can be found in a variety of situations including under rocks, aloes and in dead fallen trees.

Family BUTHIDAE
Pseudolychas pegleri multicarinatus (Hewitt, 1925) L
Nearest records: Middeldrift, Thukela river. Occurrence: Probably at Jana.
Conservation status: nil. Impact: low, negative. Mitigation: nil.

Uroplectes triangulifer marshalli (Pocock, 1896) C
Occurrence: Common under stones on soil, and under logs and dead fallen aloes, both sites.
Conservation status: nil. Impact: low, negative. Mitigation: nil.

Family: SCORPIONIDAE
Cheloctonus crassimanus depressus Hewitt, 1918 C
Found under stones on soil, and under fallen dead *Aloe spectabilis*, in shallow holes either under rocks or in the open. Found on both sites.
Conservation status: nil. Impact: medium, negative. Mitigation: nil.

Hadogenes trichiurus pallidus Pocock, 1898 C
A large species found under rocks, usually lying on other rocks- found fairly widely spread on Ganna Hoek, and apparently scarcer on Mielietuin, where it was found in rocky outcrops.
Conservation status: nil. Impact: low, negative. Mitigation: nil.

Opisthophthalmus glabrifrons Peters, 1861 C
Occurrence: Found on Mielietuin, under rocks on soil in somewhat rocky areas. Probably at Jana.
Conservation status: nil. Impact: low, negative. Mitigation: nil.

Opisthophthalmus latimanus natalensis Hewitt, 1915 L
Nearest record: Weenen. Occurrence: Probably at both sites.
Conservation status: nil. Impact: low, negative. Mitigation: nil.

THUKELA WATER PROJECT FEASIBILITY STUDY

PALAEONTOLOGICAL BASELINE STUDY

Prepared by

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SUMMARY

The area expected to be flooded by the high water levels of the proposed Mielietuin Dam on the Bushman's River, and Jana Dam on the Thukela River, as part of the Thukela Water Project (TWP) Feasibility Study by the Department of Water Affairs and Forestry, was investigated for palaeontological remains. Only insignificant and unidentifiable fragments of fossilised plant material were found.

The flooding of the dam basins would, therefore, have no impact on the palaeontology. The aqueduct routes have been planned to traverse the same lithologic units as those investigated for the dam basins so the impact from their construction is expected to be low to no impact. The construction of service roads and excavation of road material (shales) would have an unknown impact because these sites are as yet undefined. There are known deposits of fossil plants, fossil wood (Bamford, 1999) and vertebrate skulls within the Thukela Biosphere Conservancy above the high water line.

Mitigation: If palaeontological remains are discovered during excavations it is recommended that a palaeontologist be notified so that the fossils can be rescued as soon as possible and not delay further construction.

1 INTRODUCTION

In the study area, the Thukela and Bushman's Rivers cut through dolerites, sandstones and shales of the Ecca Group, namely the Vryheid Formation and overlying Volksrust Formation (SACS) (Figures 2.1 and 2.2). The Vryheid Formation to the north has been studied in detail (Cadle *et al.*, 1993) because it has economically important coal seams. According to Du Toit (1954) these shales are devoid of fossils. Nonetheless, we searched the area which would be flooded by the proposed Mielietuin and Jana Dams, and sampled all the outcrops (Figures 2.1 and 2.2).

1.1 Terms of reference

The purpose of this baseline study is to establish the presence of palaeontological deposits and to assess the significance of those to be affected by the proposed TWP footprint. The primary objective of this baseline study is, therefore, to locate and assess the palaeontological sites likely to be affected. The other objectives of this study are to:

- Describe the fossil flora affected by
  - Mielietuin Dam
  - Jana Dam
  - Aqueduct routes.
- Information on the following will be provided:
  - Fossil flora type-localities
  - Previously undescribed taxa
  - Localities with boundaries, i.e. Ecca-Beaufort contact, Permo-Triassic boundary
  - Localities with fossil flora and fauna.
- Provide an assessment of the impact (Table 1.1) of the proposed TWP footprint on palaeontological sites.
- Mitigation.
- Further investigation.

