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Thukela Water Project Feasibility Study

Volume 8: Baseline Studies

A) Aquatic human Health Baseline Study
B) HIV/AIDS Baseline Study
C) Framework for Environmental Management Systems

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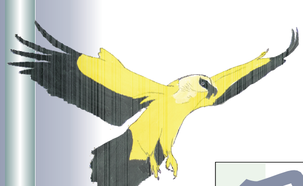

THUKELA WATER PROJECT FEASIBILITY STUDY

AQUATIC HUMAN HEALTH BASELINE STUDY

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1 INTRODUCTION

Historically, decision-making relating to dam construction was non-inclusive and failed to take into account the full range of potential impacts (health, environmental, etc.) In addition, many assessments focussed on short-term benefits but failed to evaluate long-term negative impacts and cost effectiveness (Goldmann, 1976). This led to a number of so-called "bad dams", where the negative impacts have out-weighed the positive benefits. It is estimated that by 1997 there were some 40 000 large dams (wall >15m) and some 800 000 smaller ones (Joyce, 1997). There is, however, little doubt that on a global scale the positive benefits far out-weigh the negative.

> *"There are more good dams than bad ones. The bad dams are the shallow ones that flood large areas of land or that produce relatively little power. It's in the tropics that these dams are associated with disease like schistosomiasis and malaria; these are not a problem in temperate areas ...... and with proper mitigation, dam sites can be improved"* (Robert Tillman, World Bank)

Ensuring the construction of "good dams" necessitates that all stakeholders have a clear understanding of both the potential benefits and negative impacts, and the carrying out of detailed feasibility studies, which consults all sectors.

This study was tasked to provide information to decision-makers on possible health implications of building the proposed dams of the Thukela Water Project.

2 DAMS IN THE CONTEXT OF HUMAN HEALTH IN SOUTH AFRICA

Of all continents, Africa has the highest burden of disease contributed by infectious and vector borne disease (World Development Report, World Bank, 1992). The most significant of these are water-related. The distribution of many of these does, however, not extend into South Africa. Table 2.1 below lists some of these diseases, their transmission mode and relative importance in terms of disease burden (morbidity and mortality).

Table 2.1: South Africa: Disease, transmission mode, and relative importance in relation to dam construction and associated activities

Disease	Transmission Mode	Potential for Exacerbation due to Dam Construction	Disease Burden Ranking (Scale 1-5)
Malaria	Vector borne, larval stage is aquatic, transmission by airborne adult	Yes	5
Schistosomiasis	Vector borne, vector is aquatic and transmission occurs in water	Yes	4
Amoebiasis, Balantidiasis, Giardiasis, Cryptosporidios, Ascariasis, Typhoid and Trichurus	Ingestion of water borne cysts or bacteria	Yes?	?
Fascioliasis	Snail host	No?	Not significant
Paragonimiasis	Snail host and crab	No	Not significant
Naegleriasis	Free living parasite, contracted through ingestion	No	Not significant

In the above table it is necessary to consider both the importance of the disease burden, as well as the likelihood of exacerbation through dam construction and associated activities and impacts. Of the diseases listed, only schistosomiasis and malaria rank as relevant. In the case of the parasites such as giardiasis, amoebiasis, etc., it is difficult to assess their relevance as limited information is available on the relative distribution and prevalence. It can, however, be stated that dam release rates can either increase or decrease the downstream concentration of these parasites which significantly contribute towards diarrhoeal disease. Diarrhoeal disease is a major contributing factor in childhood mortality.

Isolated cases of paragonimiasis have been reported from the lower reaches of the Thukela River. However, the relative importance of this lung fluke is unknown. Any conclusions regarding the impact of the Thukela Water Project would thus be speculative. The remainder of this report will thus deal with the two remaining diseases which are important in South Africa (in terms of disease burden) and which are affected by dams and associated activities.

2.1 Malaria

Malaria in Africa today is still probably the most significant single contributor to Africa's disease burden. Childhood mortality for under five's is estimated at 530 000 per annum (Snow *et al*., 1998). Historically, malaria in South Africa extended as far south as Port St. Johns in epidemic years (le Sueur *et al*., 1993). The historical distribution of malaria is shown in Figure 2.1. The severity of the malaria problem is indicated by the fact that in 1932, 26 332 people died of malaria in 5 months (le Sueur *et al*., 1993). This represented approximately 2.6% of the population. The impact on the economy is indicated by the following quotation by the South African Chamber of Commerce at its annual conference in 1932 (le Sueur *et al*., 1993).

> *"This convention respectfully urges upon the Government the need for continuous and effective action to eradicate the scourge of malaria which is having a serious effect upon Natal and the Eastern Transvaal, and reacting seriously upon the progress of industry, trade and agriculture in these provinces, and, through them upon the Union."*

The magnitude of the problem was such that the government mobilised, through the provision of funds and the necessary legislation, a malaria control strategy for South Africa. This involved the use of residual insecticide and experimentation with new anti-malarials. This strategy was subsequently successfully used in the eradication campaigns in Europe and the USA. Control has been maintained and today a highly structured control programme with an annual budget of R34 million is in place in KwaZulu-Natal. Control has successfully pushed back the distribution of malaria in South Africa. However, despite intensive control efforts, South Africa is experiencing a resurgence of malaria. This is largely as a result of increasing drug resistance, movement of infected migrants from uncontrolled countries into South Africa, a breakdown of control in adjacent countries, and favourable climatic conditions. Research during late 1999 and 2000 has shown that *Anopheles funestus*, a malaria vector mosquito which was thought to be eradicated in South Africa, was present in sprayed houses in northern KwaZulu-Natal province. These mosquitoes were shown to be resistant to synthetic pyrethroids, the insecticide used for vector control by house spraying (Hargreaves *et al*., 2000). To combat this problem a national decision was made to spray all houses in the malaria areas of the province with DDT to control this mosquito. Community-based drug efficacy studies in the same area during 2000, found a high level of resistance by the malaria parasite to first line malaria treatment, Sulphadoxine/pyrimethamine. Alternative and effective treatment is envisaged by the 2000/2001 malaria season with the introduction of combination therapy. These changes in drug and insecticide policy should be affective in, once again, dramatically reducing malaria transmission in the province. Figure 2.2 shows the annual case rate over the past 28 years, (1999 is up to and including September).

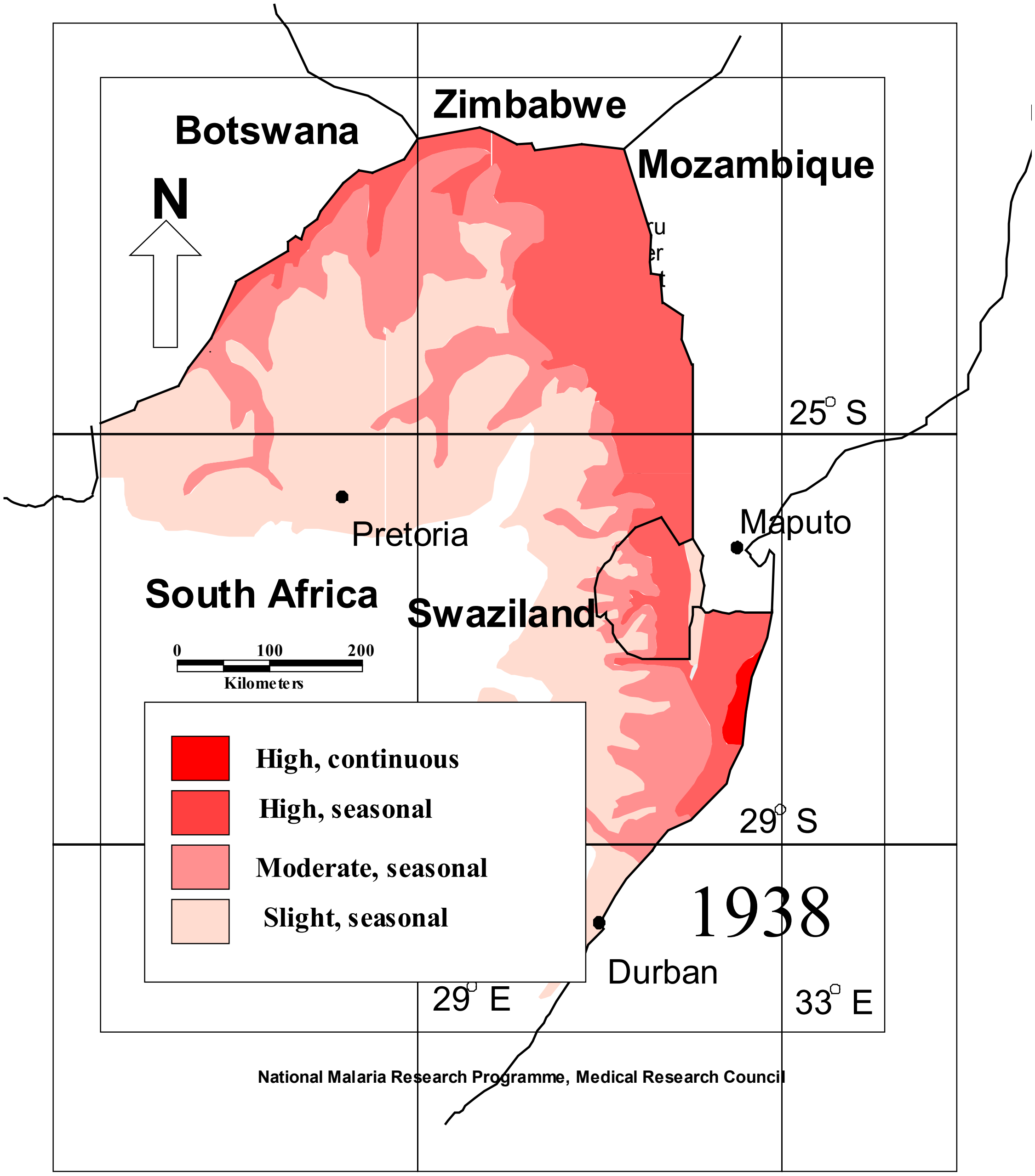


Figure 2.1: Malaria risk in South Africa before disease control by reduction of parasites and mosquito vectors

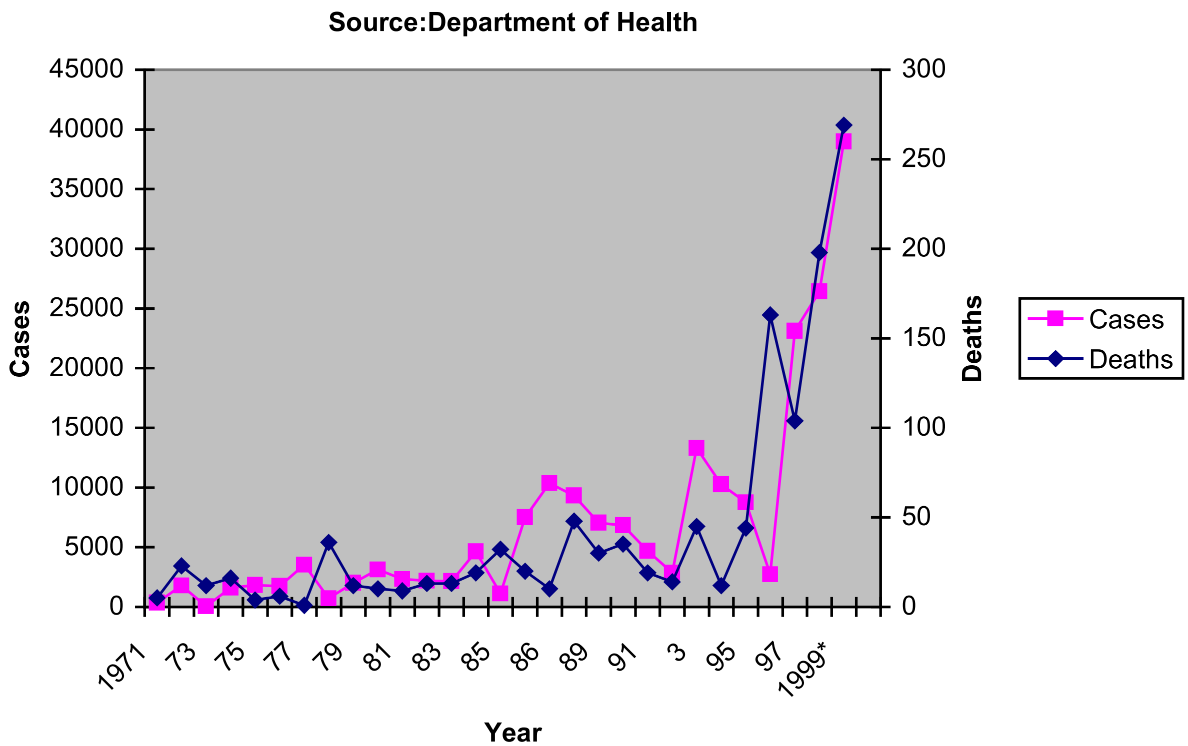
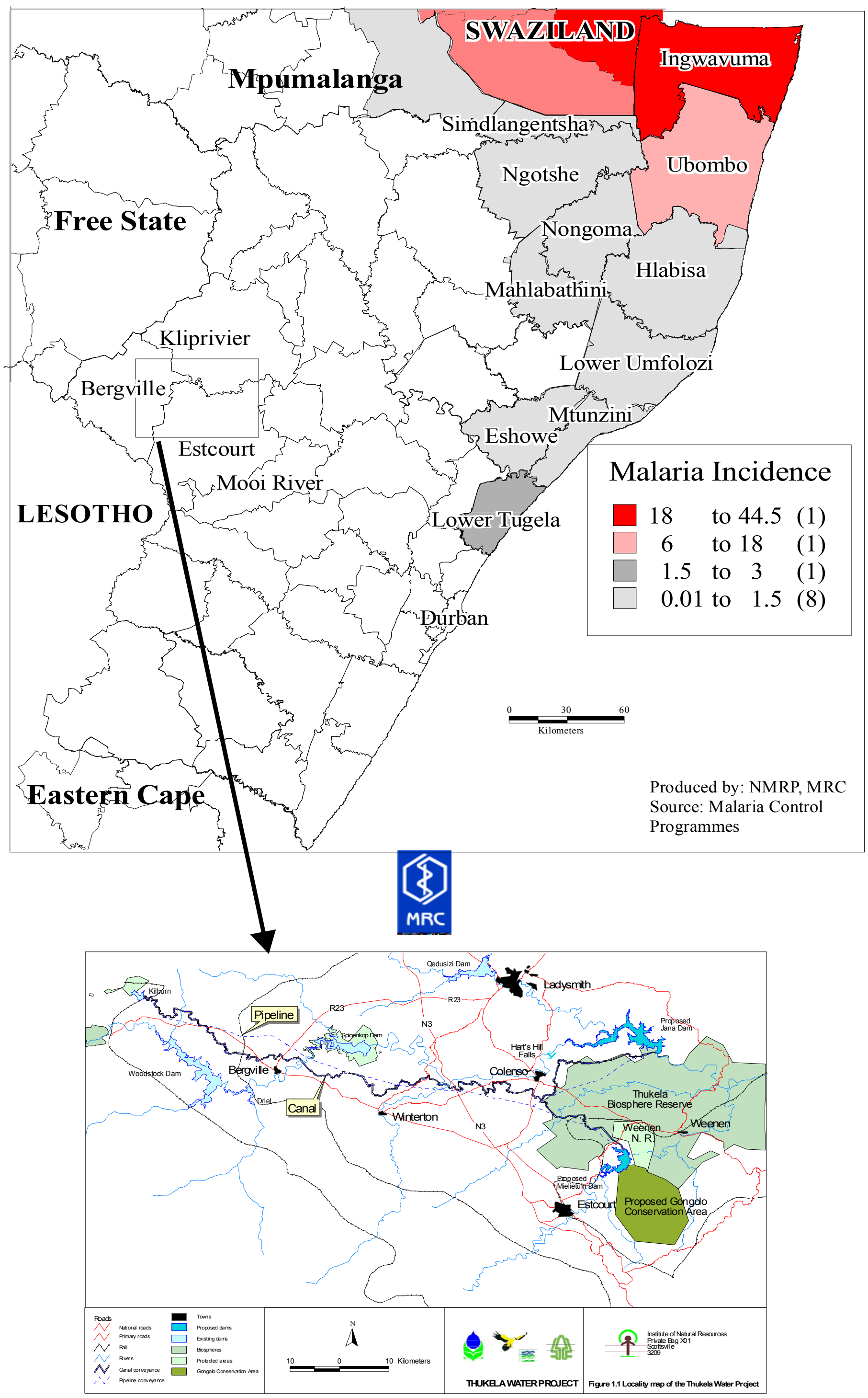


Figure 2.2: Malaria cases and deaths 1971-1999

Figure 2.3 shows the current distribution of malaria at magisterial district level based on cases recorded in 1996. This figure clearly shows that the proposed site lies out of both the current and historical distribution of malaria in South Africa. It should, however, be remembered that 1996 would be regarded as an average year and in epidemic years the distribution may be considerably extended. In 1932 every magisterial district in the then province of Natal reported malaria.



Locality map of the Thukela Water Project

Figure 2.3: KwaZulu-Natal: Malaria case incidence per thousand: Population 1996

In recent years we have once again seen an expansion of the distribution of malaria in South Africa. Currently the potential thus exists for a short transmission "window" to be sustained in and around the dam sites during the summer months. This is obviously contingent on the presence of both vectors and parasite within the region. The construction will, however, attract migrant labour and the possibility of this including asymptomatic parasite carriers is real. Such an epidemic occurred on the Natal South Coast in the 1930's due to migrant labour working on railway line construction (le Sueur *et al*., 1993).

It would be negligent not to consider the potential impact of climate change. The debate as to whether climate change is a reality will not be discussed here. The Intergovernmental Panel on Climate Change (IPCC) scenarios for global warming range between 1 and 3.5°C (IPCC, 1996). Figure 2.4 shows a comparison of current mean potential distribution (unmodified by control activities), as well as the extension, which would occur with a 1 and 3.5°C increase in temperature.

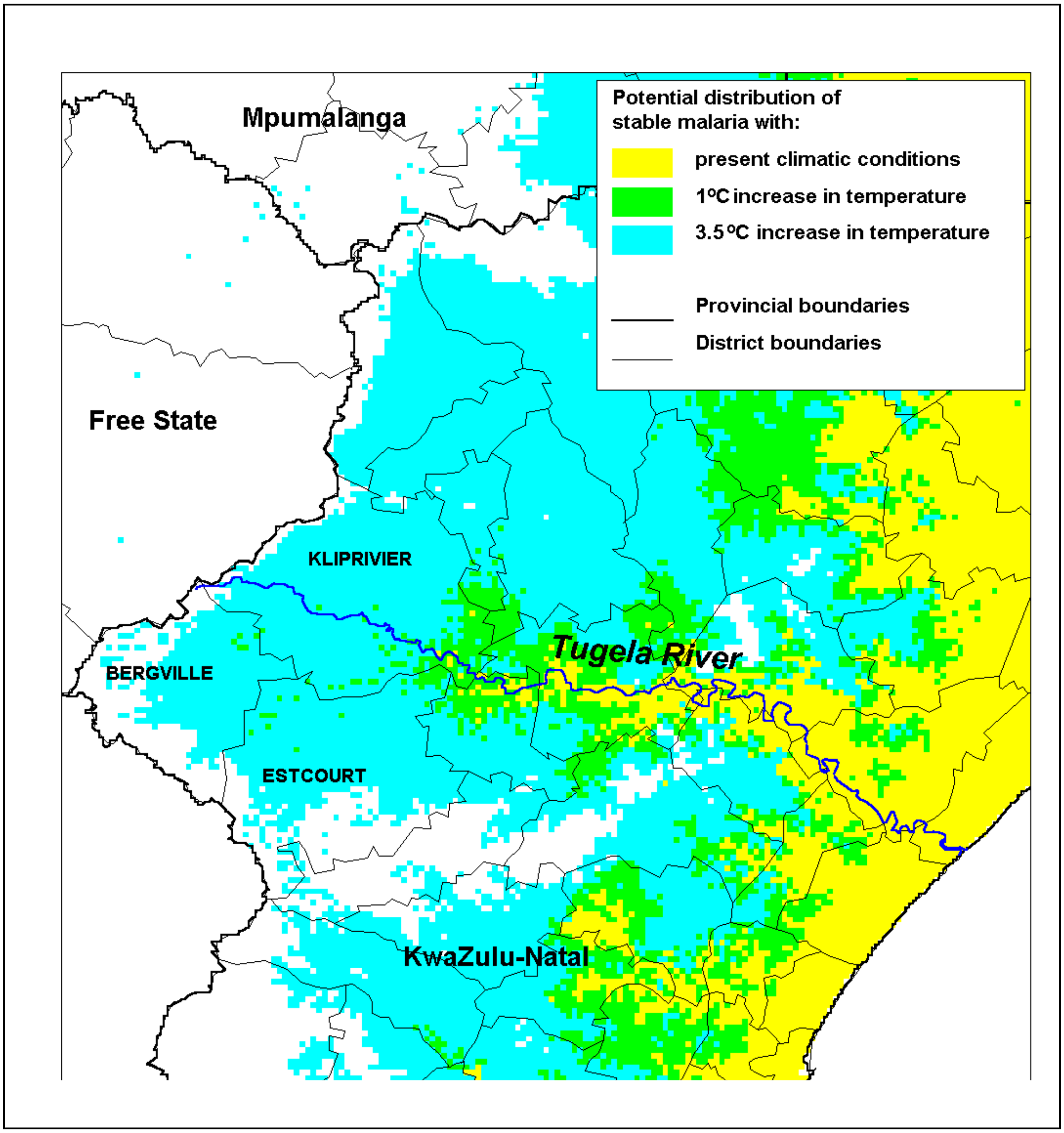


Figure 2.4: Potential impact of global warming on the distribution of malaria in KwaZulu-Natal and relevance to Thukela project

The effect of downstream irrigation practise, canal systems and cofferdams is not covered here, in view of the stated function of the dams as reservoirs for water transfer to the Vaal River. The impact of poor planning on increased malaria transmission with regard to irrigation practise in South Africa was documented by le Sueur *et al*. (1992) and Sharp *et al*. (1992).