Table 1.1 Conventions for definitions and terminology used in the description, evaluation and assessment of environmental impacts

Category	Description or Definition
Type	A brief written statement, conveying what environmental aspect is impacted by a particular project activity or action, or policy or statutory provision.
Magnitude and Intensity	The severity of the impact
· very high	- Complete disruption of process; death of all affected organisms; total demographic disruption
· high	- Substantial process disruption, death of many affected organisms; substantial social disruption
· moderate	- Real, measurable impact, which does not alter process or demography
· low	- Small change, often only just measurable
· no effect	- No measurable or observable effect
· unknown	- Insufficient information available on which to base a judgement
Extent / Spatial Scales	The geographical extent or area over which the direct effects of the impact are discernable, i.e. the area within which natural systems or humans directly endure the effects of the impact.
· international	- Southern Africa
· national	- South Africa
· regional	- KwaZulu-Natal and the Thukela catchment, the uThukela region
· local	- dam basin, conveyance servitude, river reach, specific site locality
Duration	The term or time period over which the impact is expressed, **not** the time until the impact is expressed. Where necessary the latter must be specified separately.
· short term	- up to 5 years (or construction phase only)
· medium term	- 5 to 15 years 9 (or early commissioning and operational phases)
· long term	- > 15 years (or operational life)
Sign	Denotes the perceived effect of the impact on the affected area
· positive (+)	beneficial impacts
· negative (-)	impacts which are deleterious
Certainty	A measure of how sure, in the professional judgement of the assessor, that the impact will occur or that mitigatory activity will be effective
· improbable	- low likelihood of the impact actually occurring
· probable	- distinct possibility that the impact may occur
· definite	- impact will occur regardless of prevention measures
Significance	An integration (i.e. opinion) of the type, magnitude, scale and duration of the impact. Judgements as to what constitutes a significant impact require consideration of both context and intensity. It is the assessor's best judgement of whether the impact is important or not within the broad context in which its direct effects are felt. (see Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823)
· high	- Could (or should) block the project/policy; totally irreversible (-ve impact) or provides substantial and sustained benefits (+ve impact)
· medium	- Impact requires detailed analysis and assessment, and often needs substantial mitigatory actions.
· low	- Impact is real but not sufficient to alter the approach used. Probably no mitigation action necessary.

Some Explanations and Definitions

1 Environmental impact - An environmental change caused by some human act. (DEA 1992. *The Integrated Environmental Procedure*. Vol 5).

2 Environmental impact - Degree of change in an environment resulting from the effect of an activity on the environment whether discernable or undesirable. Impacts may be the direct consequence of an organisation's activities or may be indirectly caused by them. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

3 Affected environment - Those parts of the socio-economic and bio-physical environment impacted on by the development. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

4 Environmental issue - A concern felt by one or more parties about some existing, potential or perceived environmental impact. (Department of Environment Affairs & Tourism, 1998. *Guideline Document: EIA Regulations Implementation of Sections 21 22 and 26 of the Environment Conservation Act, April 1998*).

5 Environment - means the surroundings within which humans exist and that are made up of:
- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of (i) and (ii) and the interrelationships among and between them;
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

(National Environmental Management Act No 107 of 1998).

6 Significance - (See Fuggle R.F. & Rabie M.A. 1992. *Environmental Management in South Africa*. Cape Town: Juta & Co. 823. Also in, DEA 1992. *The Integrated Environmental Procedure*. Vol 4).

7 Significance - "The definition of significance with regard to environmental effects is a key issue in EIA. It may relate *inter alia* to scale of the development. To sensitivity of location and to the nature of adverse effects." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 13).

8 Significance - "Once impacts have been predicted, there is a need to assess their relative significance. Criteria for significance include the magnitude and likelihood of the impact and its spatial and temporal extent, the likely degree of recovery of the affected environment, the value of the affected environment, the level of public concern, and political repercussions." (Glasson, J. Therival, R. and Chaduuick, A. 1995. *Introduction to Environmental Impact Assessments. Principles and Procedures, Process, Practise and Prospects*. London: UCL Press. 124).

9 Significance -" The question of significance of anthropogenic perturbations in the natural environment constitutes the very heart of environmental impact assessment. From any perspective - technical, conceptual or philosophical - the focus of impact assessment at some point narrows down to a judgement whether the predicted impacts are significant." (Beanlands, G. 1983. *An ecological Framework for Environmental Impact Assessments in Canada*. Institute for Resource and Environmental studies. Dalhausie University. Sections 7: 43).

10 Environment - Surroundings in which an organisation operates, including air, water, natural resources, flora, fauna, humans and their interrelation. (ISO 14001. 1996).
Note - Surroundings in this context extend from within an organisation to the global system.

11 Environmental aspect - Element of an organisation's activities, products or services that can interact with the environment. (ISO 14001. 1996). Note - A significant environmental aspect is an environmental aspect that has a or can have a significant environmental impact.

12 Environmental impact - Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services. (ISO 14001. 1996).

2 DESCRIPTION OF FOSSIL MATERIAL

Potentially fossiliferous areas were determined from the 1:250 000 series of geological maps from the Geological Survey (Dundee 2830, Harrismith 2828) and also from the topographic maps (1:50 000 for the same area). Further details were sought from the 1:10 000 orthophotos (2829DB - 14, 15, 18, 19, 20; 2829DD - 15, 19, 20; 2830CA - 16, 21, 22). Once the areas had been selected we visited each potential site, and found more that were not evident on the maps. Each outcrop was then sampled by excavating below the weathered surface, using a geological pick and chisels. In the field it is relatively easy to see the plant impressions that would be expected to occur. Minor outcrops which were sampled and proved to be barren are not listed here, only the larger outcrops, even if they too were barren.

2.1 Mielietuin Dam

This dam site is on the Bushman’s River immediately upstream of the western boundary of the Weenen Nature Reserve and the highest water level would be at 1033m above mean sea level.

Groot Mielietuin Farm and Rondedraay Farm:
(Access from Barry Schlanders/Jeremy Cooke; Nico and Mr Dorfling Snr.)

Locality 1:
S 28°54.414' E 29°57.087'
The cutting alongside the farm access road, and several tributary streams in the near vicinity were investigated. About 12m of blue-grey shales were exposed in total and also fairly coarse sandstones. There was evidence of rootlets and plant debris but no leaf material.

Locality 2:
S 28°54.510' E 29°57.306'
The shale quarry alongside the farm road yielded fragmentary *Glossopteris* leaf impressions with good venation on the dark shales but of sporadic occurrence. Root impressions also occur and possible trace fossils.

Locality 3:
S 28°54.192' E 29°59.419'
A large area of eroded blue-grey shales, about 1km^2 of dongas and ridges, all badly weathered, were exposed here. There were only a few fragments of unidentifiable roots and stems.

Locality 4:
S 28°53.571'   E 29°59.258'
This area near the dam wall, a narrow gorge with steep sides, was studied but there were dolerites and sandstones only, no fossil material.

Locality 5:
Buff coloured shales were exposed above the river where the road crosses it at the top end of the dam basin footprint. Only a few root markings were present. Lower down, approximately 10m, blue-grey shales were exposed along the river, capped by sandstone channels. No fossils were found here.

Locality 6:
S 28°55.326'   E 29°57.960'
There are several outcrops of buff shales along the "new" ring road past ploughed fields and alongside the river, but only one of the bigger outcrops is noted here. The shale sequences are thick but contained no fossils. Dolerite intrusions are common and have altered the adjacent shales.

Locality 11:
Far reaches of the dam basin.
The few shale deposits exposed in the streambeds were finely bedded but contained no fossil material. Dolerite intrusions and sandstones were the more common strata in this region and were also well weathered.

Figure 2.1 indicates the geology of the Mielietuin Dam area and the dam basin at the Full Supply Level of 1033m above sea level. Localities 1-6 and 11 are described in the text above.

Figure 2.1: Geology of Mielietuin Dam area

2.2 Jana Dam

This dam site, on the Thukela River, is approximately 15km downstream of the confluence of the Thukela and Klip Rivers, and could have a high water line ranging from 860-890m above sea level. The more likely Full Supply Level is 860m above sea level.

Ganna Hoek Farm and Schurfde Poort Farms:
(Access from Hugo Bosse and DWAF.)

Locality 7:
S 28°40.840' E 29°57.053'
The road cutting revealed coarse micaceous shales which are finely laminated. A narrow band (2-3cm) of darker material contains fragmentary *Glossopteris* leaf impressions, a seed and possible sphenophyte stems.

Locality 8:
S 28°40.756' E 29°56.282'
This is a large outcrop of coarse micaceous shales and has no fossils. The river course nearby has only sandstones and dolerites.

Locality 9:
S 28°40.558' E 29°58.638'
This site would be above the dam flood line. The shales exposed on the new ring road are also coarse and siltstone-like and have no fossil material.

The road alongside the river from the homestead, used by DWAF contractors, to the proposed wall site revealed sandstone deposits or Quaternary soils, no shales. On the opposite side of the river there were dolerite dykes intruding into the massive sandstones. This is State land and had steep sandstone cliffs extending from the river level to the flatter tops of the hills covered in soils.