2.2 Schistosomiasis

Two species of Schistosomiasis are distributed in South Africa, *Schistosoma haemotobium* (urinary form) and *Schistosoma mansoni*. The former is more common with prevalence rates >70% over the lowveld of Mpumalanga and the Northern Province, as well as parts of the KwaZulu-Natal coastal plain, the Transkei and Eastern Cape (Appleton *et al*., 1995). *Schistosoma mansoni* has a more limited distribution, covering the lowlands of Mpumalanga, the Northern Province, and KwaZulu-Natal, as far south as Port St. Johns.

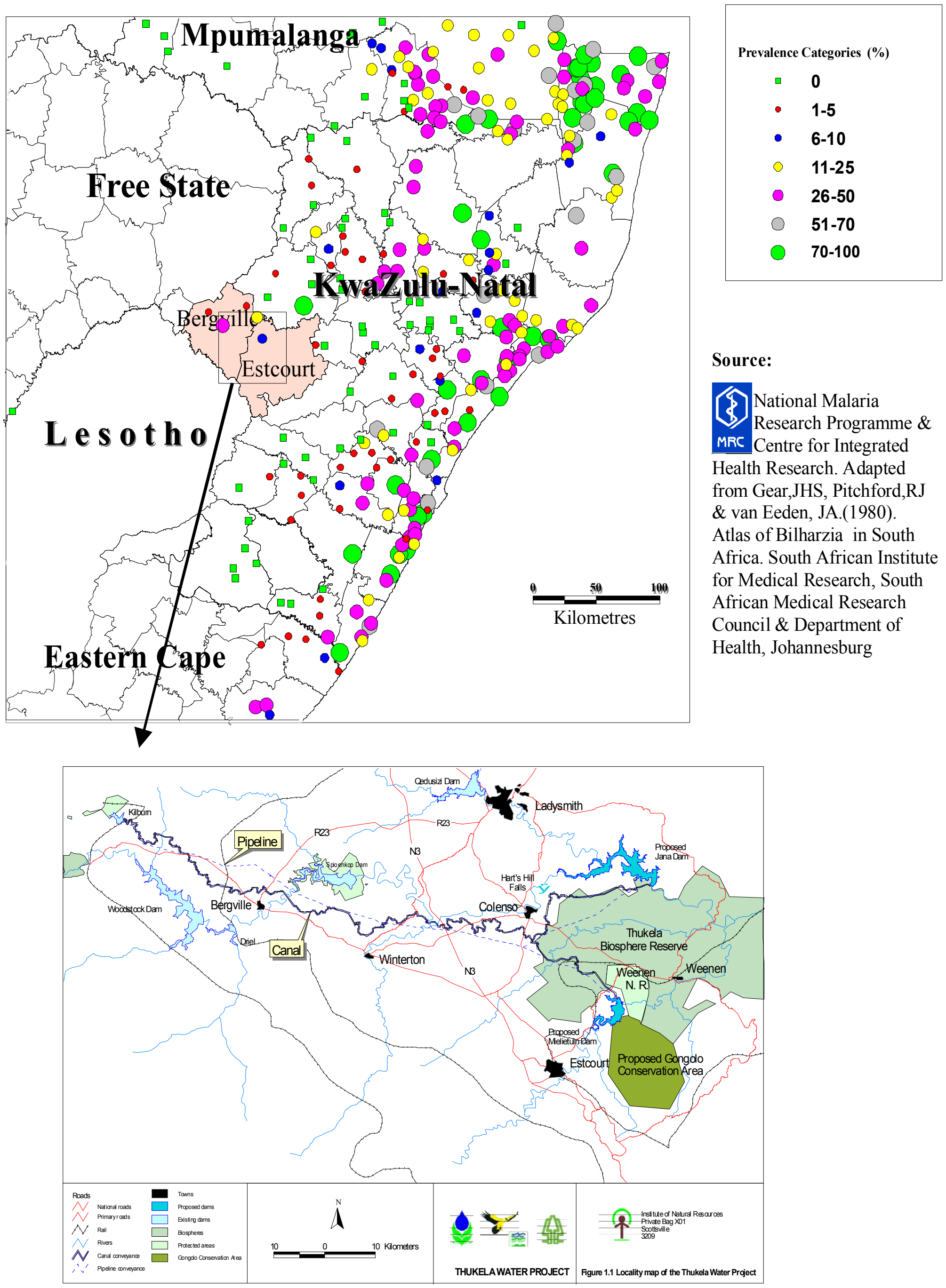
A third species, *Schistosoma matheii,* occurs in parts of Mpumalanga , the Northern Province and KwaZulu-Natal (Gear *et al*., 1980). It is, however, predominantly a parasite of cattle and ungulates and is thought to be self-limiting in man.

The association between dams and Schistosomiasis has long been recognised (Appleton *et al*., 1995; Goldman, 1976; McIntosh *et al*., 1973; Mozley, 1955; Waddy, 1996). Despite the proliferation of dams within endemic areas in South Africa, it is difficult to assess the impact on the epidemiology of the disease. Maaren and Moolman (1986) report a nine-fold increase in dams in the Estcourt area between 1944 and 1984. One of the factors which has previously limited the role of major dams in the transmission of water-borne diseases is the Water Act, 1956 (Act 54 of 1956, Sections 56and 69), which states that the areas around major dams is the property of the Department of Water Affairs and Forestry (DWAF). Changes in policy/law which result in increased community access are likely to change this situation. Classically, the Schistosomiasis transmission cycle is maintained by urine and/or faeces being deposited or washing into rivers and water bodies.

Pettijean and Davies (1988) covered the potential for intercatchment transfer of aquatic organisms. In addition, Pretorius *et al*., (1976) have suggested that *Bulinus aficanus,* the intermediate host for *Schistosoma haematobium,* could be transported from the Thukela River to the Sterkfontein Dam via the Thukela-Vaal River transfer scheme. Pitchford (1953) demonstrated that both the snails and eggs were transferred alive through centrifugal pumps.

Figure 2.5 shows a map of all prevalence studies for *Schistosoma haemat*obium, which indicated that the site falls within the current distribution of the disease. In contrast, the site falls well outside of the current distribution of *Schistosoma mansoni*. As the dam falls within the current distribution of *Schistosoma haematobium*, potential exists for the transfer of both the parasite and intermediate host between river catchments. The potential of the dam to exacerbate current transmission is unclear and requires both baseline and ongoing investigation to ascertain whether transmission will become established.

Should long-term climate change prove a reality, then the dams may play a role in the transmission of *Schistosoma mansoni*. Any conclusions in this regard at present would, however, be purely speculative.



Proposed layout of the Tugela Water Project

Figure 2.5: Prevalence of *Schistosoma haematobium*

3 CONCLUSIONS AND RECOMMENDATIONS FOR ASSESSMENT AND MITIGATION

The conclusions made here are based on the principle that the function of the dams is as described in the supplied Thukela project outline. It is, thus, assumed that there will be little or no downstream impact associated with irrigation activities. Should this change at a later stage then a separate assessment will have to be carried out. Any future plans involving the downstream construction of irrigation canals and coffer dams should consult the guidelines provided in the World Health Organisation Offset Publication, No 66 (see References).

It is clear that, although potential health impacts do currently exist in terms of malaria, Schistosomiasis and diarrhoeal disease, these are not great. The latter statement, however, assumes that careful, ongoing assessment and mitigation will be carried out. The necessary steps to reduce potential exacerbation are outlined below:

- It is essential that all migrant labour from malaria areas be screened for malaria infection at first arrival at the site and at successive returns after visits away from the site. The home location of all workers should be identified, towards establishing the need or not for screening. Guidelines detailing the above procedures, as well as treatment of positive individuals and the methodology of ongoing assessment, need to be compiled. Similar procedures need to be established for Schistosomiasis.
- A baseline survey of the potential mosquito vector population needs to be carried out in the month of February, prior to the initiation of construction activities. A similar baseline needs to be established for the snail vectors of Schistosomiasis.
- A baseline assessment of the current situation relating to snail vectors in the Kilburn Dam needs to be carried out.
- A cross-sectional baseline survey of existing *S. haemotobium* prevalence rates in the construction site area. This should be followed by subsequent surveys during the construction phase and for six years after completion. These should be carried out every second year.
- Annual follow-ups of the Kilburn baseline after the scheme becomes operational need to be carried out for 3-5 years in view of the potential transfer of *Bulinus africanus* over the Drakensberg into the Sterkfontein Dam.
- Ongoing monitoring of downstream contamination with faecal contaminants, such as *Escheri coli*, needs to be carried out. A strategy of water release to mitigate high levels needs to be established.

- If such a release plan includes water volumes likely to flood river margins, then the location of these needs to be established. This will allow assessment of the potential for the provision of additional malaria vector breeding sites through such activities.

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THUKELA WATER PROJECT FEASIBILITY STUDY

HIV/AIDS BASELINE STUDY : AN ASSESSMENT OF HIV/AIDS FOR THE THUKELA WATER PROJECT

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1 INTRODUCTION

This report was compiled according to the "Terms of Reference for an Assessment of HIV/AIDS - its Context and Implications for the TWP" issued by the Department of Water Affairs and Forestry as part of the Thukela Water Project feasibility study.

The purpose of the report is to describe the current prevalence levels and distribution of HIV in the Thukela Region of KwaZulu-Natal and then to use this data to model and forecast future prevalence and mortality levels. The Terms of Reference specifically stated that this contract should only "accumulate the relevant statistical data" as Dr Pete Ashton will prepare the impact report. Hence, none of the potential impacts on society and the economy have been discussed here, although we would be happy to liase further with Dr Ashton in this regard.

This introduction is followed by a discussion on the sources of data used to make current HIV prevalence estimates which leads into a further discussion with regard to the reliability of these estimates. The next section then provides an overview of the main issues and limitations in modelling and forecasting from current data sources.

The main body of this paper consists of the methodology used to forecast population and mortality trends until 2015. The results of the modelling process are then presented along with preliminary conclusions and, finally, the requirements for a more sophisticated forecasting model are listed.

1.1 Limitations to the report

There were a few key limitations to this report. Firstly, the paucity of data on population HIV levels in the Thukela Region meant that certain assumptions had to be made, e.g. with regard to the stability of the population and the distribution of HIV between men and women. These assumptions are made explicit later in this document.

There are also uncertainties in the data that underpin a number of the assumptions that go into the model, such as the incubation period of HIV, which creates subsequent uncertainties in the model outputs. As the population in Thukela consists of 93% black Africans, and given that HIV estimates for whites in the area are unknown but likely to be below 2%, separate modelling was not done for whites and blacks.

Secondly, an optimal modelling process would produce error estimates around the "best fit" point estimates produced by the model but this would take substantially more time and was not within the budget constraints of this contract. This is because an iterative process involving multiple simulations will have to be undertaken. We have also not modelled the potential impact of effective interventions such as the availability of a vaccine or effective intravaginal microbicide. In future developments of this model such interventions could be simulated and their effect on HIV prevalence levels estimated.

No specific modelling has been done for Gauteng, partly because we were informed that this was of secondary importance and, secondly, because, unlike for Thukela, we did not have baseline population supplied. However, evidence from studies looking at the pattern of the HIVAIDS epidemic in South Africa is that there are not substantial differences between the patterns in the different provinces. The growth rate of HIV in each province is very similar but other provinces lag behind KwaZulu-Natal to varying degrees. If we could get access to the Gauteng antenatal HIV data and data on the population demographics, we would be able to run similar models to the one used in this report to generate forecast data for Gauteng.

2 SOURCES OF DATA

South Africa's only surveillance system for HIV is the annual antenatal HIV survey that has been run for the last 9 years. Despite methodological weaknesses in the early years and changes over time, this surveillance activity has provided the country with reliable data with which to track the epidemic. In KwaZulu-Natal the survey has been run for the last 5 years by the Virology Department at the University of Natal. The same sentinel sites across the province have been used which results in valid trend data over time. The KwaZulu-Natal data, by sentinel site, from the last three years is shown in Figure 2.1. Limitations to this data are discussed in the next section.

The only other source of data on HIV prevalence levels is that originating out of special studies. To our knowledge, no published community-based prevalence studies have been done in the Thukela Region. However, a number of studies have been undertaken in other rural areas of KwaZulu-Natal and such data has been used to supplement the antenatal data. Specifically, fertility rates among women from the Hlabisa district (also a rural region of KwaZulu-Natal) were used as we have no fertility data from Thukela. However, we have no reason to believe that fertility rates would be too different between these areas.

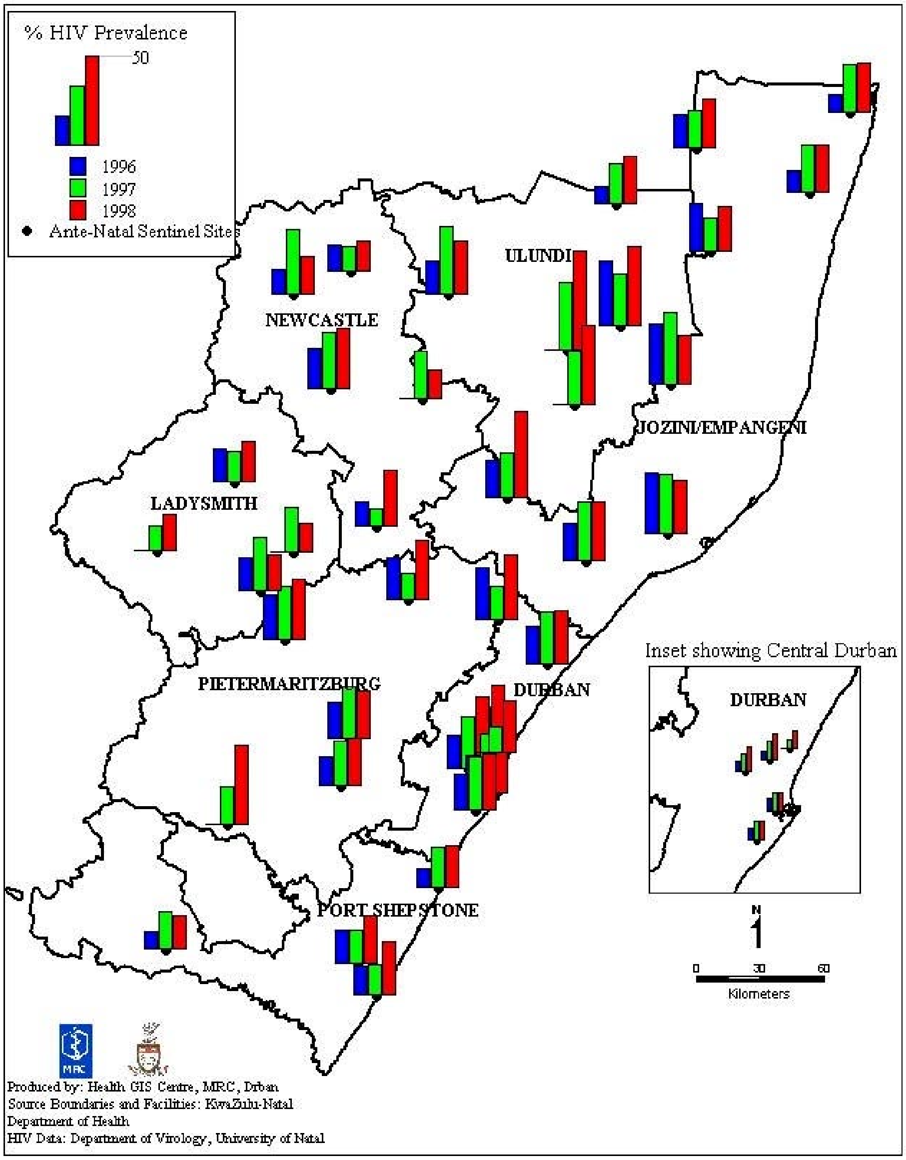

Figure 2.1: KwaZulu-Natal Province: HIV prevalence 1996-1998 by ante-natal sentinel sites

3 DISCUSSION ON CURRENT HIV PREVALENCE ESTIMATES

The latest (as yet unpublished) data from the 1999 annual antenatal survey, shows that the epidemic in KwaZulu-Natal seems to be "plateauing", i.e. the overall prevalence of HIV among pregnant women is stabilising at about 32%. We do not yet have the data for the regions, but we would expect the Thukela Region to stabilise at similar levels within the next two years.

Table 3.1 provides the 1998 HIV prevalence levels by 5 year age bands for the whole of KwaZulu-Natal, KwaZulu-Natal excluding the Thukela Region, and the Thukela Region alone. We estimate that, at present, 24% of pregnant women in Thukela are infected with HIV.

Table 3.1: HIV prevalence levels for KwaZulu-Natal and Thukela Region for 1998

Age Group	KZN: ANC data		KZN (excluding Thukela) ANC data		Thukela ANC data	
	N	% HIV	N	% HIV	N	% HIV
15-19	789	28.5	538	32.7	251	19.5
20-24	1062	34.0	720	37.0	342	28.4
25-29	830	29.8	596	42.0	234	28.2
30-34	524	28.0	371	30.2	153	22.8
35-39	238	18.0	177	21.5	61	9.8
40+	47	12.8	34	11.7	13	15.4
Total	3490	31.6	2436	34.8	1054	24.0

The current estimated age distribution of HIV by sex for Thukela is provided in Figure 3.1 and the current estimated age structure of the population is given in Figure 3.2. Note that this figure is model-based as we do not have exact data for the population and no local data on HIV among men. However, the "fit" of the graph for women is very close to the empirical antenatal data.

Whilst information from antenatal clinic attenders is acknowledged to be the most unbiased source of HIV prevalence data that is generally available in developing countries, it is not without its own biases and weaknesses. In the South African context, such data only really tells us about HIV amongst pregnant, black women who use the state health services.

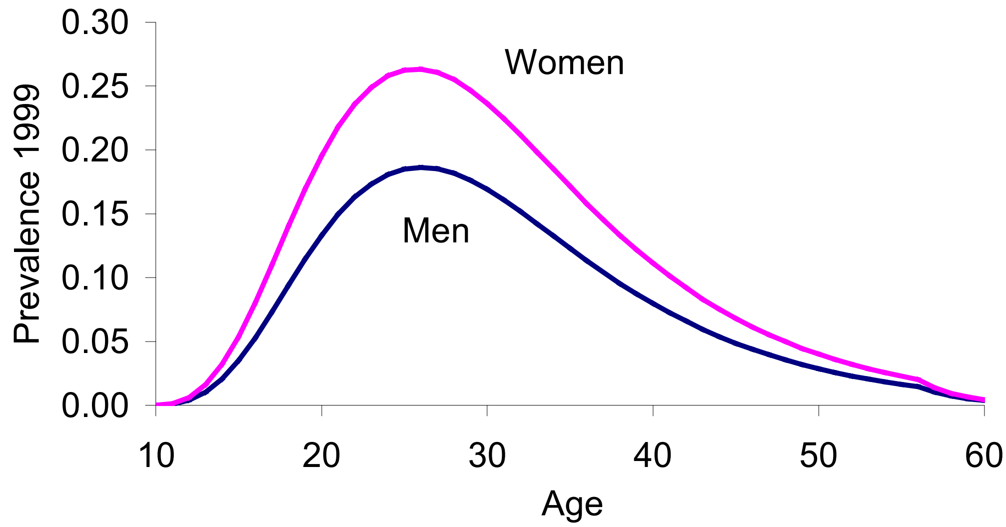

Figure 3.1: Modelled prevalence of HIV by age among men and women in 1999

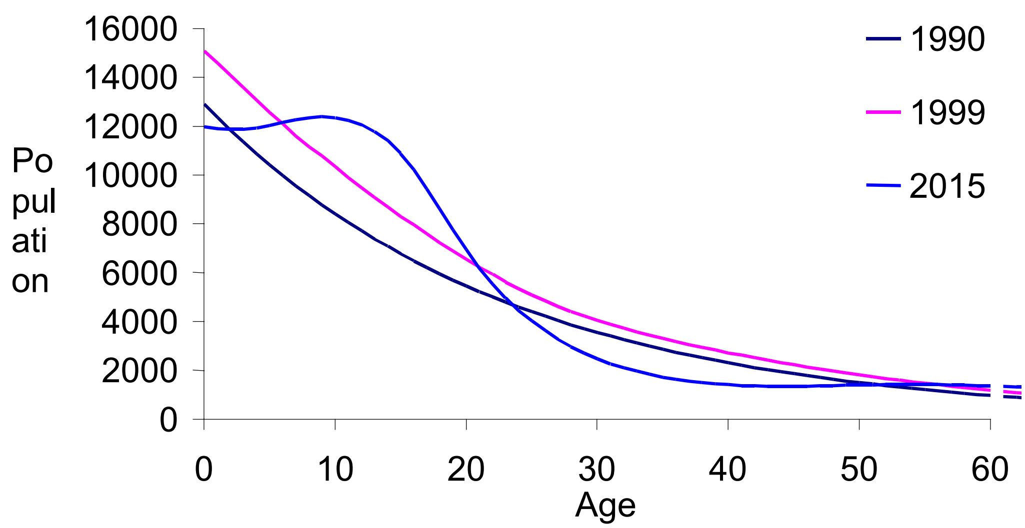

Figure 3.2: Historical, current and forecast changes in the age structure of the Thukela population

Extrapolations about the prevalence levels among non-pregnant women, women of other races, and all men, are all subject to various assumptions and less confidence can be put on their reliability.

The most recent UNAIDS/WHO AIDS epidemic update (UNAIDS, 1999) provides a better insight into how to interpret and extrapolate from antenatal data. The data from 15 studies of HIV prevalence in the general population of sub-Saharan countries, suggest that antenatal estimates tend to underestimate the real levels of HIV infection in women. The reason is that infected women progressively become less fertile: the longer their HIV infection progresses, the less likely they are to get pregnant. And because many HIV-infected women are no longer becoming pregnant, they are not showing up at antenatal clinics where blood samples for anonymous HIV testing are taken. The antenatal estimates thus fail to reflect the true extent of HIV infection in the female population as a whole.

On the other hand, the population-based studies suggest that infection levels in men are lower than the levels of HIV recorded among pregnant women.

The conclusion seems to be that there are significantly more women than men living with HIV infection in sub-Saharan Africa. The ratio of women to men is not the same everywhere, and it changes over time. Current information suggests that more men than women become infected in the early stages of a heterosexual epidemic, especially in settings where a small number of sex workers rapidly become infected and in turn spread HIV to a much larger number of men. Over time the male-female gap is closed, and eventually the ratio is reversed. On average, however, the 15 studies conducted in both rural and urban areas in nine different African countries suggest that between 12 and 13 African women are infected for every 10 African men.

Further discussion in regard to the age and sex distribution of HIV in sub-Saharan Africa is contained in Appendix 1.

4 ISSUES IN REGARD TO MAKING HIV/AIDS PROJECTIONS

Making projections about the future prevalence of HIV/AIDS is not an exact science and estimates vary widely depending on the underlying assumptions. This is well demonstrated by the discrepancies that exist between the projections made by the United Nations (UN) and the US Census Bureau. Whereas the UN estimates that AIDS will reduce the population growth of the most severely affected countries in Africa by 13 million by 2005 and 30 million by 2025, the US Census Bureau projects the reduction to be four times larger (59 million by 2005 and 120 million by 2025) (Stover, 1998).

The main reason for such large disparities is because different methodologies are used for projecting prevalence levels. Additional important factors contributing to the variations are differing estimates about current infection levels and differing assumptions about the average period from infection to developing AIDS and about perinatal transmission rates. Future developments, such as widespread access to intrapartum antiretroviral therapy for pregnant women, likely behavioural changes as people are increasingly faced with the growing AIDS epidemic and the possible development of a vaccine or effective intravaginal microbicide, will also impact on progression of the epidemic.

For the purposes of this study we have assumed that there will be no such effective interventions before 2010 and, hence, we provide a conservative estimate of the progression of the epidemic. In practice, we anticipate that, even in the absence of successful control measures, the rising death rate from AIDS will result in behavioural changes.

Finally, it must be stressed that the further into the future that forecasts go, the less reliable the estimates become. Few modellers would forecast beyond 5 years and so the 15 year forecasts presented here are very speculative.

5 INTRODUCTION TO THE FORECASTING MODEL

In order to plan the future needs and capacity of any region, it is important to be able to forecast the likely impact that HIV will have on the demography, health and social services, and the economy in the area. As a first step in such an impact forecast we need to be able to make more precise statements about the likely future course of the epidemic and its impact.

The most important features of the HIV epidemic in this regard are (a) the long incubation period so that people who are infected today will only die in seven years time (MRC Uganda, 1999), (b) the peak incidence occurs among 20 year old women and 27 year old men so that the peak mortality will occur among 27 year old women and 34 year old men (MRC Uganda, 1999; Williams, 1999) but there will be substantial mortality among men and women between the ages of about 20 and 50 years who make up the economically active section of the population, (c) rates of infection among women in general populations are believed to be about 20% to 30% higher than among men so that more women than men will be affected (Williams, in press) but (d) rates amongst some groups of men, in particular migrant men including miners and truckers, are substantially higher than in other groups and show a quite different age-prevalence (Williams, 1999).

In order to fully understand the likely socio-economic impact of the epidemic we need, at least, to be able to make projections concerning the age and gender specific mortality, morbidity and fertility, the overall population growth rate, the number of children who will be born with HIV and the number who will be orphaned. The Department of Water Affairs and Forestry will need to know how the epidemic will affect their current work force, how it will affect their ability to recruit new workers, what their training requirements will be, how it will affect their consumers and so the demand for water. This latter requirement will necessitate understanding the likely dynamics of the epidemic in Gauteng, as well as in Thukela.

5.1 Methods used in the forecasting model

Model:

A dynamical difference equation model was used with a time step of one year. The number of births each year is calculated from the age specific fertility which is scaled in such a way as to ensure that the current population distribution gives the current birth rate. Uninfected people experience a background mortality and HIV people experience an additional AIDS-related mortality. Infant mortality was not included explicitly but is effectively accounted for by scaling the fertility accordingly. In a more detailed model it would be essential to consider mother-to-child transmission and the associated mortality explicitly.

Model assumptions:

- Current prevalence rates were based on antenatal clinic data for 1998.
- Log-normal distribution was used to estimate the age-specific risk of infection (Williams, in press).
- Assume that male to female transmission is higher than female to male transmission.
- AIDS-related mortality rate of 10% per year (corresponding to a life expectancy of 7 years).
- Background mortality rate of 2% per year (corresponding to a life expectancy of 50 years).
- Age-specific fertility rates were estimated using data from Hlabisa fitted to a log-normal distribution.
- Age-specific incidence rates were estimated for 1998 using the model developed by Williams, Gouws, *et al*., and scaled for males and females.
- Baseline population structure for Thukela based on 1995 data.

6 RESULTS OF THE MODEL

Using the Williams Gouws model, annual incidence rates for HIV for KwaZulu-Natal, and the country as a whole, were calculated and are presented in Table 6.1. The estimated annual incidence for Thukela is 5.6%. Based on this data and on the estimated population structure in 1995, prevalence levels for men and women aged 15 to 49 until 2015 are provided in Figure 6.1. The prevalence levels projected beyond 2005 are very high and in practice we expect to see a decrease in the incidence of HIV in the near future as people adapt their behaviours in the light of the massive mortality that we will soon witness from AIDS. This decreasing incidence of HIV will then have a knock-on effect on the prevalence, which will begin to slow down its rise and level off.

Table 6.1: Increase in HIV prevalence and incidence rates from 1992 to 1998 from national and KwaZulu-Natal data sources

Year	KwaZulu-Natal		National	
	Prevalence (%)	Estimated Annual Incidence (%)	Prevalence (%)	Estimated Annual Incidence (%)
1992	4.8	5.1	2.69	2.1
1993	9.6	5.5	4.69	3.1
1994	14.4	4.5	7.57	3.2
1995	18.2	2.1	10.44	4.2
1996	19.9	9.1	14.07	3.5
1997	26.9	7.9	17.04	6.3
1998	32.5		22.8	

Based on the projected prevalence levels, the probable impact on population levels is given in Figure 6.2. We expect the Thukela population to peak at about 387 000 for men in about 2006 and at about 410 000 for women in 2003. By 2015 these figures will come down to about 351 000 and 350 000 respectively for men and women.

With regard to mortality, it is already clear that by the year 2005 there will be approximately 0.5 to 1 million AIDS-related deaths each year in the country as a whole (Figure 6.3). Given that the population of Thukela is about 1.6% of the national total, this translates into about 8 000 to 16 000 deaths per year in Thukela.

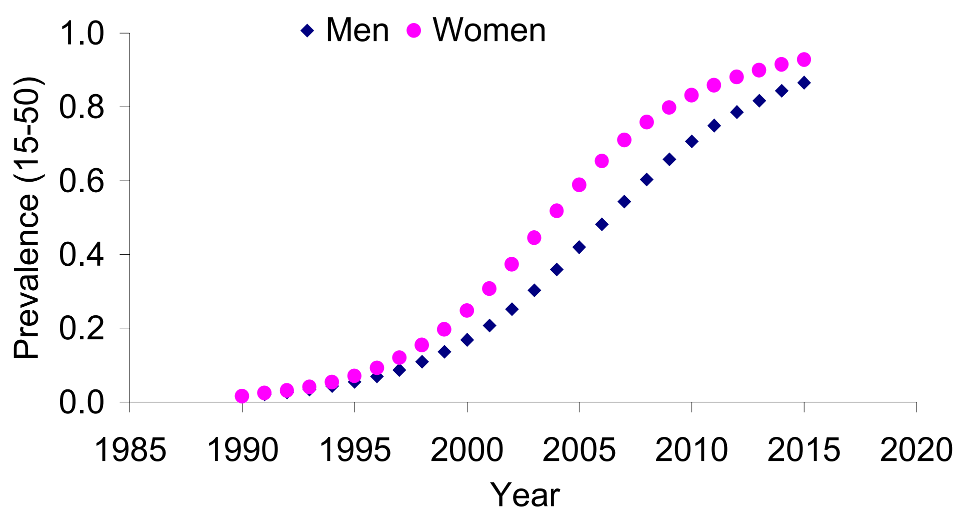

Figure 6.1: Forecast changes in the prevalence of HIV over time

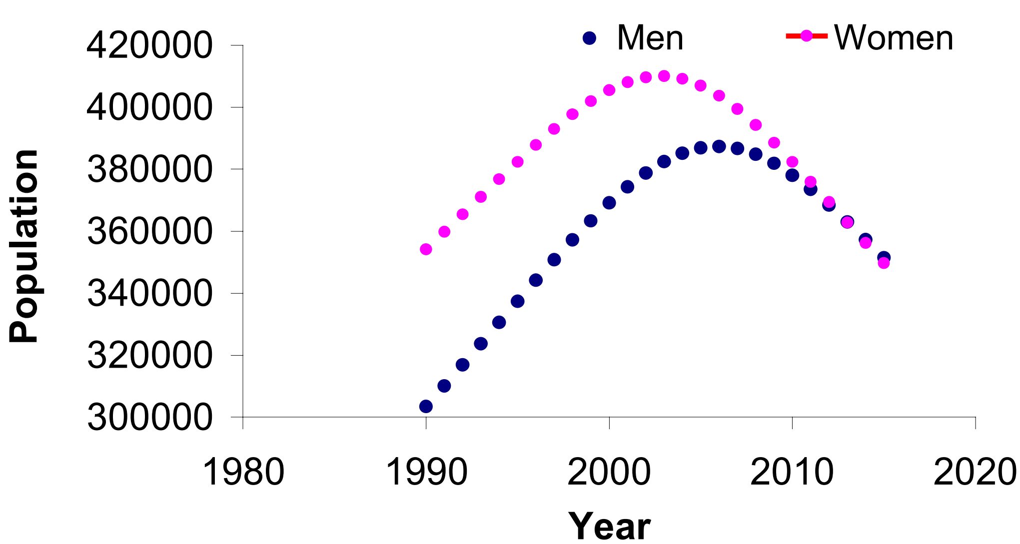

Figure 6.2: Predicted change in the total population of Thukela.

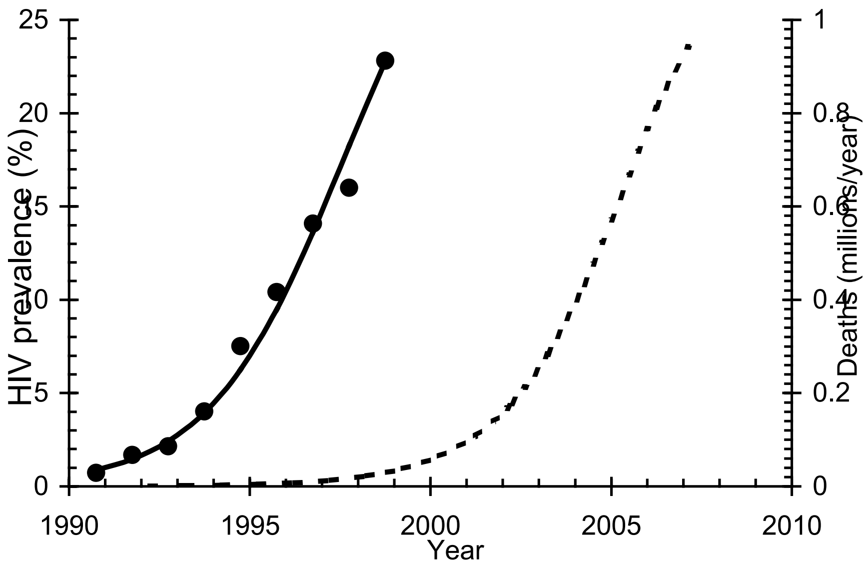

Figure 6.3: Prevalence of HIV infection amongst women attending antenatal clinics nationally (solid line and observed data) and forecast deaths per year (dashed line).

The effect of this mortality on the population age structure will also be profound (Figure 3.2). By 2015 there will be a relative depletion of the working age population and a relative increase in the under 25 year olds who are typically dependent on adults. The effects that this will have on the national and rural economies have not been determined but, again, are likely to be substantial.

6.1 Preliminary conclusions

It is clear from these preliminary calculations that, while the overall size of the population will not change drastically in the next 15 years, the age structure of the population will change unless steps are taken to reduce the rate of infection. In particular, it will be increasingly hard to include adult workers while the number of young people who need to be supported will increase dramatically. Using models such as this, it will be possible to make best estimates of morbidity, mortality, number of orphans, and so on, which will be needed to plan ways of dealing with the epidemic. It will also be possible to demonstrate the likely benefits to be gained from different levels of intervention.

7 REQUIREMENTS FOR PRODUCING A MORE SOPHISTICATED MODEL

In order to produce a model that is more comprehensive and that will produce more reliable estimates, the following factors will be needed as input data:

- Current age and gender specific population estimates;
- Current age and gender specific estimates of the prevalence of HIV infection;
- Current age specific fertility estimates;
- Age and gender specific mortality prior to the HIV epidemic;
- Age-specific AIDS-related mortality and morbidity;
- The burden and spectrum of AIDS-related diseases and, in particular, TB;
- The probability of vertical transmission.

As better data become available, it will be possible to include these in the model quite simply and so improve on the forecasts. In addition, simulations can be run on the likely impact of effective interventions, and sensitivity analyses to examine critical factors impacting on the epidemic may be done.

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APPENDICES

APPENDIX 1: A DISCUSSION ON THE SOUTH AFRICAN ANNUAL ANTENATAL HIV SURVEYS

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A DISCUSSION ON THE SOUTH AFRICAN ANNUAL ANTENATAL HIV SURVEYS

APPENDIX 1.

A discussion on the South African annual antenatal HIV surveys

National HIV seroprevalence surveys of pregnant women have been run annually by the Department of Health (DoH) since 1990 and have formed the cornerstone of South Africa's surveillance system for HIV (Epi comments, 1995). The surveys consisted of anonymous and unlinked testing of residual blood specimens which were collected for routine syphilis and rhesus testing. This is the methodology recommended by the WHO and CDC and used in many countries throughout the world (CDC, 1990).

Approximately 20 000 blood specimens were collected each year over the study periods from the laboratories that conducted routine blood typing tests. Efforts were made to ensure that all regions were covered although sample sizes per region were not usually proportional to the population size (Epi comments, 1995). These surveys have produced relatively unbiased national and provincial point estimates of the prevalence of HIV infection among pregnant women, in addition to age-specific levels. This data was particularly useful for following trends over time and in highlighting geographical variations in prevalence. The data also made the calculation of the number of perinatally infected newborn children possible where vertical transmission rates were known.

Probably the greatest weakness of these antenatal surveys until 1997 was the lack of a consistent sampling frame. Because blood was collected from laboratories, there was no control over which clinics submitted samples, nor over how individual patients were sampled. In addition, provinces used different sampling methodologies. The introduction of bedside test kits for rhesus testing biased results further as some clinics were not submitting blood specimens for routine testing. The problems posed by this haphazard sampling were graphically demonstrated in 1996 when the HIV prevalence levels for one province increased three-fold and yet it was impossible to determine whether this was a real increase or caused by bias in the sampling. From 1998 this problem has been addressed because the MRC produced a standardised national protocol which has been used subsequently and which utilises a probability based sampling method.

Antenatal seroprevalence studies are particularly useful in the early stages of the epidemic when the epidemic curve is still rising. However, in the more mature phase of the epidemic prevalence data becomes more difficult to interpret. This is because there may be a stable prevalence in spite of a steady incidence rate because the number of new cases is balanced by the mortality due to HIV. Therefore, in the mature phase the obtaining of incidence data becomes imperative.

Although, strictly speaking, the estimates apply only to pregnant women using state health services, the data has been used to extrapolate HIV infection levels to all women, men and the general population. This extrapolation involves making a number of assumptions which greatly reduces the reliability of the data the further one moves away from the study population. Indeed, biostatisticians contend that such extrapolations are invalid and should not be done. However, if for political or other reasons, extrapolations are to be made, the DoH at least needs to know the limitations of the estimates generated.

Limitations of using antenatal data to generate population prevalence estimates

Recent studies have shown that antenatal studies are likely to produce under-estimates of the study population prevalences because of the relationship between HIV and decreased fertility. This is because HIV, particularly in cases of more advanced disease, tends to reduce fertility. In the future, when increasingly women will be aware of their HIV status, a voluntary reduction in fertility will further result in antenatal surveys underestimating HIV seroprevalence levels. Ideally, the infertility bias could be corrected for if the fertility rate among HIV infected and uninfected was accurately known. Unfortunately, this is not the case and only when cohorts of HIV positive and negative women are followed over time will this bias be accurately catered for.

Extrapolating from the study population to the population of all women involves a number of assumptions, most of which cannot be accurately verified based on existing data. The study population does not include the following categories of women: Those of all ages who are not engaged in sexual activity, women who effectively use contraceptives, sterile women and those who either do not attend any antenatal clinics or use those in the private sector. Omission of the private sector results in under-representation of the middle class and substantial proportions of race groups other black Africans.

Extrapolation of the results to men involves making assumptions about the ratio of women to men who are HIV infected. Historically, this has been done by assuming a fixed ratio of 1:0.73, regardless of geographic area or age group. As more data on this ratio becomes available from population-based studies in different geographic areas and among varying age groups, it may be possible to refine this assumption further.

Finally, prevalence figures in the under 15 and over 49 year olds have to be estimated. Vertical transmission rates of HIV from mother to child and mortality rates in children may be useful to generate results in the youth. In the older age group, data from community based studies may be used to estimate prevalence levels in older people.

It is the uncertainty raised by these assumptions and the fact that sub-groups (e.g. prison populations, drug users, men who have sex with men) are not adequately represented, that underlies the need for alternative sources of data on HIV prevalence levels among men and non-pregnant women.

EXTRACT FROM "UNAIDS: AIDS Epidemic update: December 1999"

A discussion on the differing HIV prevalence levels between men and women in sub-Saharan Africa.

Why more women than men are infected is not fully understood. A combination of factors are clearly involved, including the fact that HIV passes more easily from men to women through sex than from women to men. However, a prime factor is surely the difference in age patterns of HIV infection in men and women. Women tend to become infected far younger than men for both biological and cultural reasons. According to recent studies in several African populations, girls aged 15-19 are around five or six times more likely to be HIV-positive than boys their own age. The infection rate in men eventually catches up, but not until after they reach their late 20s or early 30s. Clearly, older men, who often coerce girls into sex or buy their favours with sugar-daddy gifts, are the main source of HIV for the teenage girls.

This age pattern has two consequences for the sex ratio of infections. The first has to do with the pyramid-shaped age structure common to the growing populations of sub-Saharan Africa. HIV prevalence - the total proportion of people who are infected at a given point in time - rises very quickly in women, peaking at young ages. This is the age group that constitutes the broad base of the population pyramid in Africa. In contrast, prevalence does not peak in men until they are older, by which time they belong to an age group that makes up a smaller fraction of the overall population, higher up the narrowing pyramid. Prevalence figures that span the entire 15-49 year age range will therefore be weighted towards the sex that has higher infection rates in younger age groups - in the case of HIV, that is clearly women..

The second factor involves survival time from infection with HIV to death. There is little evidence of differences in survival time between men and women infected with HIV at a given age. However, studies in industrialised countries before the advent of antiretroviral therapy have shown that the length of survival of HIV-positive people does differ according to their age at initial infection. The older one is when one gets HIV, the shorter the time between infection and death. A community-based study in rural Uganda that has been running for many years appears to suggest that the same pattern holds in sub-Saharan Africa. Therefore, African women, who as a rule become infected younger than their male counterparts, can expect to live longer with HIV on average than men and be counted for a longer time among the female population alive with HIV. Because of this survival factor, even if women did not experience more new infections than men, female prevalence would still be higher than male prevalence.

It is only recently that evidence has been available to allow us to assert with confidence that more women are infected than men in Africa. (It should be noted that no such evidence as yet exists in other continents, where different patterns of transmission have tended to yield more male than female infections.) This is the first time that different sex ratios of infection and reduced fertility in HIV-positive women have been taken into account in the UNAIDS/WHO estimates for sub-Saharan Africa. In accordance with evidence emerging from studies in a number of African countries, HIV-positive women are assumed to bear 20% fewer children once they become infected than they otherwise would. That of course affects estimates of mother-to-child transmission and orphans. The 20% reduction in fertility translates into fewer children at risk of acquiring the virus and, hence, fewer children born with HIV (or infected through their mother's milk), as well as fewer children left orphaned by their mother's death from AIDS. Overall, however, the reduction in these estimates is not substantial because the reduced fertility of HIV-positive women is largely balanced out by the fact that HIV prevalence in women is higher than previously thought.

It is expected that estimation methods will continue to improve as the understanding of the dynamics of this evolving epidemic expands.