Locality 10:
S 28°41.690' E 30°02.599'
The river banks are heavily vegetated with steep slopes leading to cliffs of thick sandstone and dolerite; no shale outcrops were noted.

Figure 2.2 indicates the geology of the Jana Dam area and the dam basin at the Full Supply Level of 890m above sea level. Localities 7-10 are described in the text above.

Figure 2.2: Geology of Jana Dam area

2.3 Aqueduct routes

The geology along the aqueduct routes, which would link the two proposed dams to the existing Kilburn Dam, is the same as that for both dams (Figure 2.3). As these sediments proved to be virtually devoid of fossils, the chances of there being good fossil material along the aqueduct routes is very small. With the time constraints it was not possible to sample the aqueduct routes.

If fossil material is discovered by the excavation teams during construction of the open canal, pipeline and service roads, it is recommended that palaeontologists be asked to rescue any good material as soon as possible, and thus prevent any undue delays in the construction.

Figure 2.3 indicates the geology of the proposed aqueduct routes from the proposed Mielietuin and Jana Dams, to the existing Kilburn Dam.

Figure 2.3: Geology of the aqueduct routes

3 IMPACT ASSESSMENT

3.1 Mielietuin Dam

As there were no well preserved fossils within the footprint of this dam and its basin, there would be no impact on the palaeontology of this inundated area. Fossils were preserved a very long time ago so the duration is not relevant, and the status neutral. The assessment of confidence is definite because fossil fragments of the expected type were found, thus confirming that we were searching in the correct strata. Their preservation was very poor and abundance extremely low throughout the area sampled so it is unlikely that we overlooked any good deposits.

3.2 Jana Dam

There were no well preserved or identifiable fossils of any significance within the footprint of this dam basin. The inundation caused by this dam would have no impact on the palaeontology and it is unlikely that any well preserved fossils would be found with further field work.

3.3 Aqueduct routes

The impact on the construction of the pipeline and open canal would be very low because there would be a very low probability of finding significant fossils in the sediments which, to the west, have only rare, fragmentary and unidentifiable fossils. It is uncertain that there would be any impact at all.

Table 3.1: Assessment of impacts

Criterion	Mielietuin Dam	Jana Dam	Aqueduct Routes
Magnitude and Intensity	no impact	no impact	very low impact
Extent / Spatial Scale	dam basin	dam basin	subregional
Duration	indefinite	indefinite	indefinite
Status	neutral	neutral	neutral
Confidence	probable	probable	uncertain
Significance	no effect	no effect	very low
Probability	definite	definite	definite

4 MITIGATION

4.1 Aqueduct routes

There is only a small probability of finding any palaeontological sites along the aqueduct routes because the same sedimentary units were studied in detail in both dam basin footprints and found to contain only very poor material. There are no published records of fossils from sites in this region, to the best of my knowledge, except for fossil woods (and undescribed dicynodon cranial and post cranial material) from the Thukela Biosphere Conservancy (Bamford, 1999) which is stratigraphically above, and close to but not in the Mielietuin Dam footprint.

It is recommended that a palaeontologist be contacted if and when any fossil material is discovered during excavation for the pipeline, open canal, service roads and source materials, particularly shales, to collect and “rescue” any good palaeontological material, to be housed in an institute recognised by the National Monuments Council.

Costs for the rescue of any fossils would be small: transport and a professional fee for the one to few days of field work required.

5 FURTHER INVESTIGATION

No further investigation is recommended at this stage and would only be necessary if fossils are found during excavations (see Section 4 above).