THUKELA WATER PROJECT FEASIBILITY STUDY

FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT SYSTEMS

Prepared by

J.S. BALLOT, ENVIRONMENTAL ASSESSMENT TECHNOLOGIES

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SUMMARY

Both the Integrated Environmental Management (IEM) procedure and the regulatory authorisation process in this country, do not provide for or stipulate any formal measures to ensure that impacts are managed within a formal management system, throughout the operational life of a project. To actually ensure that impacts are mitigated and the benefits of the development enhanced, as the case may be, it is essential that ongoing management of all the main environmental aspects is undertaken. This is what is generally referred to as cradle-to-grave environmental management.

The environmental assessment work for the Thukela Water Project (TWP) was carried out within a framework, which identified three distinct development and planning levels, namely:

(i) National policy or multi-regional development;
(ii) Regional development; and
(iii) Site specific projects.

It will be very difficult, if at all possible, to manage the environmental impacts at these different levels by making use of project-based or focused management systems alone. A much broader framework will have to be sought. It is, therefore, suggested that the framework provided by the National Environmental Management Act (NEMA) is used, together with the main elements of the ISO 14000 framework.

One of the pillars of NEMA is that it requires co-operative governance in the environmental sector. Government Departments and Provinces have to draw up Environmental Implementation Plans and Environmental Management Plans (EIP's/EMP's) to co-ordinate and harmonise their environmental policies, plans, programmes and decisions, with the express purpose of managing the environment.

The TWP must, therefore, make use of this statutory framework, together with the elements of a system such as ISO 14000, to ensure that effective management plans are drawn up, implemented, monitored and controlled, for managing the environmental impacts caused by national and regional issues associated with the development.

For those issues which are relevant at a very site specific level, it is recommended that mitigation be managed in a system that is designed for project-based activities, such as the ISO 14000 framework.

The impacts that are derived from them will be caused by actions and activities that are undertaken in pursuit of specific projects such as:

- the construction of dams;
- the construction of roads;
- the operation of dams and pipelines.

The minimum which should be taken up in such a system should be the following:

- Establishment of appropriate environmental policy;
- Identification of environmental aspects and significant environmental impacts;
- Identification of relevant legislative and regulatory requirements;
- Identification of priorities, appropriate environmental objectives and targets;
- Establishment of a structured process to implement policy, achieve objectives and meet targets;
- Planning, control, monitoring and review of policy implementation for continuous improvement;
- Adapt to changing circumstances.

1 INTRODUCTION

Integrated Environmental Management (IEM) in South Africa was designed to ensure that the environmental consequences of development proposals or projects, are understood and adequately considered in the planning process (Department of Environmental Affairs and Tourism, 1992). The IEM procedure sets out three distinct phases in the process of considering the effects of development projects on the environment. They are:

(i) Plan and assess the development proposal;
(ii) Decision; and
(iii) Implementation.

In terms of implementation, IEM lays stress on the monitoring aspects associated with the conditions of approval, but does not detail any requirements for the ongoing management of environmental impacts.

In addition, an EIA-based official authorisation process has been established in this country, that allows government jurisdictions to exert control over development proposals. The environmental impacts of proposed development projects have to be assessed, and proposals made as to how undesired impacts may be mitigated, in order to gain government approval to go ahead with an undertaking.

Within the broad context of the TWP, and the environmental management plans that need to be implemented to deal with the environmental impacts that will result from all the many developments associated with it, throughout their **operational** life, there are two important aspects that need to be noted.

Firstly, both IEM and the regulatory authorisation procedures do not provide for or stipulate any formal measures to ensure that impacts are managed within a formal management system, throughout the operational life of the project. Virtually all the major impacts from a development occur as a result of the **operational activities** after the project has been commissioned. During the planning stages, as required by IEM, impacts can only be identified. To actually ensure that the impacts are mitigated and the benefits of the development enhanced, as the case may be, it is essential that ongoing management of all the main environmental aspects is undertaken. This is what may be referred to as cradle-to-grave environmental management. What is good is that the authorities are increasingly writing environmental management requirements into the authorisations that they issue.

Secondly, both IEM and the regulatory procedures are project-based, in that it is the environmental impacts of specific, unique or discrete projects that are looked at and for which the mitigatory actions and measures can, to a very large degree, be identified and implemented fairly easily. As such, there are also well developed environmental management systems available which can be used to do this. The best known are probably the internationally recognised ISO 14000 management system and the EMPR (Environmental Management Programme Report) approach that is used in the mining industry in this country.

The challenge for the TWP is that, while it does have a large amount of project-based work, many of the activities and the greatest environmental effects will be from policy and programme impacts resulting from implementation of the Thukela Water Project as a whole. The limitations and inadequacies of project-based environmental assessment has been recognised for some time. Because of this, strategic environmental assessment (SEA) approaches have been developed over the last 10 years or so, both in South Africa and in the rest of the world. However, as with project-based EIA, SEA practise has not provided for, and has not stipulated any formal measures to ensure that the environmental effects caused by the cycle of policy and strategy implementation are managed within the framework of a formal management system.

Policy level impacts and their associated mitigating actions must also be managed within the framework of an environmental management system that can be monitored, audited, and corrective action taken where necessary. The structure of the TWP is such that the use of project-based environmental management systems will not be sufficient to deal with the environmental effects and impacts of a development that is geographically so widespread, reaches so many different groups and institutional structures, and also involves consideration and coordination of so many different policy and planning levels.

2 THE STRUCTURE OF THE TWP

The environmental assessment work for the TWP was carried out within a framework, which identified three distinct development and planning levels. They are:

(i) National policy or multi regional development;
(ii) Regional development; and
(iii) Site specific.

These three levels were then used as a basis to differentiate or categorise the key issues that formed the basis of the approach used in the assessment process. The baseline studies have answered the questions and concerns articulated in the issues, with an added dimension in the use of various alternatives during assessment.

The implementation of an environmental management system (EMS) and the design of environmental management plans (EMP) for the TWP, must take this structure into account. Any EMP that is set up to address policy level issues and regional development, will differ markedly from one that is used at the site specific level. The basic difference is that, on the one hand the question being asked is, "*Where do we go?*", while on the other it is, "*How do we get there?*"

In both cases, the basic purpose would be to provide the right information to decision-makers at the right time. But in the one case it would be to guide the formulation and implementation of policy level issues, and in the other, it would involve managing environmental impacts at a site specific level.

2.1 Environmental Management Systems

For the Thukela Water Project, which is a very large and complex development project, it is essential that at different levels and for different aspects or sections of the overall development, environmental management systems are implemented, the ultimate goal of which is improved institutional and organisational performance.

The following elements are inherently part of any environmental management system framework. Those listed below, come from the framework provided by ISO 14000. However, it is submitted that they are generic to any management system under consideration for a particular planning or policy level in question.

- Establishment of appropriate environmental policy;
- Identification of environmental aspects and significant environmental impacts;
- Identification of relevant requirements, legislative and regulatory;
- Identification of priorities, appropriate environmental objectives and targets;

- Establishment of a structured process to implement policy, achieve objectives and meet targets;
- Planning, control and monitoring, as well as review of policy implementation for continuous improvement;
- Flexibility and ability to adapt to changing circumstances.

All of the environmental assessment work which has been done for the TWP, must be used to put the mitigation recommendations into the framework of an environmental management system that may be applied at all the different levels at which the effects of the TWP will impact on the environment.

What must be stressed is that this report is **not recommending** that any particular environmental management system be adopted, such as the ISO 14000 programmes. Only the framework of the ISO 14000 management system has been used, within which to structure the mitigation actions that need to be taken. The ISO systems are becoming the world standards and are basically sound and well thought through. What is suggested is that when such systems are eventually implemented, the basic framework and thinking will already have been established so that ISO 14000 programmes can then more easily be applied.

It is also not the intention to identify and describe the environmental management systems in detail. This must only be seen as a guide and as a basis for the initial planning of environmental management systems and plans that must be drawn up and implemented at various levels and for the many different aspects of the overall development.

2.2 EMS for policy level impacts

In the Issues Report, the following were typical of the kind of concerns and values that were taken up in the key issues that were identified.

- *What effects can be expected from the export of water out of the Thukela Basin to the receiving economic, social and biophysical environments of the Vaal River supply area?*
- *What significant implications and consequences are there for the DWAF in building and operating large dams, in a global environment where it is seemingly becoming more inadmissible and inappropriate? Is such action by DWAF advisable and appropriate, in the light of legal action and/or international pressure, or other forces or threats which can be brought to bear on the DWAF?*
- *What implications and consequences for the TWP should be considered, both from the side of the receiving environment, as well as the source environment, as the spread and effect of AIDS takes hold on the country, over the next two to three decades?*
- *In what way will the economic development of the uThukela Region and KwaZulu-Natal*

be affected by the export of water out of the Thukela catchment? What is the opportunity cost to KwaZulu-Natal of exporting water out of the province?

- *How much will the local economy, or in what way will the local economy be affected by the construction of dams and conveyance routes? What will the economic effect be on centres such Ladysmith, Colenso, Winterton and Bergville?*
- *In what way will current levels of crime and security in the region be influenced by the TWP?*
- *What are the social, economic, and biophysical forward and backward linkages of a project on the regional resource use and development activities in the Thukela catchment and KwaZulu-Natal?*

These are all policy or regional development level issues. The assessment of these key issues was done and certain mitigation actions were proposed. The kinds of mitigation actions that have been proposed are the following;

- *The changing public opinion about the relevance of large dams and Amanzi Awethu, if left unmanaged, can derail the project. A sophisticated management strategy is (therefore) called for from the early stages of planning right through to final commissioning and operating (to address this).*

- *There is likely to be a growth in informal settlements within the uThukela Region resulting from the implementation of the TWP. This will be caused by existing easy access routes, creation of new transport linkages, job opportunities, secondary opportunities, influx of money to the region, AIDS deaths and changing population dynamics and distribution, diminishing opportunities in rural areas, perception of better prospects elsewhere, rural poverty and climbing death rates from AIDS and other diseases. Land reform programme.*

  The result will be overcrowding, human health hazards, environmental degradation, stripping of bio-mass, overloading and possible collapse/dysfunctioning of public services at local and regional level (clinics, schools, water, sanitation, community services).

  To mitigate these effects, proactive participation by project people in social upliftment programmes is needed. Education programmes for project personnel. Comprehensive regional development plan and implementation of integrated strategic town and regional planning principles into all aspects of project planning activities. Effective communication, liaison and joint action by national, provincial and local government *departments (e.g. coordination of budgeting procedures and spending).*

These are only two examples of the type of mitigation action that will be necessary. The question that must now be asked is, what management framework must be used to address this?

An ISO 14000 framework, which is project- or site-based would not be appropriate, although as mentioned above in Section 2.1, the main elements of the ISO 14000 system are inherently part of any environmental management system framework. What is, therefore, suggested is that this, together with the framework provided by NEMA, is used.

2.2.1 National Environmental Management Act

The National Environmental Management Act (NEMA) was promulgated on 27 November 1998 (Government Gazette, 19519) and commenced on 29 January 1999 (Proclamation R8, Government Gazette, 19703).

The central pillars of NEMA are:

- Quality in environmental decision-making.
  - Principles (Chapter 1) and procedures (Chapters 4 & 5) for improving the quality and consistency of decision that may have a significant effect on the environment.

- Co-operative governance in the environmental sector.
  Co-operative governance mechanisms in NEMA include:
  - the Committee for Environmental Co-ordination (CEC), an interdepartmental committee, responsible for promoting integration and co-ordination of environmental functions by the relevant organs of state;
  - Environmental Implementation Plans and Environmental Management Plans (EIP's/EMP's) to be compiled by listed departments and provinces. The purpose of the EIP's and EMP's is to co-ordinate and harmonise the environmental policies, plans, programmes and decisions of various departments (at national, provincial and local level) whose functions may affect the environment, or whose powers and duties are aimed at managing the environment.

- Role of civil society in environmental governance.
  NEMA creates a framework for facilitating the role of civil society in environmental governance, including:
  - the National Environmental Advisory Forum, which advises the Minister, among others, on appropriate methods of monitoring compliance with the principles in Section 2 of the Act, and the Environmental Management Co-operation

Agreements, that provide a mechanism for the Minister, every MEC and municipality to enter into an agreement with any person or community for the purpose of promoting compliance with the principles in Section 2 of the Act;
- the provisions on protection of whistle-blowers that protect the public from prejudice or harassment for disclosing information on environmental risk, in good faith, and using the required procedures;
- the provisions that relax legal standing and enable any person or group of persons, in the public interest or in the interest of protecting the environment, to seek appropriate relief for a breach or threatened breach of a provision of NEMA;
- the provisions that facilitate private prosecutions of environmental offenders.

- Constitutional imperative to respect, protect, promote and fulfil the environmental right in the Bill of Rights.
  Mechanisms in the Act to achieve this include:
  - the duty of care that requires anyone that causes, has caused or may cause significant pollution or degradation of the environment, to take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring;
  - provisions that protect workers from prejudice or harassment, for refusing to do environmentally hazardous work; and
  - procedures for the control of emergency incidents, including a major emission, fire or explosion that may endanger the public, or lead to potentially serious pollution of, or detriment to the environment.

What is important for the TWP is the section of NEMA dealing with co-operative governance mechanisms. The basic framework has, therefore, already been laid for the relevant organs of state, such as DWAF, DEAT, Housing, Health and others, together with KwaZulu-Natal, to compile Environmental Implementation Plans and Environmental Management Plans (EIP's/EMP's). The purpose of these is to co-ordinate and harmonise the environmental policies, plans, programmes and decisions of these various departments at national, provincial and local level.

What the TWP must do is to see to it that the different elements as listed above are taken up in these programmes, namely:

- Policy.
  Policies are already taken up in legislation such as the National Water Act. In Section 2, the purpose of this Act is specifically stated as:
  The purpose of this Act is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors -
  (a) meeting the basic human needs of present and future generations;
  (b) promoting equitable access to water;
  (c) redressing the results of past racial and gender discrimination;
  *(d) promoting the efficient, **sustainable** and beneficial use of water in the public interest;*
  (e) facilitating social and economic development;
  (f) providing for growing demand for water use;
  *(g) **protecting aquatic and associated ecosystems and their biological diversity**;*
  *(h) **reducing and preventing pollution and degradation of water resources**;*
  (i) meeting international obligations;
  (j) promoting dam safety;
  *(k) **managing floods and droughts**,*
  *and for achieving this purpose, to **establish suitable institutions** and to ensure that they have appropriate community, racial and gender representation.*

- Identification of environmental aspects and significant environmental impacts.
  All the important environmental aspects and issues that have been identified, or will be identified in future assessment work, must now be taken up in the EMP's that must be prepared in terms of NEMA.

- Application of relevant requirements, legislative and regulatory.
  All the necessary legislation and regulations do, in fact, already exist. Where there are any gaps or disparities, the relevant government departments should address these.

- Identification of priorities, appropriate environmental objectives and targets.
  The TWP must ensure that the needs of the development are adequately addressed in the priorities, objectives and targets set by the EMP's.

- Establishment of a structured process to implement policy, achieve objectives and meet targets.

Once again, there is an onus on government to ensure that the necessary structures and processes are established to deal with the issues that have been identified.

- Planning, control and monitoring, as well as review of policy implementation.
  This is the task of the TWP project management structures, as well as the institutional body or organisation, tasked with the overall responsibility or authority to implement the development.

- Flexibility and ability to adapt to changing circumstances.
  The EMP's must be flexible and adaptable enough to suit the changing circumstances that are bound to occur over the construction and operating lifetime of the development. To support this it is imperative that the TWP undertake a monitoring and audit function to give feedback on the performance of the EMP's, so that, where necessary, corrective action can be taken.

2.3 EMS for site level impacts

In the Issues Report, the following were typical of the kind of concerns and values that were taken up in the key issues that were identified for site level impacts.

- *What will the direct effects of the construction, commissioning and operation of the dams and conveyance routes be on existing infrastructure and access, the affected biophysical environment and the directly affected people?*
- *What effect will the provision of roads and other new infrastructure, such as pump stations and power stations, have on the people and the biophysical environment on or near to these secondary infrastructural projects?*
- *What will be the effect of construction and operation of the dams on the ecosystems and organisms in the dam basins and downstream riverine and aquatic habitats?*

These are all issues which are relevant at a very site specific level. The impacts that are derived from them will be caused by actions and activities that are undertaken in pursuit of specific projects such as:

- the construction of dams;
- the construction of roads;
- the operation of dams and pipelines;

These actions are all discrete project-based actions, undertaken by a specific organisation or body such as a construction contractor or utility operating company. The kind of mitigation action that one finds is also the following:

- *Migrant labour should be screened for malaria, as well as Schistosomiasis on arrival at the construction sites, and infections treated immediately.*
- *Business arrangement of supplying accommodation to construction staff, to maintain occupancy rates and compensate for loss of business.*
- *Strategic location of infrastructure to minimise visual impact.*
- *Establish enterprises for the commercial production of muthi resources among the Mziyonke community, outside of the flooding boundaries.*
- *The adverse impacts resulting from the testing of valves in the dam walls could be ameliorated through the provision of several valves so that the increase in river flow at the time would be less than* $280m^3/s$.
- *The management of sediment dynamics in the river can only be achieved through manipulation of the IFR (channel maintaining floods), or managing landuse in the catchment as a whole, and particularly along the riparian zone.*
- *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 surface water. Algae, turbidity and temperature impacts would be mitigated by mixing surface and bottom water on release.*

These mitigating actions can very easily be taken up in an environmental management system that is designed for project-based activities, such as the ISO 14000 framework.

The goal of any environmental management system is improved performance through a structured process in the light of economic and other circumstances which influence an organisation or institution. The system must be so designed that it is a tool which achieves and systematically controls environmental performance levels. As has been stated above, for the ISO 14000 framework, the minimum which the system should administer is:

- Establish appropriate environmental policy;
- Identify environmental aspects and significant environmental impacts;
- Identify relevant requirements, legislative and regulatory;
- Identify priorities, appropriate environmental objectives and targets;
- Establish a structured process to implement policy, achieve objectives and meet targets;
- Plan control and monitor and review policy implementation for continuous improvement;
- Adapt to changing circumstances.

2.3.1 Environmental policy

An environmental policy is a statement by an organisation of its intentions and principles for environmental performance. All subsequent actions by the organisation will be judged against the goal of the policy statement.

The ISO 14000 environmental management standard states that an organisation's environmental policy must:

- Be appropriate to the nature scale and environmental impacts of the organisation's activities, products and services;
- Include a commitment to continual improvement and prevention of pollution;
- Include a commitment to comply with relevant environmental legislation and regulations, as well as other requirements to which the organisation subscribes;
- Provide the framework for setting and reviewing environmental objectives and targets;
- Be documented, implemented, maintained and communicated to all employees;
- Be available to the public.

TWP environmental policy

The TWP as such does not have a specific environmental policy. What must happen, is that all organisations that work on the TWP, or that are contracted to do work on it, must be required to have an environmental policy which conforms to the requirements set out above. Such organisations will include but need not necessarily be limited to:

- engineering design consultants;
- scientific services consultants, e.g. for reserve determination and other work;
- public participation;
- environmental assessment consultant;
- all construction contractors;
- suppliers of support services during construction;
- operating and utility companies.

2.3.2 Environmental aspects and significant environmental impacts

In order to fulfil its policy, an organisation must formulate a plan to do so. The first step in doing this is to establish and maintain a procedure for identifying the environmental aspects of its activities, products or services that it can control, and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment (ISO 14000).

An environmental aspect refers to any element of an organisation's activities, products or services, which can have a beneficial or adverse impact on the environment (ISO 14000). Examples would be discharges, emissions, consumption or reuse of material or resources, noise, and programmes that an organisation would institute for its employees and their dependants, such as training, health and safety, education and sport.

The identification of environmental aspects must be an ongoing process. It is intended to identify the significant aspects associated with activities, products and services. It is not necessary to identify each and every product, component or raw material input. Categories or different areas of concern may be used.

On the TWP there will be a large number of organisations involved with a correspondingly very large number of different significant environmental aspects. Operations over the extent of the TWP will encompass things such as:

- The built environment;
- The design environment;
- The construction environment;
- Major auxiliary services such as water supply and effluent treatment;
- Lesser auxiliary services including maintenance, laundry, housing, fuel storage and use, administration and tour operations.
- Operating inputs;
- Solid waste management.

Environmental aspects can be identified in each of these areas. However, probably the area of major concern will be the construction period and the management of environmental issues during this period.

2.3.3 Identification of environmental aspects

An environmental aspect refers to any element of an organisation's activities, products or services, which can have a beneficial or adverse impact on the environment. For each of the areas or activities identified above, the inputs and outputs from each must be considered to determine what environmental aspects they have. This should be done at a high level first and then screened so that the principal or most important aspects are dealt with.

What should be remembered is the following:

Resource use = Inputs
Pollution = Outputs

Inputs

Some of the more important environmental aspects associated with each area are listed in Table 2.1 below.

Table 2.1: Inputs and environmental aspects

Activity / Area of Concern	Inputs	Environmental Aspect
The built environment	- building materials - air conditioning - recreation and entertainment - water - power - furnishings	indoor air quality human health/toxicity solid waste total water use resource use efficiency use of CFC's noise light safety (fire, accident) training
Water supply and effluent treatment	- potable water - domestic sewage - workshop effluent - hazardous chemicals	resource use efficiency total water use human health/toxicity chemical storage
Lesser auxiliary services	- potable water - hazardous chemicals - lubricants - fuel - organic materials - people	total water use storage of materials human health/toxicity groundwater pollution solid waste management noise safety training
Operating inputs	- food - drink - power - cleaning materials - consumables - water	solid waste management total water use storage/use of chemicals safety fire toxic effects
Solid waste management	- food - paper - organic material - glass - plastic - tin - steel - transport	resource use/re-use resource use/control toxic effect groundwater pollution visual effects security/safety noise odours

Activity / Area of Concern	Inputs	Environmental Aspect
Construction activities	- site clearing - water - power - building materials - temporary structures - people - transport - fuel/energy - construction machinery - housing	uncontrolled activity total water use water quality material storage human impact road damage noise water pollution erosion vegetation damage security
Social and socio-economic environment	- finance - Trust funds - job opportunities - training - other community benefits - health and welfare	auditing of funds monitoring of social effects - tribal - regional public participation transparency

Outputs

For outputs to have an environmental impact they must have a polluting effect or be a cause of concern to interested and affected parties. In Table 2.2 below, the outputs from typical areas have been identified together with the associated environmental aspects.

Table 2.2: Outputs and environmental aspects

Activity / Area of Concern	Outputs	Environmental Aspect
The built environment	- solid waste - domestic effluent - leisure activities - prepared food and drink - human activity - guest accommodation - administration - maintenance and upkeep	solid waste management effluent treatment water quality human health noise light building maintenance cleaning visual impact
Water supply and effluent treatment	- treated effluent - irrigation water - wetlands - sludge	total water use water quality human health (bilharzia, malaria) solid waste management surface and groundwater pollution erosion

Activity / Area of Concern	Outputs	Environmental Aspect
Lesser auxiliary services	- maintenance - administration - fuel and lubricants - effluent	total water use treated effluent water quality solid waste management disposal of toxic waste groundwater pollution human health
Solid waste management	- recycled waste - transport waste to dump - compost - toxic waste	solid waste management human health waste reduction security maintenance noise
Construction activities	- human activity - construction activity - construction plant	
Social and socio-economic environment	- training and education - industrial relations - wages - jobs - raised community health and welfare	changing rural values rural development life skills regional economy

2.3.4 Significant environmental aspects

From these two tables, significant aspects may be identified. In a rigorous analysis of environmental aspects, criteria for significance are set, and each aspect subjected to such a test of significance. Those with the highest significance are the significant environmental aspects. From experience on similar projects and a superficial assessment of the aspects listed, the following will probably be identified as the significant environmental aspects on most projects.

- Total water utilisation;
- Solid waste management;
- Effluent treatment;
- Aesthetic aspects such as noise pollution, visual scarring and odours;
- Ecological monitoring;
- Fire management in terms of building safety and ecosystem (veld) management;
- Stormwater management and control of erosion;
- Monitoring of social effects;
- Human health risks (bilharzia, malaria and water quality).

These apply to virtually all the areas identified. In addition, each of the significant aspects listed above must also be assessed in terms of the elements given below. These elements all cause different intensities of environmental impacts, and must be brought in line with the company's environmental policy, the objectives that have been set, and the targets that are laid down to be achieved.

- The effects of emergencies and accidents;
- Normal and abnormal operation;
- Past, current and planned activities.

2.3.5 Objectives and targets

An environmental impact, in terms of the ISO 14000 framework, refers to a change which takes place or could take place, as a result of an environmental aspect. It is these significant aspects that will have **significant environmental impacts**. Impacts are identified in the different specialist reports prepared during the environmental assessment process. This includes the identification of mitigation actions. What must happen is the following:

- Establish and maintain procedures to identify the environmental aspects of activities, products and services that can be controlled, and over which it is expected there will be some influence.
- Establish and maintain procedures to identify significant environmental aspects that have or could have significant environmental impacts.
- Establish and maintain documented environmental targets and objectives at each relevant function and level in the organisation to deal with the significant environmental aspects.
- These targets and objectives must be related to and be consistent with or meet:
  - the environmental policy, specifically related to a commitment to the prevention of pollution;
  - legal and regulatory requirements;
  - objectives should be specific and targets measurable preferably within set time frames;
  - where appropriate, the targets and objectives can be designed to apply broadly across the whole of the operation or more narrowly to a specific area of operation.

In moving from environmental policy to objectives, targets and action plans, there is a cascade of steps, which may be illustrated in the following examples.

Example 1

Policy: Conservation of resources such as natural vegetation.

Objective: No measurable veld degradation against set standard.

Target: Maintain or increase tree, shrub and grass species on an annual basis, on five test plots, evaluated in a baseline survey.

Example 2

Policy: Water conservation.

Objective: Average water consumption per person employed on site, on a seasonal basis, in a specific area on site, not to exceed agreed levels.

Target: Water consumption on site to be less than $\boldsymbol{x}$ ℓ / m^3 of concrete placed in the dam wall.

This may then be translated into a number of action plans, applicable for the whole of a particular operation, or at specific points in the system. Such points must be established from a rigorous assessment of all environmental aspects and ratings of significance. The execution of such an exercise is beyond the scope of this brief review.

3 GENERAL

For the ongoing effective implementation of such an environmental management plan, ISO 14000 has other guidelines and provisions that have to be followed. These include:

- The roles, responsibilities and authority of employees in general, and specific employees involved in the day-to-day functioning of the system, must be defined, documented and communicated throughout the organisation.
- The necessary resources that are essential for the implementation and control of the environmental management system must be provided and allocated.
- Top management must appoint (a) specific person(s) who, irrespective of their other duties and responsibilities, will have defined roles, responsibilities and authority for the environmental management system, to:
  - ensure its implementation;
  - report on performance.
- Ongoing communication and commitment at all levels in the organisation to the environmental programme.
- Training and awareness programmes.
- Documentation of all the core elements of the management system and their interaction.
- Procedures to control all documents so that:
  - they can be readily located;
  - they can be periodically reviewed;
  - they are the latest versions;
  - obsolete versions are removed.
- Ongoing measurement, monitoring and evaluation of environmental performance.
- Non-conformance and corrective and preventative action.
- Keeping of records and environmental audits.

Finally, it is management's duty to review and continually improve its environmental management system, with the objective of improving its overall environmental performance.

4 REFERENCES

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Republic of South Africa
Department of Water Affairs and Forestry

THUKELA WATER PROJECT FEASIBILITY STUDY

WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

MAIN REPORT

MARCH 2001

Prepared by:
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THUKELA WATER PROJECT FEASIBILITY STUDY WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

MAIN REPORT

Job No 2354/10
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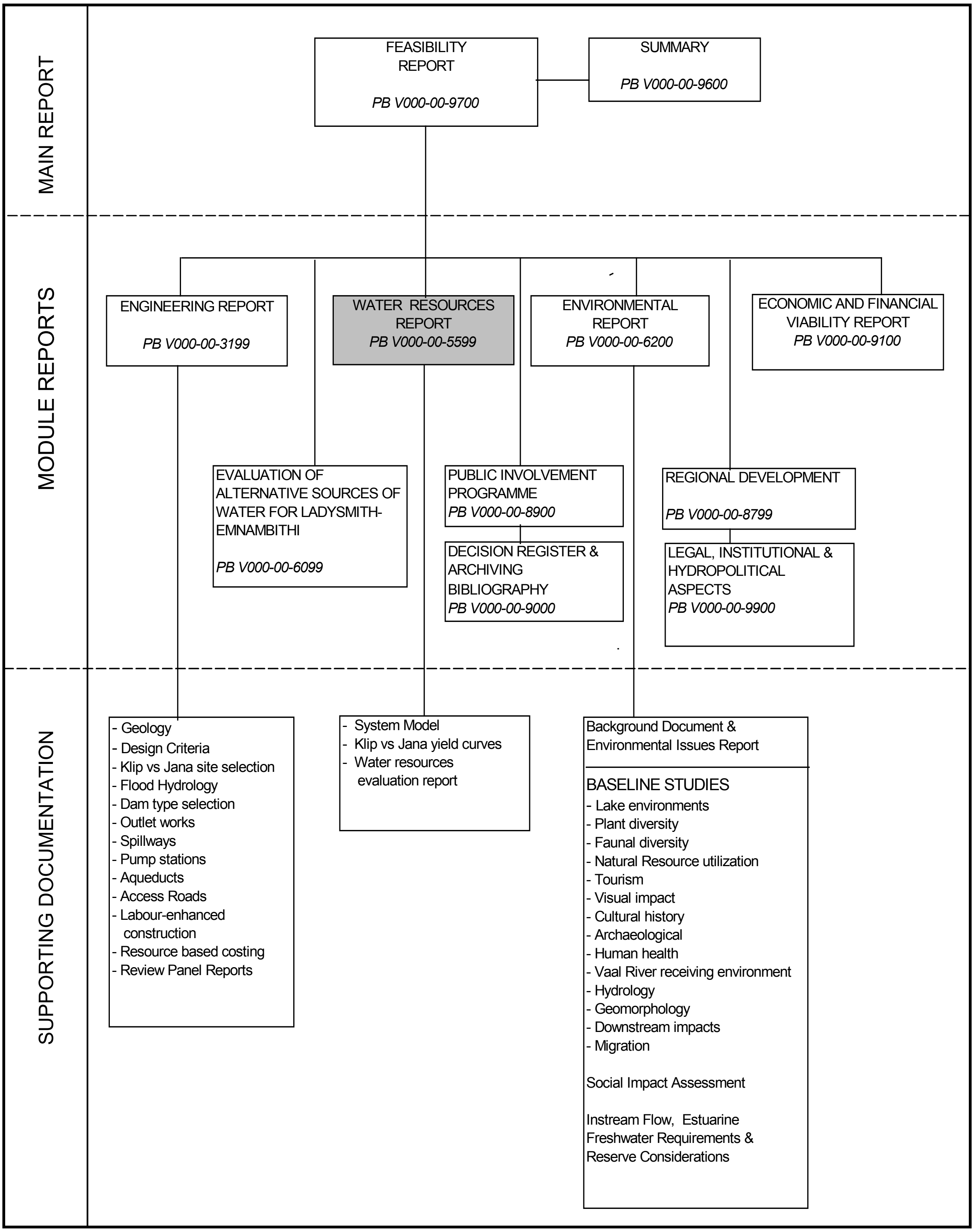
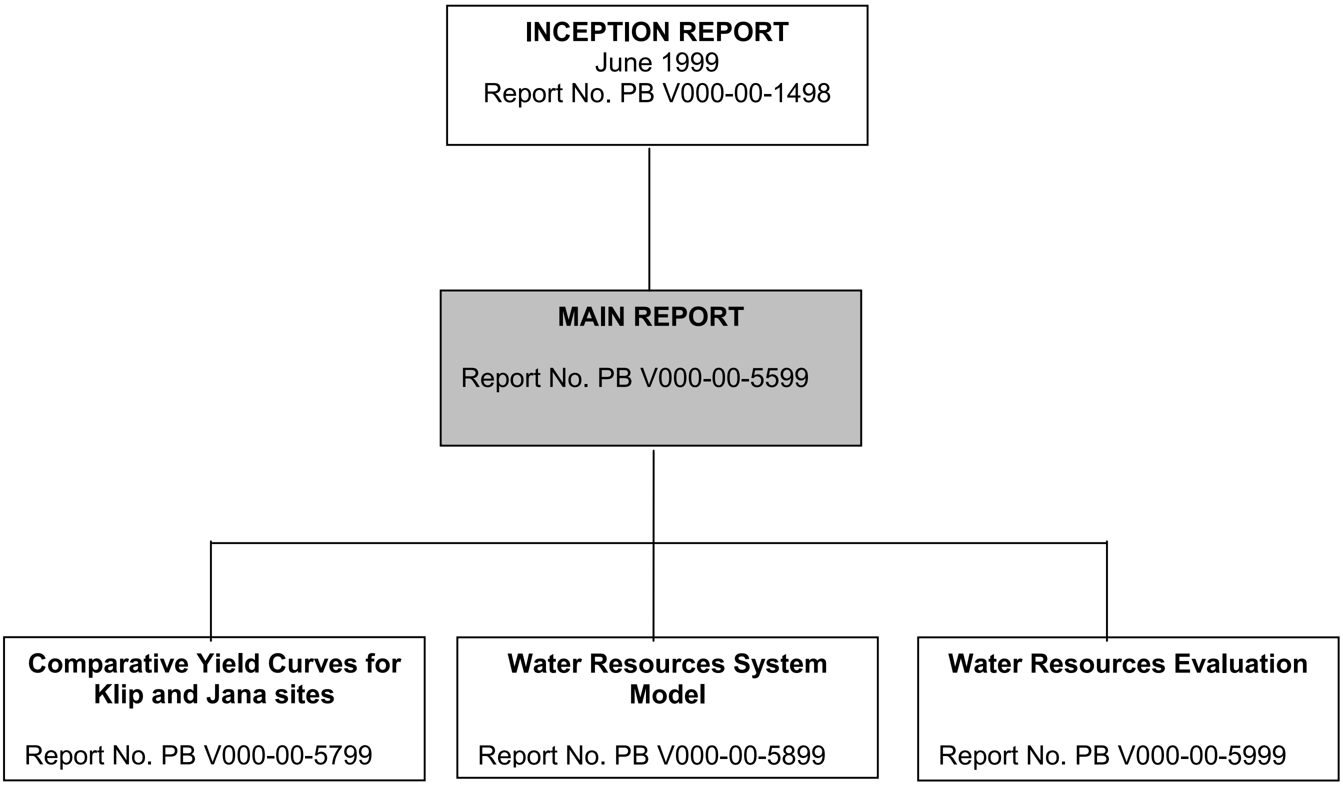


THUKELA WATER PROJECT : FEASIBILITY STUDY
WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

MAIN REPORT

REPORT STRUCTURE

The following reports form part of the documentation produced during the Water Resource Evaluation and Systems Analysis Task. The shaded block depicts this report.



THUKELA WATER PROJECT FEASIBILITY STUDY

TBC CONSORTIUM MARCH 2001

Approved for TBC Consortium by:

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AK Bailey
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PREFACE

This Module Report on the Water Resource Evaluation and Systems Analysis associated with the Thukela Water Project proposals emanating from the Feasibility Studies was prepared by the Thukela Basin Consultants consortium. The authors were appointed to undertake one of 15 modules in the Feasibility Study and obtained information from and liased, inter alia, investigating teams assigned to the other modules. The report was prepared under the direction of the Project Management Team.

The report has been accepted as representing the outcome of the terms of reference assigned to the Thukela Basin Consultants and has been used as an important source document for the preparation of a Main Feasibility Report on the Thukela Water Project. All the views, findings, interpretations and recommendations of the authors may not necessarily have been included in full in the Main Feasibility Report. Deviations from this report are noted in the Main Feasibility Report.

THUKELA WATER PROJECT: FEASIBILITY STUDY
WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

SUMMARY

1. INTRODUCTION

This summary gives an overview of the water resources evaluation and systems analysis task as described in this report and three supporting technical reports.

The Thukela-Vaal Transfer Scheme (TVTS) reconnaissance, pre-feasibility and interim studies served to eliminate a large number of potential dam sites in the Thukela and its tributaries and to narrow development proposals down to two possible schemes, one in the upper Thukela and the southern tributaries, the other in the northern tributaries. The pre-feasibility study proposed a series of dams in the southern tributaries, however, one of the main dams, Deeldrift, on the Little Thukela River, was ruled out primarily for environmental reasons. The interim study proposed two dams, one at Mielietuin on the Bushmans River and one at either the Klip or Jana site on the Thukela River. These proposals were examined in more detail in the Thukela Water Project (TWP) Feasibility Study. The purpose of the feasibility phase water resources study was to accurately determine the size of the two dams required to deliver water at a rate of 15 m^3/s (up to 473 million m^3 /annum), the rate at which Eskom have indicated they can pump additional water up to Sterkfontein Dam and hence into the Vaal catchment.

The Water Resources Yield Model (WRYM) was used for the Pre-feasibility and Interim study. Although an attempt to account for the Instream Flow Requirements (IFRs) was made during the Interim Study, the version of WRYM available at that stage did not have a facility to model IFR releases realistically. The results obtained during the Interim Phase nevertheless indicated that supplying IFRs would reduce yields from storage significantly. Using the updated WRYM (Mark 5) which caters for IFR releases, IFRs and the Estuarine Flow Requirement (EFR) were incorporated in the feasibility phase system model.

2. FEASIBILITY PHASE

2.1 Water Resources System Model

The supporting report “Water Resources System Model” describes the various revisions to the system model including updating hydrology, improvements to the system model, particularly in the modelling releases for Instream Flow Requirements (IFRs) and increased system complexity, refinement of demands and elevation – area – storage data and revision of priorities for supplying demands. The Mooi River was modelled in more detail in a separate study, the Mgeni River Augmentation Planning Study. This system was therefore included as an input channel to the Thukela system. Two dummy dams, Uitkyk in the Sundays and Buffelshoek in the Buffalo, were included in the system model and sized to supply demands in the tributary catchments including IFR's down to their confluences with the Thukela. These revisions are summarised in this report and described in detail in the "Water Resources System Model" supporting report. The current natural runoff, demands, transfers, return flows and IFR details are summarised in this report and the comparative tables are given in the "Water Resources System Model" report.

2.2 Comparative yield curves for Klip and Jana sites

Storage-yield curves for the Klip and Jana sites were required early in the study to facilitate the selection between the two mutually exclusive sites. Development of these curves is described in the supporting report "Comparative Yield Curves for Klip and Jana Sites". The two sites are situated close to one another in the Thukela so the effect of the rest of the Thukela system on the yields from the two dams is taken to be similar. Therefore it was possible to use the pre-feasibility system model, updated to include the extended hydrology time series, the IFRs and the EFR.

The yield from storage at these sites was found to be very similar for equivalent dam sizes and therefore did not influence the preference for one site over the other.

2.3 Water Resource Evaluation

2.3.1 Introduction

The "Water Resources Evaluation" supporting report describes the effect of changes in demands, IFRs and operating rules on yield from the proposed dams, determination of historic and stochastic yields and estimation of filling times for Mielietuin and Jana Dams.

These analyses showed that small changes to the IFR patterns could significantly increase yield from the Mielietuin and Jana Dams. Accordingly, proposals were made to the IFR specialist team, which resulted in adjustments being made to the IFR recommendations.

2.3.2 Operating rules

The yield model was set up to supply water to the various consumer user sectors at different priorities. The order of priority of supply was as follows:

a) IFRs (and EFR) to meet the ecological Reserve
b) In-basin water requirements for industrial and domestic use, projected to the year 2030.
c) In-basin irrigation requirements, projected to the year 2030 but then reduced by 75% to allow for a smaller assurance of supply. The reasoning behind this is that irrigators should not receive a higher

assurance of supply following the construction of the Jana and Mielietuin Dams than they receive currently.

d) The remaining water is assumed to be available for transfer to the Vaal River System.

Operation of the system was set up so that the transferable yield from Mielietuin would be maximised. This is because Mielietuin Dam, situated at a higher elevation than Jana, provides a lower unit cost of water than Jana Dam.

The existing transfer scheme was assumed to operate essentially as it has in the past except that IFRs, not currently released from either the Driel Barrage or the Spioenkop Dam, were provided in the yield analyses at a higher priority than transfers to the Vaal River System.

In setting up the system model it was assumed that water would be pumped at a constant rate equivalent to the yields of Jana and Mielietuin Dams. No allowance was made for downtime for maintenance purposes. This aspect needs to be addressed in detail during the design phase of the project.

2.3.3 Instream Flow Requirements

IFRs, which are estimates of the minimum flow requirements to maintain the riverine ecology in an acceptable state, were determined at various points in the Thukela system by a team of specialists. Initially IFRs were only modelled in the main stream of the Thukela and Bushmans River but it was found that this drastically reduced the transferable yield of the Jana Dam. Based on the reasoning that sufficient water would have to be released down the tributaries of the Thukela, especially the Sundays, Buffalo and Mooi Rivers, to meet the IFRs on these rivers, these flows were also modelled. In the case of the Sundays and Buffalo Rivers, it was found that storage will be required on these rivers in future if the in-basin requirements up to the year 2030 are to be met, together with the IFRs. These hypothetical dams were included in the yield model.

It was found that inclusion of IFRs downstream of Driel Barrage and Spioenkop Dam reduces the amount of water that can currently be transferred through the existing Thukela-Vaal Scheme. However, while the IFRs downstream of the proposed new developments can be determined with fairly high confidence, it was not possible to determine the IFR required below the existing transfer scheme with the same certainty. The reason for this is that while IFRs below new dam sites will normally be set to maintain the river in its current ecological management class (EMC), an EMC of the river downstream of the existing scheme must be negotiated to be acceptable to all stakeholders. On the other hand, in-basin stakeholders will require a high EMC to support recreation and agricultural activities while water users in the Vaal River System will strive to maximise the amount of transferable water at minimum cost with a concomitant lower EMC. This could not be negotiated in the Feasibility Study but will be addressed in a separate study in which the Reserve is determined for the whole Thukela basin. To cope with this uncertainty, a realistic upper and lower bound was set to the IFR and the scheme configuration and transferable yields determined for these two possible extremes. This range of uncertainty only affects the yield from the Jana Dam and not the yield from Mielietuin Dam. It is expected that the actual Reserve will lie somewhere between the two extremes.

2.3.4 Yield estimates

Yields were determined for both a high and low IFR scenario as described in section 3.3.3 and a wide range of dam sizes at Mielietuin and Jana using historic inflow time series. The results of these historic yield analyses are summarised in Tables S1 to S3.

For the low and high IFR scenarios, the transfers possible from the existing Thukela-Vaal Scheme reduce from 527 million m^3/a to 448 million m^3/annum and 357 million m^3/annum respectively. Water released from Driel Barrage and Spioenkop Dam to supply IFRs will, however, be available for transfer from Jana and it was found that the total average transfer from the combined existing Drakensberg scheme and Jana Dam is the same for both high and low IFR scenario (see Figure S1). In other words, the amount of water, which can be transferred from the Thukela basin to the Vaal River System, is essentially the same whether it is pumped from Jana Dam or the Driel Barrage. However, there is a pumping cost implication because Jana Dam is, at a much lower elevation than the Driel barrage. The aqueduct capacity from the Jana/Mielietuin system would also have to be greater for the high IFR scenario.