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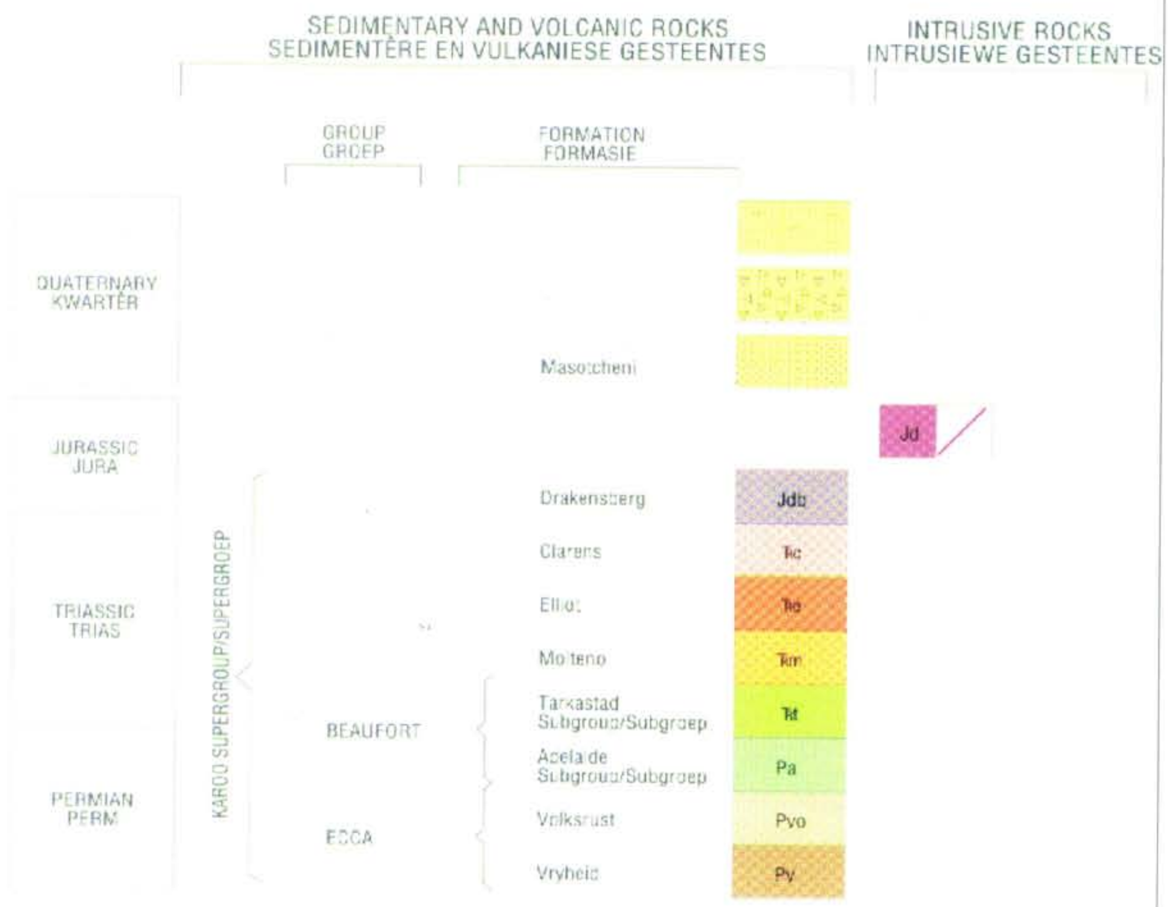
GEOLOGICAL LEGEND

GEOLOGIESE LEGENDE



LITHOLOGY
LITOLOGIE

	Alluvium Alluvium
	Scree Glooiingspuin
	Partly consolidated fine-grained sediments with silcrete nodules Gedeeltelik gekonsolideerde fynkorrelrige sedimente met silkreetknolle
Jd	Dolerite; dolerite dyke ( ) Doleriet; dolerietgang ( )
Jdb	Basalt Basalt
Ŧc	Yellow to pale-red, fine-grained sandstone Geel tot ligrooi, fynkorrelrige sandsteen
Ŧe	Red and purple mudstone; interbedded yellow to grey siltstone; fine- to medium-grained sandstone Rooi en pers moddersteen; tussengelaagde geel tot grys sliksteen; fyn- tot middelkorrelrige sandsteen
Ŧm	Medium- to coarse-grained glittering sandstone; gritstone; subordinate green and red mudstone; carbonaceous shale Middel- tot grofkorrelrige glinsterende sandsteen; gruissteen; ondergeskikte groen en rooi moddersteen; koolstofryke skalie
Ŧt	Fine- to medium-grained sandstone; red, green and blue mudstone Fyn- tot middelkorrelrige sandsteen; rooi, groen en blou moddersteen
Pa	Grey mudstone; dark-grey shale (carbonaceous in places); siltstone; sandstone Grys moddersteen; donkergrys skalie (koolstofhoudend op plekke); sliksteen; sandsteen
Pvo	Blue-grey to dark-grey shale Blougrys tot donkergrys skalie
Pv	Medium- to coarse-grained sandstone; micaceous shale; coal Middel- tot grofkorrelrige sandsteen; glimmerryke skalie; steenkool