Table S1: Transferable yield from Mielietuin Dam (Historic analysis)

Full supply level (m amsl)	Working storage (million m^3)	Transferable yield (million m^3/a)
1010	206	105
1015	250	114
1020	297	123
1025	352	129
1030	417	137
1033	464	141
1035	498	143

Table S2: Transferable yield from Jana Dam (Historic analysis)

(Low IFR below existing transfer scheme)

Full supply level (m amsl)	Working storage (million m^3)	Transferable yield (million m^3/a)
800	364	204
820	630	271
840	991	322
850	1213	335
860	1469	351
870	1763	368
880	2177	393
890	2639	422

TableS3: Transferable yield from Jana Dam (Historic analysis)

(High IFR below existing transfer scheme)

Full supply level (m amsl)	Working storage (million m^3)	Transferable yield (million m^3/a)
800	364	253
820	630	347
840	991	416
850	1213	431
860	1469	446
870	1763	464
880	2177	489
890	2639	517

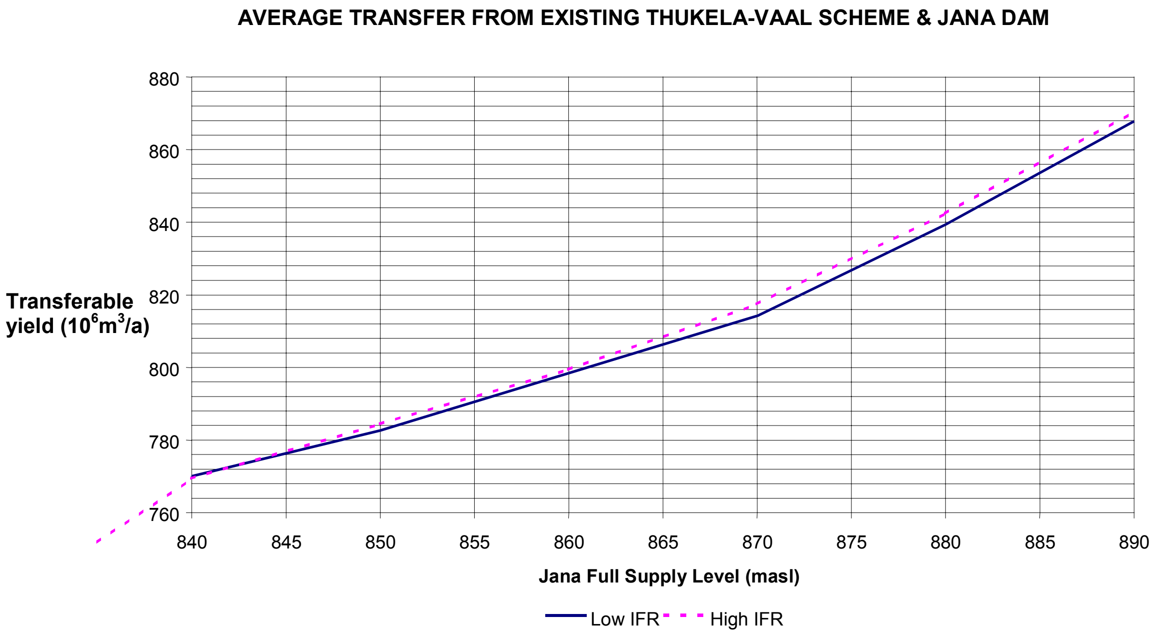

Figure S1: Average transferable yield from the existing Thukela-Vaal Scheme and the Jana Dam

2.3.5 Stochastic analyses

Once all modifications and enhancements to the feasibility study system model had been incorporated and thoroughly tested using a single historic inflow time series, yield analyses were carried out using stochastic inflow time series so as determine the assurance of supply of the proposed scheme (see Table S4 to S6).

Table S4: Transferable yield from Mielietuin Dam (Stochastic analysis)

Reservoir FSL (m amsl)	Transferable yield at an assurance of: (million m^3/a)		
	95%	98%	99%
1015	125	108	99
1025	136	120	112
1033	147	129	122

Table S5: Transferable yield from Jana – low IFR scenario (Stochastic analysis)

Reservoir FSL (m amsl)	Transferable yield at an assurance of: (million m^3/a)		
	95%	98%	99%
810	300	260	235
840	390	338	315
860	435	390	355
890	520	455	420

Table S6: Transferable yield from Jana – high IFR scenario (Stochastic analysis)

Reservoir FSL (m amsl)	Transferable yield at an assurance of: (million m^3/a)		
	95%	98%	99%
810	380	340	310
840	490	435	400
860	530	485	450
890	610	545	520

The Engineering module of the Feasibility Study identified a scheme comprising a dam with FSL at 860m at the Jana site and a dam with FSL at 1025 at the Mielietuin site as the preferred layout.

Note that the contribution from the existing transfer scheme has not been included in this analysis. This is because the water is supplied from Driel Barrage to Kilburn at well beyond this system's firm yield and is therefore not comparable with the high assurance supply from the TWP. In order to determine the assurance of supply of the combined scheme, the storage available in the Vaal River System must also be taken into account. An analysis of the combined Vaal and Thukela systems is currently being carried out under a separate contract in order to determine total yield and hence the incremental yield and its assurance as perceived in the Vaal River System.

The required aqueduct capacities necessary for the proposed TWP scheme layout to deliver water at an assurance of 98% are shown in Table S7. A larger capacity will almost certainly be required to cater for downtime and aqueduct losses.

Table 9: Aqueduct capacities required to deliver water at a 98% level of assurance

IFR Scenario	Mielietuin aqueduct capacity (m^3/s)	Jana aqueduct capacity (m^3/s)
High IFR	3.8	15.4
Low IFR	3.8	12.4

2.3.6 Filling times

Filling times were assessed by simulation using 201 stochastic inflow time series and starting with the dams empty. Downstream IFRs and in-basin demands were supplied during filling. It was assumed that when filling commenced for Jana Dam, Mielietuin Dam would be fully operative. The simulation results were presented graphically in the form of boxplots showing projected water levels in the dam.

These results are included in Appendix A of the “Water Resources Evaluation” supporting report. The number of years required to fill the dams at an assurance of 95%, to 100%, 75%, 50% and 25% of working storage are summarised in Table S8.

Table S8: Reservoir filling times (with 95% confidence)

Full supply level (m)	Years to fill dam to (at assurance of 95%)			
	25%	50%	75%	100%
Mielietuin				
1033	3	4	5	6
1025	2	3	4	5
1020	2	3	4	5
Jana: Low IFR scenario				
890	4	6	8	10
875	3	5	6	9
860	3	4	5	8
835	2	3	3	5
Jana: High IFR scenario				
890	3	5	6	8
875	3	4	5	6
860	3	4	5	6
835	2	3	3	5

2.3.7 Water Quality

The Thukela and Klip rivers that will feed Jana carry good quality water with regard to inorganic constituent concentrations and will not affect any user detrimentally. Water that will flow into Mielietuin will show the effects of pollution from Estcourt as raised conductivity levels (but still low) and associated ion concentrations. Elevated phosphate-P concentrations will stimulate algal growth, possibly resulting in mesotrophic conditions.

Possible problems with manganese, iron and ammonia are anticipated, as are low temperature releases form bottom outlets. Maximum temperature differences between surface and bottom water of about 10°C are expected to occur in January/February and this could cause considerable shock to the ecosystem when monthly bottom water releases introduce much colder water to the rivers. Temperature changes in the river immediately downstream of the dam should not exceed a few °C if serious impacts on the aquatic environment are to be avoided. Dissolved oxygen concentrations could also be depleted below 4 mg/l (lower limit for aquatic life) and the great depths of Jana and Mielietuin may prevent mixing and resulting in bottom water releases being anoxic the whole year round.

Most of the detrimental water quality effects could be minimised by ensuring that as much surface water as possible is released when monthly bottom water releases are made and by providing dilution in tailponds before overflow to the rivers. Spraying of water into tailponds will be necessary to rapidly re-oxygenate the water before it enters the rivers.

3. CONCLUSIONS

- The system analysis model of the Thukela system developed during the feasibility study adequately simulates operation of the system, including supplying water demands and IFR's.

- IFRs downstream of the proposed Jana and Mielietuin Dams significantly reduce the transferable yield from these dams. Dummy dams were included in the Sundays and Buffalo rivers to supply water requirements in these catchments as well as IFR's down to the confluence with the Thukela. These tributary IFRs contribute to the IFRs in the lower Thukela River as well as the EFR and reduce the releases that would otherwise be required from Jana Dam and hence increase the transferable yield from the TWP.

- IFRs, which will in future be required below Driel Barrage and Spioenkop Dam, will reduce the transfers from the Thukela-Vaal Scheme. However, these IFRs will also increase flow into the Jana Dam resulting in increased transferable yield from Jana. The net result is that these IFRs will not significantly influence the total transferable yield from the combined scheme. Dams sized at the preferred FSLs (Mielietuin 1025 m amsl and Jana 860m amsl) will be able to deliver additional flows of 3.8 m^3/s (Mielietuin) and between 12.4 m^3/s and 15.4 m^3/s (Jana) at an assurance of 98%. The impact of the TWP on the yield of the Vaal River System is being investigated under a separate contract.

- The reduction in transfers from the Thukela-Vaal Scheme due to IFR releases from Driel Barrage and Spioenkop Dam must be taken into consideration when sizing components of the proposed scheme. The size of Jana Dam is not affected by these IFRs but the capacity of the aqueduct from Jana to Kilburn Dam is.

- Both proposed dams are large relative to MAR and will take 6 to 10 years to fill.

- Most of the detrimental water quality effects could be minimised by ensuring that as much surface water as possible is included in monthly bottom water releases. Spraying of water into tailponds will be necessary to rapidly re-oxygenate the water before it enters the river. The quality of the transferred water should be good, since this would consist mostly of surface water.

THUKELA WATER PROJECT – FEASIBILITY STUDY
WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

MAIN REPORT

ABBREVIATIONS

DSL	Dead Storage Level
DWAF	Department of Water Affairs and Forestry
EFR	Estuarine Flow Requirement
FSL	Full Supply Level
IFR	Instream Flow Requirement
MAR	Mean Annual Runoff
M AMSL	Metres Above Mean Sea Level
PMT	Project Management Team
ToR	Terms of Reference
TVTS	Thukela-Vaal Transfer Scheme
TWP	Thukela Water Project
VAPS	Vaal Augmentation Planning Study
WRYM	Water Resources Yield Model

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THUKELA WATER PROJECT : FEASIBILITY STUDY
WATER RESOURCE EVALUATION AND SYSTEMS ANALYSIS TASK

MAIN REPORT

1 INTRODUCTION

The previous Thukela-Vaal Transfer Scheme (TVTS) pre-feasibility and interim studies served to eliminate a large number of potential dam sites in the Thukela and its tributaries and to narrow development proposals to two layouts, one in the upper Thukela and the southern tributaries and one in the northern tributaries. The Thukela Water Project (TWP) Feasibility Study focuses primarily on the proposed development in the upper Thukela and the southern tributaries. The interim study defined the project as comprising Mielietuin in the Bushmans River and either Klip or Jana in the Thukela. The proposed location of the dams is shown in Drawing W1.

The Water Resources Yield Model (WRYM) was used for the system analysis in the pre-feasibility study. An interim study then was undertaken in order to incorporate into the system analysis model Instream Flow Requirements (IFR's). However, at that stage WRYM did not have a facility to model IFR releases properly and, consequently, the results of the analysis were inconclusive. The results did, however, indicate that supply of the IFR's would reduce yield from the reservoirs. Channels to model IFR's and the estuarine flow requirement (EFR) have since been added to the WRYM model and IFR's and the EFR could be properly modelled in the system model for the feasibility study.

2 STUDY OBJECTIVES

The main objectives of the study were to provide the following information:

- comparative storage-yield curves for the Klip and Jana sites to facilitate selection between the two sites.
- an assessment of the transferable yields using historic inflow time series from the proposed dams with due allowance to meet all projected in-basin demands including environmental requirements and existing and planned inter-basin transfers.
- the yield-assurance relationships for the dams using long-term stochastic inflow time series.
- estimated filling times for the proposed dams from the results of simulations using multiple stochastic inflow time series.

3 REVISIONS TO THE SYSTEM MODEL

The report “Water Resources System Model” describes the various revisions to the system model.

3.1 Implementation of first phase revisions

3.1.1 Hydrology update

The hydrological database used in the interim study spanned the period 1920 to 1992 (hydrological years). Subsequently these time series of natural streamflow, afforestation and irrigation usage were extended by two years to the end of the 1994 hydrological year (i.e. to September 1995). This coincides with the end of the 90’s drought. When, for the sake of compatibility with analyses done for the Mooi-Mgeni transfer, the Mooi-Mgeni system model was used to generate an inflow time series for the Mooi River, the period of the hydrology data files was changed to the period used in the Mooi-Mgeni study (1925 to 1994).

3.1.2 Replacement of minimum flow channels

In the Mark 3 version of WRYM, there was a restriction on the number of general flow channels and minimum flow channels and a minimum flow of zero had to be used. The maximum number of general flow channels was increased in the current Mark 5 version of WRYM and therefore minimum flow channels could be replaced with general flow channels.

3.1.3 Updating of elevation-area-storage data

More detailed elevation-area-storage data for Mielietuin, Jana and Klip dams was supplied by DWAF and used in the model.

3.1.4 Implementation of IFR channels

The IFR channels introduced in the Mark 5 version of WRYM enabled the IFR’s and the EFR to be effectively modelled. Flow requirements were specified for five IFR sites and the EFR that are shown in Drawing W5. These sites are:

IFR A Thukela River, downstream of Spioenkop Dam
IFR B Klip River, downstream of Qedusizi Dam
IFR 2 Thukela River, downstream of proposed Jana/Klip Dam
IFR 3 Bushmans River, downstream of proposed Mielietuin
IFR 5 Thukela River, upstream of Mooi river confluence
EFR Thukela River estuary

IFR data is entered in a new input datafile (F14 file). In this file the IFR requirement is specified as a function of the inflow at up to ten nodes (reference nodes) having incremental inflow. The in-house program “RANKGRAF” was written to rank and plot, for each calendar month, the IFR flows and also to combine, rank and plot the reference node inflows. This information was used to prepare the data for the F14 datafiles. The IFR channel is a special case of the min-max channel and will not pass more than the specified flow, therefore a general flow channel was placed in parallel to the IFR channel to allow floods to pass. Full details are given in the "Water Resources System Model Report".

3.2 Implementation of second phase revisions

3.2.1 Renumbering of nodes and channels

Due to the addition of nodes and channels primarily for the IFR's, it became necessary to renumber the nodes and channels to make the system more ordered and to facilitate checking and further revisions.

3.2.2 Review and revision of priorities and penalties for supplying demands

To refine and optimise the system operation, certain penalties were revised, the number of operating zones in the dams was increased to allow for the possible inclusion of restrictions based on water level in the reservoirs and the prioritisation of supplying demands was revised.

In-basin demands and existing and planned transfers must be supplied in preference to the new transfers to the Vaal. In accordance with this rule the following priority for supplying users was adopted:

- IFR's and the EFR
- primary demands – industry, urban and rural,
- inter basin transfers both existing and planned,
- irrigation,
- proposed Thukela Vaal transfer.

It should be noted that IFR's should receive priority of supply but that actual penalty values allocated were not the highest. However, as all in-basin demands must be supplied before water can be allocated to the proposed transfer scheme, the IFR penalties were not of significance. Furthermore checks were made to ensure that the IFR's were fully supplied which in turn showed that the other demands would also be fully supplied.

The order of supplying demands from reservoirs was set as listed below.

- Chelmsford
- Craigieburn
- Zaaihoek
- Mearns (dummy dam in the Mooi system that was included to model the Mooi-Mgeni transfer before the system was modified to utilise an inflow time series from the Mooi-Mgeni system model).
- Jana
- Spioenkop
- Mielietuin
- Wagendrift

The order of prioritising reservoirs was selected so that in-basin demands would be supplied in preference from storage that could not supply water to the proposed transfer scheme.

The WRYM system model utilises a system of penalties to decide which demands should be supplied in preference and from which storage demands can be supplied. As the model developed changes had to be made to the penalty system to ensure correct operation of the system. These changes are described in detail in the "Water Resources System Model" report.

3.3 Implementation of third phase revisions

3.3.1 Farm dams

There are many farm dams in the tributaries of the Thukela River and water stored in these dams is not available to supply downstream demands. Individually these dams are small but together have a combined capacity of some $338x10^6m^3$. The Mark 3 version of WRYM limited the number of dams that could be modelled and in addition to the major dams only two dams could be included to represent groups of farm dams. The Mark 5 version of WRYM relaxed this restriction and an additional five dummy dams were included in the system model. The total storage in dummy dams is only two thirds of the total storage in farm dams. This is because the location of the other dams did not permit them to be logically included in the system model without introducing an unrealistic level of detail. The effect of ignoring these dams will, however, be negligible.

3.3.2 Irrigation demands

In times of drought, restrictions will be applied to irrigators. It was agreed that rigorous modelling of irrigation supply, incorporating restrictions dependent on water level in the reservoirs, was not warranted and that a suitable compromise would be to supply 75% of the average irrigation demand on a firm basis. Accordingly the irrigation datafiles were adjusted to reflect only 75% of irrigation demand.

3.3.3 Mooi River system

To ensure that the Mooi River was operated as postulated in the Mooi-Mgeni study, it was requested that the system model utilised by the Mooi-Mgeni study consultants be incorporated in the Thukela system model. This proved to be unrealistic as incorporating the significantly more detailed Mooi-Mgeni system into the Thukela system model would have resulted in a very large, cumbersome model. Accordingly it was agreed to generate a time series of inflow from the Mooi River to the Thukela using the Mooi-Mgeni system model. The hydrological time series for the Mooi-Mgeni system starts in 1925 and ends in 1994. As the critical period is not at the beginning of the time series, it was decided to shorten the Thukela hydrology to also start in 1925 rather than extend the Mooi River hydrology. This would have no effect on the historical analyses but would affect stochastic generation of time series. However, the effect would more than likely be conservative because the years being removed are better than average.

3.3.4 Zaaihoek hydrology

During the study the hydrology for the Zaaihoek Dam catchment was revised. The revisions had a knock-on effect on the TM26 and TM31 catchments so the time series for these catchments were also revised. The combined mean annual runoffs for the revised inflow time series dropped by $28x10^6m^3/a$. In addition, the Zaaihoek Dam transfer to Majuba Power Station was reduced by about $20x10^6m^3/a$ for 2030 development levels (more recent information from Eskom).

3.3.5 Buffalo urban demands

Following recent trends in water use for Newcastle, the combined Newcastle, Madedeni and Osizweni urban demand in the Buffalo catchment was reduced by about $55x10^6m^3/a$ for the 2030 development level resulting in an increase in transferable yield from Jana.

3.3.6 Uitkyk and Buffelshoek Dams

Growth in water demands in the Sundays and Buffalo rivers will reduce the contribution from these catchments towards supplying IFR's. For these projected growths to be realised, further development of water resources in these catchments would also have to take place. IFR's downstream of these developments would ensure that the contribution to supplying IFR's in the Thukela would be maintained and that the burden would not fall unrealistically on Jana Dam. Two dummy dams, Uitkyk in the Sundays and Buffelshoek in the Buffalo, were included in the system model and sized to supply demands in the tributary catchments including IFR's down to their confluences with the Thukela. The more realistic approach to modelling these tributaries resulted in significantly more water being available for transfer from Jana Dam.

These assumptions will have to be tested with and without these dummy dams during the Decision Support Phase of the study in order to provide decision-makers with indication of the relative impacts on the transfer to the Vaal River System.

3.4 Miscellaneous system changes

3.4.1 System renumbering

As for the second phase revisions, it became necessary to renumber the nodes and channels following further additions and modifications to the system.

3.4.2 Ladysmith demand

At times a portion of Ladysmith's demand is supplied directly from Spioenkop Dam. In the initial model the entire demand was abstracted from the Thukela upstream of the Klip confluence. When the IFR downstream of Spioenkop was introduced this was no longer acceptable because flow past the IFR site would incorrectly include the portion of the demand supplied directly from the dam. Accordingly the model was modified to include the direct supply to Ladysmith so that flow past the IFR site could be properly checked.

3.4.3 Revised instream flow requirements

During the study it was decided, based on the outcome of a detailed investigation that storage would not be provided at Qedusizi Dam. Without storage, supply of the IFR in the Klip River cannot be controlled. Accordingly, IFR B in the Klip River was removed. At a workshop held in November 1998, IFR2 and IFR5 were modified to take account of improved measurement of the cross-sections at the sites.

The primary task of this workshop was to define the requirements at IFR A downstream of Spioenkop Dam. The requirements for IFR A were significantly higher than determined using the "Rapid Assessment" method and now could not be fully supplied from Spioenkop Dam only. To supply IFR A fully the penalties were modified to allow water to be released from Woodstock Dam as well.

IFR 2 and IFR 5 were revised and a new IFR A was generated at the November 1998 workshop. IFR A is dealt with in detail in the supporting report "Water Resources Evaluation". It is important to note that IFR A is now able to draw on Woodstock Dam in preference to everything else in the system. These assumptions will be tested during the Reserve Determination scheduled for the Decision Support Phase.

The EFR was revised by the EFR team but had no impact on the transferable yield from Jana.

3.4.4 Elevation-area-storage revisions

DWAF improved the elevation-storage-area data for both Mielietuin and Jana dams. For Jana these differences were negligible. Accurate surveys are only available up to 870m for Jana but have been extrapolated to 890m. For Mielietuin the changes were quite significant and resulted in a decrease in transferable yield for a given storage capacity. The elevation-area-storage data is listed in Tables 3.9 and 3.10 in section 3.5.8 of this report. It is essential that if a dam with a FSL of greater than 870m at the Jana site is selected that the elevation-storage-area data above this level be determined accurately.

3.4.5 General changes

The source of supply for the Klip River urban and rural demand and irrigation at Nondlolothi was moved from the Thukela River to a postulated dam at Uitkyk in the Sundays River. The working storage of Uitkyk Dam was set so that these demands together with the IFR could be fully supplied.

There was some further revision of penalties to ensure that water was supplied according to the priorities for supply

A buffer level was included in Woodstock Dam to reserve water for IFR A, the Ladysmith demand (that portion abstracted from Spioenkop) and demands between Woodstock and Spioenkop Dams because with IFR A in place these demands cannot be supplied from Spioenkop alone. The penalty for drawing water from the buffer zone was set so that the existing Drakensberg transfer scheme would not have access to this water.

3.4.6 Driel IFR

Late in the study an IFR was introduced downstream of Driel Barrage to ensure the environmental integrity of the stretch of river between Driel Barrage and Spioenkop Dam. No IFR was considered downstream of Woodstock Dam because the water level in Driel Barrage is such that it backs up almost to the toe of Woodstock Dam with the result that there is no riverine environment in this reach. The IFR specialist team investigated the river reach between Driel Barrage and Spioenkop Dam in order to determine the current ecological management class. This IFR was therefore determined as a D and B class using the "Desktop" method.

3.5 The Feasibility System Model

During the Feasibility study the system model was developed as described in the previous sections. This section summarises the data and information that is used in the Feasibility system analysis model shown in Drawing W5.

The Mooi River system is included as an inflow time series. For this reason, details of the runoff time series, demands and return flows from the Mooi catchment are not included in the tabulated data. These details are, however, included in the "Water Resources Evaluation" supporting report.

3.5.1 Inflow time series

The 32 sub-catchments used in the pre-feasibility and interim studies were retained for the feasibility study. The Mooi catchment was input to the model as a streamflow time series at the Mooi-Thukela confluence. This time series was generated using the Mooi-Mgeni system model. Accordingly the four Mooi River inflows in the original Thukela system model are excluded in the feasibility study model. The inflow time series together with the MAR's for the period 1925 to 1994 are listed in Table 3.1 below.

Table 3.1: Sub-catchment runoff time series

Catchment name	Natural MAR ($10^6m^3/a$)	Catchment name	Natural MAR ($10^6m^3/a$)
TM01.INC	73.24	TM15.INC	110.47
TM02.INC	357.59	TM16.INC	79.82
TM03.INC	19.24	TM17.INC	32.42
TM04.INC	217.90	TM18.INC	25.64
TM05.INC	87.40	TM19.INC	203.75
TM06.INC	30.68	TM24.INC	106.97
TM07.INC	15.07	TM25.INC	133.88
TM08.INC	300.83	TM26.INC	97.07
TM09.INC	6.77	TM27.INC	151.21
TM10.INC	87.95	TM28.INC	214.14
TM11.INC	226.63	TM29.INC	191.50
TM12.INC	35.33	TM30.INC	195.54
TM13.INC	19.63	TM31.INC	140.78
TM14.INC	82.84	TM32.INC	157.91
		Total	3402.20

The MAR of the four Mooi River sub-catchments in the original system model totals $298.22x10^6m^3/a$. Adding this to the $3402.12\ x10^6m^3/a$ gives a total natural MAR for the Thukela of $3700.42x10^6m^3/a$.

The average inflow for the Mooi system was $93.84x10^6m^3/a$.

3.5.2 Water usage by afforestation and dryland sugar cane

The afforestation and dry land sugar cane demands for 1995 and projected to 2030 are listed in Table 3.2.

Table 3.2: Mean annual afforestation and dry land sugar cane water requirements

Catchment Name	Afforestation and dry land sugar usage ($10^6m^3/a$)		Catchment Name	Afforestation and dry land sugar usage ($10^6m^3/a$)	
	1995	2030		1995	2030
TM01.AFF	0	0	TM15.AFF	0	0
TM02.AFF	0	0	TM16.AFF	0	0
TM03.AFF	0	0	TM17.AFF	0	0
TM04.AFF	1.19	2.86	TM18.AFF	2.66	4.80
TM05.AFF	0	0	TM19.AFF	0	0
TM06.AFF	0	0	TM24.AFF	0.34	2.00
TM07.AFF	0	0	TM25.AFF	0.84	4.86
TM08.AFF	0	0	TM26.AFF	0	0
TM09.AFF	0	0	TM27.AFF	1.74	6.38
TM10.AFF	0	0	TM28.AFF	1.74	6.38
TM11.AFF	0	0	TM29.AFF	1.46	2.54
TM12.AFF	3.08	5.89	TM30.AFF	2.54	2.94
TM13.AFF	2.89	5.23	TM31.AFF	0.95	5.41
TM14.AFF	0	0	TM32.AFF	2.47	2.87
			Total	21.91	52.18

Note: The pre-feasibility TM20, TM21, TM22 and TM23 annual afforestation and sugar cane usage totalling 3.78 and 6.60 $x10^6m^3/a$ for 1995 and 2030 respectively is in the Mooi system

3.5.3 Irrigation usage

Irrigation demands are not supplied at the same assurance as primary demands. To avoid unnecessarily complicating the system model irrigation demands were set at 75% of full requirement rather than implement a system of restricted supply based on water levels in the dams. Irrigation requirements were determined as time series using WRSM90. In some months the requirements exceeded available runoff from the catchments. Accordingly irrigation supply time series were generated by taking 75% of the demand with the maximum for each month being the available runoff. These irrigation time series are listed in Table 3.3. All pre-feasibility ".IRR" data files have been converted to ".IRD" data files.

Table 3.3 : Irrigation usage (full development assumed by 2010)

Irrigation demand name	Annual demand ($10^6m^3/a$)		Irrigation demand name	Annual demand ($10^6m^3/a$)	
	1995	2030		1995	2030
CHELD75.IRD	1.28	1.88	TM0275.IRD	1.32	1.67
KLIP75A.IRD	2.40	3.80	TM0675.IRD	6.76	8.35
KLIP75B.IRD	10.94	17.33	TM0875A.IRD	2.38	2.76
LOCHS75.IRD	7.79	12.02	TM0875B.IRD	6.44	7.48
MAND75.IRD	4.70	11.03	TM1175A.IRD	2.09	3.70
MHL75.IRD	4.49	13.94	TM1175B.IRD	4.07	7.19
MNGWEN75.IRD	11.51	17.80	TM1275.IRD	1.02	1.60
MUNGU75B.IRD	2.38	4.18	TM1475B.IRD	7.57	8.53
NON75.IRD	2.81	4.54	TM14_MUN.IRD	6.23	7.49
RORK75B.IRD	4.64	8.70	TM2475.IRD	5.58	6.53
THDRIE75.IRD	1. 40	1.76	TM2675.IRD	2.16	2.29
THLTUG75.IRD	19.85	23.00	V375B.IRD	9.89	18.06
THSKDS75.IRD	2.40	3.01	V3_RORK.IRD	2.70	5.05
THSKOP75.IRD	26.81	33.71	WAG75.IRD	0.83	1.28
THWOOD75.IRD	2.96	3.73	ZAAID75.IRD	5.38	7.62
			Total	170.77*	250.03*

Note: The pre-feasibility HARL75.IRD, MEARNS.IRD and MFUN.IRD mean annual irrigation demands totalling $39.18x10^6m^3/a$ for 2030 are now included in the Mooi system

3.5.4 Urban, rural and industrial demand

Urban, rural and industrial demands are summarised in Table 3.4.

3.5.5 Return flows

Return flows were taken from the report by Simonis “Water demands in the UVW catchments” prepared in 1991 for the Water Research Commission study to update “Surface Water Resources of South Africa”. Return flows were projected in relation to the estimated growth rates of contributing demands to give the values listed in Table 3.5. Return flows from irrigation were estimated to range between 10 and 15% but were not included in the analysis. Table 3.5 lists average annual return flows for various time horizons.

Table 3.4: Urban, rural and industrial water demands

Demand Name	Demand Type	Annual demand ($10^6m^3/a$)				Description
		1995	2010	2020	2030	
DEM1	Urban	0.23	2.37	4.29	4.39	Bergville, Emmaus
DEM2	Rural	0.83	8.87	12.02	12.24	Community water supply
DEM3	Urban	0.00	0.00	2.27	6.22	Ladysmith (part)
DEM3b	Urban	1.38	6.25	7.89	7.89	Ladysmith (drawing from Spioenkop Dam)
DEM4	Urban	6.23	28.15	45.19	62.77	Ezhakeni, Pieters industry
DEM5	Urban/rural	0.54	2.43	3.16	4.39	Driefontein, Peacetown
DEM6	Urban	0.54	9.63	14.23	14.55	Winterton, Loskop
DEM7	Urban/rural	0.89	1.96	2.78	3.50	Colenso, Nkanyezi
DEM10	Urban	22.69	42.92	61.79	95.68	Newcastle, Madedeni, Osizweni
DEM11	Urban	5.26	8.77	12.56	23.32	Dundee, Glencoe, Utrecht
DEM12	Rural	2.83	12.18	21.46	32.63	Community water supply
DEM13	Urban/ind.	9.85	12.81	19.28	25.25	Mandini area
DEM14	Urban/rural	7.05	20.58	32.69	46.33	Klipriver area
DEM15	Urban/ind.	2.27	6.628	10.26	14.52	Tugela Ferry
DEM16	Urban	22.11	24.93	28.81	35.19	Estcourt area
DEM17	Urban	1.48	1.67	3.79	4.61	Weenen, Noodkamp
DEM18	Urban/rural	2.66	3.00	3.95	4.83	Kwadamini, KwaMazel, Sobabili
DEM19	Urban	0.14	0.32	0.73	1.07	Wakkerstroom, Esizamelani
DEM20	Urban	1.04	2.46	4.20	6.22	Volksrust, Charlestown
DEM21	Urban/ind.	1.06	2.53	4.61	6.82	Durnacol, Dannhauser
TOTAL		89.08	258.11	295.96	412.42	

Note: The pre-feasibility DEM8 and DEM9 mean annual urban demands totalling $7.39x10^6m^3/a$ for 2030 were included in the Mooi system

Table 3.5: Return flows

Return flow name	Annual return flow ($10^6m^3/a$)				Description
	1995	2010	2020	2030	
LADY	3.15	14.22	22.20	30.57	Ladysmith
UTREC	0.74	1.23	1.73	2.24	Utrecht
DUND	1.77	2.95	4.55	5.87	Dundee
VOLKS	16.42	38.89	53.29	78.92	Newcastle, Volksrust
DURN	0.61	1.46	2.30	3.42	Durnacol
ESCRT	8.07	9.10	14.41	17.74	Estcourt
TOTAL	30.76	67.85	98.48	138.76	

Note: The pre-feasibility MOOI.RET mean annual return flows of 0.16, 0.43, 0.58 and $0.77x10^6m^3/a$ for 1995, 2010, 2020 and 2030 respectively are included in the Mooi system

3.5.6 Inter-basin transfers

There are two current schemes to transfer water from the Thukela basin to the Vaal. The largest is the Thukela-Vaal Scheme that diverts water primarily at Driel Barrage with inflow regulated by Woodstock dam. The design capacity of the combined scheme is $23m^3/s$ but this is not available on a firm basis and the scheme is normally operated to transfer at a maximum rate of $20m^3/s$. The average transfer rate achievable by this scheme is $17.3m^3/s$. The second scheme is the transfer of $28x10^6m^3/a$ from Zaaihoek dam (2030 requirement) for Majuba power station.

It is proposed to transfer $250x10^6m^3/a$ from the lower Thukela at Middledrift to the Mhlathuze catchment. This scheme is currently transferring $34x10^6m^3/a$ and is expected to reach full capacity by 2010.

A Mooi-Mgeni transfer scheme is planned and is expected to be in operation in the near future. The capacity of this scheme will be $120x10^6m^3/a$ but delivery will depend on water levels in the Mgeni dams. This transfer is included in the detailed Mooi system model that is used to provide the inflow time series for the Thukela system model.

The average inter-basin transfers used in the system model are summarised in Table 3.6.

Table 3.6: Mean annual inter-basin transfers from the Thukela system

Transfer Name	Transfer ($10^6m^3/a$)		Description
	1995	2010, 2020 & 2030	
Thukela-Vaal	631.15	631.15	Existing Drakensberg transfer to Vaal
Zaaihoek	1.99	47.34	Existing Zaaihoek transfer to Vaal
Mhlathuze	0.00	252.46	Proposed Middledrift transfer to Mhlathuze
TOTAL	633.14	930.95	

Note: The MOOI-MGENI scheme transfers up to $120x10^6m^3/a$ and is included in the Mooi system

3.5.7 Instream and estuarine flow requirements.

The IFR and the EFR sites are listed in Table 3.7.

Table 3.7: IFR and the EFR sites

IFR name	Location
IFR 2	Thukela downstream of Jana Dam
IFR 3	Bushmans downstream of Mielietuin Dam
IFR 5	Thukela downstream of the , Bushmans and Sundays confluences
EFR	Thukela estuary
IFR A	Thukela downstream of Spioenkop Dam
IFR BUF	Buffels at Thukela confluence
IFR SUN	Sundays at Thukela confluence
IFR C	Thukela downstream of Driel Barrage

Note: IFR's for the Mooi River are included in the Mooi system

The IFR specialists defined drought, maintenance flows and floods for the IFR's. These requirements were used as input to specialist software to generate an IFR time series. These time series were used together with the reference node time series to derive the data for the WRYM datafile. This data gives the relationship between inflow at the reference node(s) and IFR for each calendar month. These are included in Appendix M of the "Water Resources System Model" supporting report. The maximum, minimum and average requirement for each IFR over the 70-year simulation period is listed in Table 3.8. It should be noted that the values given in Table 3.8 are based on the monthly IFR requirements. Actual flows at the IFR sites will often exceed the requirement because of water released for downstream users and because of the upstream reservoir spilling.

Table 3.8: **Maximum, Minimum and Average IFR requirements**

IFR site	Maximum (m^3/s)	Minimum (m^3/s)	Average (m^3/s)
IFR A ("low" IFR scenario)	21.26	0.65	3.47
IFR A ("high" IFR scenario)	27.60	1.24	7.04
IFR C ("low" IFR scenario)	19.49	0.63	4.01
IFR C ("high" IFR scenario)	33.04	0.77	7.79
IFR 2	40.59	1.00	8.18
IFR 3	8.60	0.40	2.17
IFR 5	56.22	1.40	12.08
IFR SUN	3.04	0.78	1.75
IFR BUF	4.47	0.19	1.13
EFR	10.00	1.00	5.88

3.5.8 Elevation-storage-area data of Jana and Mielietuin

The elevation-area-storage relationship used for Jana and Mielietuin dams are listed in Tables 3.9 and 3.10 respectively.

Table 3.9: Elevation-area-storage relationship for Jana Dam

Elevation (m)	Area (km^2)	Storage ($10^6 m^3$)	Elevation (m)	Area (km^2)	Storage ($10^6 m^3$)
704	0.00	0.23	830	17.84	812.06
720	0.25	3.68	840	20.40	1004.29
740	1.60	22.98	850	23.89	1226.14
760	4.21	82.23	860	27.44	1482.56
780	7.06	197.57	870	31.27	1776.62
800	10.89	377.15	880	36.04	2190.00
810	13.17	498.31	890	41.27	2652.00
820	15.57	643.71			

Table 3.10: Elevation-area-storage relationship for Mielietuin Dam

Elevation (m)	Area (km^2)	Storage ($10^6 m^3$)	Elevation (m)	Area (km^2)	Storage ($10^6 m^3$)
938	0.00	0.00	1002	6.84	150.45
950	0.09	0.32	1010	7.99	209.58
960	0.61	3.42	1018	9.57	279.27
970	1.71	14.57	1024	11.68	342.20
978	2.83	32.53	1030	14.58	420.57
986	4.30	60.86	1034	16.67	482.89
994	5.66	100.44	1040	20.34	594.07

3.5.9 Dummy farm dams

Seven dummy dams were used in the system model to represent the numerous farm dams in the catchment. The location and capacities of these dummy dams are listed in the Table 3.11.

Table 3.11: Dummy dams

Dummy dam No.	Catchment description	Storage ($10^6 m^3$)
1	Upstream of Woodstock Dam	14.14
2	Downstream of Driel and upstream of Spioenkop Dam	32.38
3	Upper reaches of the Little Thukela river	36.16
4	Upper reaches of the Klip river	48.86
5	Between the confluence of the Klip with the Thukela rivers, and Jana, but not on the Thukela river	41.75
6	Upper reaches of the Sundays river	28.19
7	Between V3 and Rork irrigation of the Buffels river, but not on the Buffels river	38.18
	Total storage in dummy dams	239.66

4 COMPARATIVE YIELD CURVES FOR KLIP AND JANA SITES

4.1 Yield analyses

The relationship between storage at full supply level and yield for the two proposed dams (Klip and Jana) was required early in the study as important information in the selection of the preferred site for storage in the Thukela River. As the two sites are situated close to one another on the same river, the catchments are virtually the same and the effect of the rest of the Thukela system on the yields from the two proposed dams would be the same. It was therefore appropriate to use the pre-feasibility system model suitably revised to include IFR channels, updated elevation-area-storage data for the proposed reservoirs and the extended hydrology for the comparative analyses.

Historic firm yields from a range of storage sizes for Klip and Jana were determined for the following four scenarios:

- Total firm yield
- Transferable yield
- Transferable yield without IFR's and the EFR supplied
- Transferable yield with IFR's but without the EFR supplied

These scenarios were necessary to assess the worth and cost effectiveness of both sites from a national and project perspective as well as the impact of IFR's and the EFR on system yield.

4.2 Historic storage-yield

The yield for a range of FSL's at each site are given in section 4 of the supporting report "Comparative Yield Curves for Klip and Jana Sites". The results showed that 10% to 15% of the total yield from Jana or Klip Dam would be required for downstream demands and transfers, 40% to 50% for IFR's and only 40% to 50% would be available for additional transfer to the Vaal.

It should be noted that the yield estimates presented in section 4 of the above-mentioned report are for comparison between the Jana and Klip sites only and should not be used to assess transferable yield from the sites.

The estimates analyses show that for equal storage, yield from the two dams would be equal. Accordingly, selection between the two sites will not be a function of the hydrology. Importantly, much larger storage could be provided at Jana as the FSL at Klip is limited by the proximity of Colenso Town.

After a comparative evaluation of the two sites taking all aspects into account, Jana site was selected for further consideration. Accordingly the rest of the Water Resources study focussed only on the Jana Site and no further reference is made to storage at Klip.

5 WATER RESOURCES EVALUATION

The "Water Resources Evaluation" supporting report describes the analyses that were done to determine the effect of changes in demands and operating rules on yield from the proposed dams, final historic and stochastic transferable yields and to estimate filling times for Mielietuin and Jana dams.

5.1 Sensitivity analyses

The Thukela system is large and extremely complex and it is not always easy to envisage how changes to one part of the system may affect the functioning of the rest of the system. Analyses were done to assess the effect on transferable yield of the following:

- System sensitivity to IFR's and the EFR
- Effect of the size of Mielietuin Dam on the transferable yield from Jana Dam
- Irrigation upstream of Spioenkop Dam
- The current system
- 2010, 2020 and 2030 demand scenarios
- Effect of Mhlathuze transfer on yield from Jana
- Transferable yield curves for Uitkyk and Buffelshoek Dams
- Mielietuin and Jana dams storage-transferable yield curves

These issues are briefly described in what follows.

5.1.1 Sensitivity of yield to changes in the IFR's and the EFR

Analyses were done to assess the effect of changes in the IFR and the EFR on transferable yield. These changes included reducing the maintenance and drought flows by 10% and increasing the frequency of drought flows. The results showed that a significant increase in transferable yield could be achieved, from a water resources perspective, with small changes in the IFR's. These findings were presented to the IFR specialists at the November 1998 workshop. The reductions in maintenance and drought flows, even by as little as 10%, were regarded as unacceptable by the specialists. They did, however, propose changes that effectively extended the period of transition between drought and maintenance flows. This philosophy was used in re-defining all IFR's in the Thukela.

5.1.2 Effect of the size of Mielietuin Dam on the transferable yield from Jana.

Analyses to determine the effect on the transferable yield from Jana Dam of changing the size of Mielietuin Dam showed that the yield from Jana is not affected as long as the firm transferable yield is abstracted at Mielietuin. This is because, when the firm yield from Mielietuin is being abstracted, the dam will only spill during very wet periods when there is plenty of water available from the rest of the system to supply the downstream demands without releases being made from Jana.

5.1.3 Irrigation upstream of Spioenkop Dam

Some concern was raised as to the likelihood of irrigation areas upstream of Spioenkop Dam increasing as projected. Analyses showed that there was no difference in the transferable yield from Jana whether the irrigation area stayed at its present level or increased as projected. However, with less irrigation the average transfer through the existing Drakensberg Pumped Storage Scheme would increase slightly.

5.1.4 The current system

A present day analysis was done to gain an understanding of the current system and to assess the effect that IFR's would have on supplying present day demands. Analysis showed that only the transfers from the existing Thukela-Vaal scheme would reduce if IFR's were implemented. This is because IFR A has to draw on Woodstock Dam to be fully supplied i.e. under present day conditions only the reach of river downstream of Spioenkop has lower flows than required by the IFR's.

5.1.5 2010, 2020 and 2030 demand scenarios

Comparative assessment was required for 2010, 2020 and 2030 demand scenarios to assess future trends in demand and identify possible water shortages and the need for future planning within the Thukela Basin. All proposed dams and transfers were included in the analyses. Supply of in-basin demands for the three scenarios were not affected but transferable yield from Jana and Mielietuin dams decreased over time.

5.1.6 Effect of Mhlathuze transfer on yield from Jana

The transferable yield from Jana was determined with the Mhlathuze transfer set to 34, 85 and $250 \times 10^6 m^3/a$. In all cases the same yield was obtained at Jana Dam. This shows that the Mhlathuze transfer is supported from the Buffalo River (Chelmsford Dam) and Mooi River and does not need to be supplied from Jana Dam. This finding confirms the conclusions drawn in the Mhlathuze Basin augmentation feasibility study (DWAF) done some years ago.

5.2 Assessment of changes to the system model on transferable yield

Numerous historic yield analyses have been carried out on Jana and Mielietuin as a result of new and updated information as well as enhancements to the system model. Detailed checks on the system were carried out at each stage of the revisions to the model and any shortfalls in supply were investigated and explained. Some changes resulted in an increase and others in a decrease in transferable yield as follows:

5.2.1 Revised assessment of water demands

In line with the requirement that all in-basin demands should be fully supplied before water is transferred, full irrigation demands were included at a high security of supply. This is clearly unrealistic, as irrigators do not require the same assurance of supply as primary users. Restricting supply to irrigators during droughts was considered but regarded as too complex to implement in the Thukela system model at this stage. It was agreed that supplying irrigators with 75% of their demand at the same assurance as primary users would be a more practical way of allowing for reduced supply to irrigators in the system model. This approach will have to be refined in the next phase of the project cycle. Reducing irrigation increased the water that could be transferred.

The assessment of transferable yield also increased after the Newcastle, Madedeni and Osizweni urban demand in the Buffalo catchment was revised. This demand was significantly reduced from the original 2030 projection in a re-evaluation of projected demands. The decrease of about $55x10^6m^3$ (2030 development level) resulted in an increase in transferable yield from Jana.

Transfers from Zaaihoek for Majuba Power Station were also reduced in accordance with the latest information received from Eskom and resulted in an increase in transferable yield from Jana.

5.2.2 Incorporation of additional farm dams

The inclusion of additional farm dams made possible using the Mark 5 version of WRYM resulted in more water being available for irrigators. This reduces flow in the rivers resulting in lower inflow to Jana and a greater dependency on Jana from downstream demands causing a reduction in transferable yield.

5.2.3 Revision to Zaaihoek hydrology

Inflow time series in the upper reaches of the Buffalo catchment were revised. The revision affected two of the system model inflow time series and resulted in a net decrease in inflow. This caused a reduction in the transferable yield.

5.2.4 Revision to IFR’s and addition of new IFR’s

Small changes made to IFR2, IFR3 and IFR5 had a negligible effect on transferable yield. The inclusion of new IFR’s had a more significant effect. Inclusion of IFR’s in the Sundays and Buffalo rivers reduced the burden on Jana Dam to release water for IFR5 and the EFR. This addition increased transferable yield from Jana Dam. The two new IFR’s upstream of Jana Dam cause an increase in inflow to the dam. This causes the transferable yield to increase, however, to fully supply these IFR’s, releases have to be made from Woodstock and Spioenkop Dams. This reduces transfers by the existing Thukela-Vaal Scheme. Overall transferable yield from the Thukela-Vaal scheme and the Jana Dam reduces when the FSL in Jana is less than 840m amsl because some of the water released from Woodstock for the IFR’s is spilled at Jana. Above 840m amsl losses from the Thukela-Vaal scheme are made up by increases in transfers from Jana albeit at much increased cost as a result of the higher pumping and enlarged infrastructure that would be required.

5.2.5 Revised period of inflow time series

The period of the streamflow time series was changed from 1920 to 1994 to 1925 to 1994 to be compatible with the Mooi River inflow time series generated using the detailed Mooi-Mgeni system model. In the historic analyses yields were not affected by the shorter simulation period because the discarded years do not affect the critical period in the seventies. This shortened time series will affect generation of stochastic time series but because the discarded years are above average, yields determined using the stochastic time series will be conservative.

5.2.6 Uitkyk and Buffelshoek Dams

Including Uitkyk and Buffelshoek dams together with their IFR's in the system model increased transferable yield from Jana by 1.5m^3/s. Should development of these dams to supply local demands and IFR's on the Sundays and Buffalo Rivers, be delayed or not implemented, the transferable yield from Jana would decrease because the burden of meeting the IFR of the lower Thukela would become the responsibility of Jana Dam.

5.3 Feasibility yield analyses

The feasibility study transferable yields were determined using the system model shown in Drawing W5 with inflow time series, data and information as described in Section 3.5 of this report.

5.3.1 Historic yield analyses

The transferable yield from Mielietuin Dam depends on requirements in the Bushmans River catchment only since it was assumed that Jana Dam would release water for demands downstream of the Bushmans-Thukela confluence. Also the transferable yield from Jana Dam was shown to be independent of the size of Mielietuin Dam as long as the firm transferable yield was abstracted from Mielietuin. Accordingly the system model was used to determine the transferable yield from Mielietuin Dam for a range of dam sizes and then the corresponding transferable yields for Jana Dam were determined by simulation with Mielietuin Dam transferring at capacity. The transferable yield from Jana Dam is affected by the upstream IFR's (Woodstock and Spioenkop). The uncertainty relating to the IFR below the existing transfer scheme could not be resolved during the feasibility study but will be resolved in a separate study in which the Reserve is determined for the whole Thukela basin. To cope with this uncertainty, an upper and lower likely bound was set to the IFR and the scheme configuration and transferable yields determined for these two possible extremes. This range of uncertainty only affects the yield from the Jana Dam and not the yield from Mielietuin Dam. It is expected that the actual Reserve will lie somewhere in between the two extremes. The historical yield analysis results for the Mielietuin and the "low" and "high" IFR scenarios for Jana are summarised in Tables 5.1 to 5.3.

Table 5.1: Transferable yield from Mielietuin Dam

Full supply level (m amsl)	Working storage (10^6m^3)	Transferable yield ($10^6m^3/a$)
1010	206	105
1015	250	114
1020	297	123
1025	352	129
1030	417	137
1033	464	141
1035	498	143

Table 5.2: Transferable yield from Jana Dam – "low" IFR

Full supply level (m amsl)	Working storage (10^6m^3)	Transferable yield ($10^6m^3/a$)
800	364	204
820	630	271
840	991	322
850	1213	335
860	1469	351
870	1763	368
880	2177	393
890	2639	422

Table 5.3: Transferable yield from Jana Dam – "high" IFR

Full supply level (m amsl)	Working storage (10^6m^3)	Transferable yield ($10^6m^3/a$)
800	364	253
820	630	347
840	991	416
850	1213	431
860	1469	446
870	1763	464
880	2177	489
890	2639	517

For the low and high IFR scenarios, the transfers possible from the existing Thukela-Vaal Scheme transfer reduce from the 527 million m^3/a which is currently possible (using 2030 in-basin demands) to 448 million m^3/annum and 357 million m^3/annum respectively. Water released from Driel Barrage and Spioenkop Dam to supply IFRs will, however, make more water available for transfer from Jana and it was found that the total transferable yield from the combined transfer schemes (existing plus Jana and Mielietuin Dams) is the same for both high and low IFR scenario (see Figure 5.1). In other words, the amount of water which can be transferred from the Thukela basin to the Vaal

River System is essentially the same whether it is pumped from Jana Dam or the Driel Barrage. However, there is a cost implication since the cost of pumping from the Jana Dam, at a much lower elevation than the Driel barrage, will be higher. The aqueduct capacity from the Jana/Mielietuin system would have also have to be greater for the high IFR scenario.

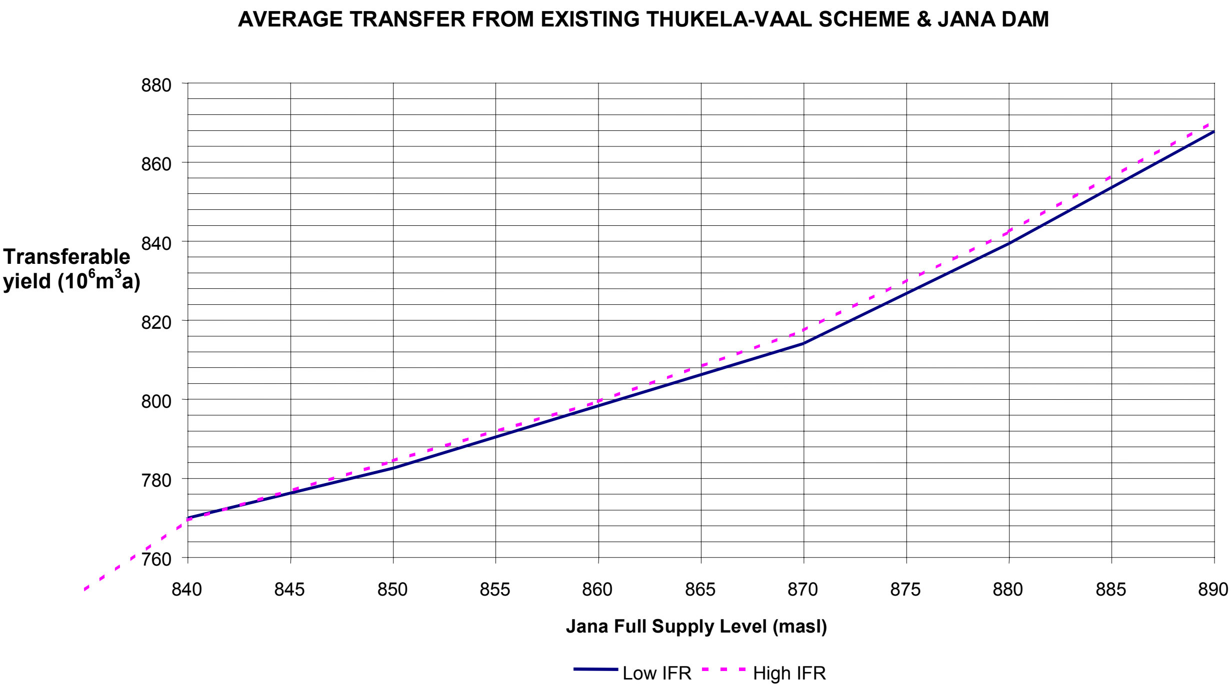

Figure 5.1: Average transferable yield from the existing Drakensberg scheme and the Jana Dam

The target of the TWP is to transfer an additional $15m^3/s$ to the Vaal River System. At the time of preparing the ToR for the study it was not envisaged that operating policy in the Thukela would affect the existing transfer scheme. Simulations show that under current operating rules and 2030 in-basin demands the average transfer rate for this scheme is $16.7m^3/s$. Thus the combined target delivery of the existing and proposed schemes would be $31.7m^3/s$. Subsequently changes in operating strategies result in water being released from Woodstock Dam to supply IFR's. Water released from Woodstock Dam cause the average transfer via the existing Thukela-Vaal Scheme to reduce. However, as the water flows into Jana it can be transferred from there. To preserve the total target transfer of $31.7m^3/s$ the proposed scheme should transfer $15m^3/s$ plus the reduction in transfer via the existing scheme. These operating rules must be optimised during the next phase of the project cycle. It also should be noted that if Jana is not built, IFRs would still have to be released from the upper catchment storage units.

Transmission losses between the proposed dams at Mielietuin and Jana and Kilburn are expected to be approximately $0.5m^3/s$ for canal aqueducts and close to zero for pipelines. This should also be included in transferable yields from the proposed dams.

5.4 Long-term stochastic analysis

The historic yield analysis gives no indication of the assurance of yield. In order to determine assurance, long-term stochastic analyses were done using 201 stochastic inflow sequences each 70-years long. The yield assurance relationships for Jana and Mielietuin were analysed for a range of sizes for each dam. The system operates so that Jana and not Mielietuin would supply demands downstream of the confluence of the Bushmans and Thukela Rivers. Thus the transferable yield from Mielietuin is independent of the rest of the system. For Jana, water spilled from Mielietuin will be available to users downstream of the Bushmans-Thukela confluence and could therefore reduce demands on Jana. Thus theoretically the transferable yield from Jana will depend on the size and draft on Mielietuin. However, both the historic and stochastic analyses showed that as long as the draft from Mielietuin equalled it's firm yield for the desired assurance, the size of Mielietuin did not affect the transferable yield from Jana.

Due to the fact that the IFR's below Driel Barrage and Spioenkop Dam affects the transferable yield at Jana, results have been shown for the two IFR scenarios ("low" and "high") between which the final IFR's for these sites is expected to fall. The "low" scenario relates to reaches below Driel Barrage and Spioenkop Dam being both class "D" rivers and the "high" scenario relates to a class "B/C" below Driel Barrage and a class "B" below Spioenkop Dam. Tables 5.4 to 5.6 show the results of the stochastic analyses for Mielietuin and Jana for levels of assurance of 95, 98 and 99 percent. The results show that for the "high" IFR scenario, the transferable yield from Jana is 2.5 to 3m^3/s more than for the "low" scenario. Additional yield is available because Woodstock and Spioenkop dams have to release more water to satisfy the "high" IFR scenario. Both the "low" and "high" IFR scenarios reduce the average transfer to the Vaal from the existing Drakensberg scheme.

Table 5.4 : Transferable yield from Mielietuin (Stochastic analysis)

Reservoir FSL (m amsl)	Transferable yield at assurance of		
	95%	98%	99%
	$10^6m^3/a$	$10^6m^3/a$	$10^6m^3/a$
1015	125	108	99
1025	136	120	112
1033	147	129	122

Table 5.5: Transferable yield from Jana – "low" IFR[1]

Reservoir FSL (m amsl)	Transferable yield at assurance of		
	95%	98%	99%
	$10^6m^3/a$	$10^6m^3/a$	$10^6m^3/a$
810	300	260	235
840	390	338	315
860	435	390	355
890	520	455	420

Table 5.6: Transferable yield from Jana – "high" IFR[1]

Reservoir FSL (m amsl)	Transferable yield at assurance of		
	95%	98%	99%
	$10^6m^3/a$	$10^6m^3/a$	$10^6m^3/a$
810	380	340	310
840	490	435	400
860	530	485	450
890	610	545	520

Note 1: Yields quoted for Jana Dam are correct only when abstraction at Mielietuin is at the same assurance.

5.5 Reservoir filling time analysis

The time required to fill the proposed dams will affect the timing of the program for design and construction so that the dams can be commissioned in time to supply demands. Filling times were assessed by simulation using 201 stochastic inflow time series and starting with the dams empty. Demands were set to 2010 levels except for existing and planned transfers and the Mooi system, which were left at 2030 level, both of which should have a minimal impact. Filling times for Mielietuin Dam were determined with no TWP transfers. For the Jana analysis, the level of Mielietuin was set at 1020m and the 1:20 year transferable yield (i.e. 95 % level of assurance) was abstracted from the dam. No TWP transfers were imposed on Jana Dam for the analysis. The analyses results were processed using the in-house program PLOTANL. This program presented as a function of time "box and whiskers" plots of the water levels in the dams. The number of wet seasons to fill the dams at an assurance of 95 percent to 25, 75 and 100 percent of working storage was read off the plots and are summarised in Table 5.7. Analyses were done for Jana Dam with both the "low" and "high" IFR scenarios.

Table 5.7: Reservoir filling times (with 95% confidence)

Full supply level (m)	Wet seasons to fill dam at assurance of 95% to			
	25%	50%	75%	100%
Mielietuin				
1033	3	4	5	6
1025	2	3	4	5
1020	2	3	4	5
Jana "low" IFR scenario				
890	4	6	8	10
875	3	5	6	9
860	3	4	5	8
835	2	3	3	5
Jana "high" IFR scenario				
890	3	5	6	8
875	3	4	5	6
860	3	4	5	6
835	2	3	3	5

5.6 Short term yield analyses

It is intended that first delivery of water to the transfer scheme should commence before the dams are full. How full the dams need to be before transfers commence depends on the accepted risk of shortfalls occurring in the short term. Accordingly analyses were done to assess the risk of shortfalls if the full transfers were commenced when the dams were 25, 50 and 75% full. Only the preferred dam sizes at Mielietuin and Jana of 1025 m amsl and 860m amsl respectively were analysed.

The feasibility system model was used in the analyses with 201 stochastic inflow sequences each 5-years long and demands set at 2010 levels. The results showed that the short-term risk of failure to supply the target draft would not be worse than 1:20 years.

6 WATER QUALITY

Consideration of water quality was limited to that pertaining to IFR releases and transferable yield. This summary was taken from the report "Specialist Study on the Impacts Relating to the creation of Impoundment's for the Thukela Water Project on Water Quality and the Water Quality that will be released" undertaken by the Integrated Environmental Module of TWP Feasibility Study.

The Thukela and Klip rivers that will feed Jana show good water quality with regard to inorganic constituent concentrations that will not affect any user detrimentally. Water that will flow into Mielietuin will show the effects of pollution from Estcourt as raised (but still low) conductivity levels and associated ion concentrations. Elevated phosphate-P concentrations will stimulate algal growth, possibly resulting in mesotrophic conditions.

Regarding the water quality in Jana and Mielietuin and the likely quality of downstream releases, three components were evaluated as follows:

- Inflow to the dams
- dam surface water
- water at the bottom of the dam

Due to settlement of sediment, bottom water releases will be turbid and hence increase the turbidity in the relevant rivers whereas surface water spills will result in far lower turbidity in the rivers than normal. Iron and manganese concentrations in downstream rivers would be reduced by a factor of about two when surface water is spilled whereas when bottom water is released, high concentrations of reduced dissolved iron and manganese could have harmful environmental effects. E. *coli* levels should drop drastically in the dams and in spilled and released water. The pH of surface water spills should not affect the rivers much but bottom water releases are likely to have lower pH values by about 0.5 to 1.0 pH units, which are potentially harmful to the ecosystem (although the overall pH is generally within tolerable limits). Total ammonia concentrations are much higher in bottom water and about 45% of bottom water releases could be harmful to the ecosystem due to the toxic free ammonia content.

Changes in temperature of the rivers below the dams will depend on the level the water is released from and the time of year. Maximum temperature differences between surface and bottom water of about 10°C should occur in January/February and could cause considerable shock to the ecosystem when monthly bottom water releases introduce much colder water to the rivers. Temperature changes for aquatic considerations should generally not exceed 2°C. Dissolved oxygen concentrations could be depleted below 4 mg/l (lower limit for aquatic life) and the great depths of Jana and Mielietuin may prevent mixing and as a result bottom water releases would be anoxic the whole year round. These effects should be confined to a relatively short length of river below the dams and could be mitigated by storage in tailponds.

7 CONCLUSIONS

A system analysis model of the Thukela River System was developed during the Feasibility Study that adequately simulates operation of the whole Thukela system including supplying water demands both inside and outside of the basin and Instream Flow Requirements (IFR’s).

As can be expected, IFR's downstream of the proposed Jana and Mielietuin dams significantly reduce the transferable yield from these dams. Dummy dams were included in the Sundays and Buffalo rivers to supply local water demands in these catchments (assuming significant growth in irrigation water demand) as well as IFR's at their confluences with the Thukela. These dummy dams are to be either local developments or will later form part of a possible Northern Tributaries Transfer Development. Either way the dams will not form part of the configuration of the currently proposed scheme. This reduced the burden on Jana dam to supply IFR's in the Thukela upstream of the Mooi confluence and the EFR allowing more water to be transferred. This assumption needs to be reviewed in the Decision Support Phase.

IFR's upstream of Jana Dam increase flow into the dam resulting in increased transferable yield from Jana. However, transfers via the existing Thukela-Vaal Scheme are reduced because releases have to be made from Woodstock and Spioenkop to supply the IFR's. The reduction in transfers via the existing Drakensberg Pumped Storage Scheme due to releases from Woodstock to supply IFR's as well as transmission losses must be taken into consideration when sizing components of the proposed scheme. Releases from Woodstock to supply the IFR's will not affect the size of Jana Dam, but will affect the capacity of the aqueduct from Jana. Based on the results of simulation analyses to determine transferable yields from Mielietuin and Jana, a combination of dam sizes at the two sites could be selected to achieve the desired delivery at Kilburn.

The preferred FSL’s for the dam are Mielietuin 1025 m amsl and Jana 860m amsl. The transferable yields for this option for the “low” and “high” IFR scenarios for the Woodstock and Spioenkop IFR's are shown in Table 7.1 .

Table 7.1 : Summary of Mielietuin (1025 MSL) and Jana (860mSL) option

IFR scenario	Assurance of transfer (%)	Average transfer from existing Drakensberg (m^3/s)	Transferable yield from Mielietuin (m^3/s)	Transferable yield from Jana (m^3/s)
“low” IFR	95	14.4	4.3	13.8
	98	14.4	3.8	12.4
	99	14.4	3.6	11.3
“high” IFR	95	11.5	4.3	16.8
	98	11.5	3.8	15.4
	99	11.5	3.6	14.3

The storages behind both the proposed dams are relatively large in terms of the catchment MAR at those points in the river system and therefore are expected to take between 6 and 10 years to fill.

Most of the detrimental water quality effects downstream of the proposed dams could be minimised by ensuring that as much surface water is released as possible when monthly releases are made and that there is sufficient dilution in the dam tailponds. Spraying of water into tailponds is required to rapidly re-oxygenate the water before entering the rivers. The effects of varying water quality should be further investigated in time. The quality of the transferred water should be good, since this would comprise essentially surface water. Potential aggressiveness towards concrete needs to be investigated.