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MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Main Report

Original

FINAL REPORT

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Main Report

Report no.: WMA 11/T50/00/3009 Volume 1

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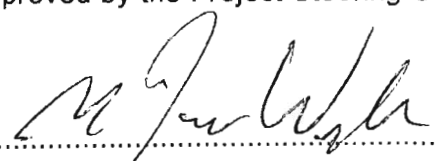

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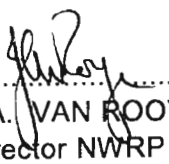

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LIST OF REPORTS	
Title	**Report Number**
Main Report	**WMA 11/T50/00/3009 Volume 1**
Management and Development Options	WMA 11/T50/00/3009 Volume 2
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Executive Summary

INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as there was a concern that the flows might have dropped below the requirements of the Ecological Reserve, as a result of heavy afforestation and irrigation developments in the catchment. The Department was under pressure to grant licences for further afforestation which, if allowed, would exacerbate the situation.

The main objectives of the study as defined in the inception phase are as follows:

- *To determine the existing and potential future water use in and from the catchment;*
- *To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry;*
- *To reassess the hydrology and the water supplies available from existing sources; and*
- *To recommend possible schemes for meeting future requirements, including potential additional plantation forestry, as well as potential future usage requirements.*

This report describes the assessment of possible development scenarios.

CATCHMENT DESCRIPTION

The Mzimkhulu River catchment comprises tertiary catchments T51 and T52 with a total catchment area of approximately 6 668 km^2. A map showing the location of the catchment is shown in ***Figure 1.***

The Mzimkhulu River rises at a height of just over 3 000 m, in the Southern Drakensberg in the Ukhahlamba Drakensberg Park (Garden Castle Forest), a World Heritage Site. This area is preserved for its pristine, ecological, and historical nature. As it winds down to its way to the Indian Ocean at Port Shepstone, the river is joined by the Mlambonja, the Mzimkhulwana the Pholela, the Ngwangwane the Bisi and lower down, the (second) Mzimkhulwana River, as well as numerous smaller tributaries.

The upper part of the catchment is characterised by agricultural development, mainly under irrigation and fed by numerous farm dams. Tourism also plays a large role in the upper catchment. Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested.

The middle part of the catchment is predominantly rural tribal trust land and formed part of the previously independent Transkei, with scattered subsistence rural communities drawing water from run-of-river.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water from local streams, boreholes and springs.

Lower down, the river enters a deep gorge, where it is joined by the Mzimkhulwana River, emanating from the Oribi Gorge Nature Reserve, a World Heritage Site and well known tourist attraction, with spectacular scenery.

The Mzimkhulu River and its tributaries offer a variety of "wild and scenic" sections, and is utilised in many recreational activities. Climate-wise, the Mzimkhulu River catchment falls within the summer rainfall region of South Africa. Rainfall is strongly seasonal with roughly 80% of rainfall occurring from October to March.

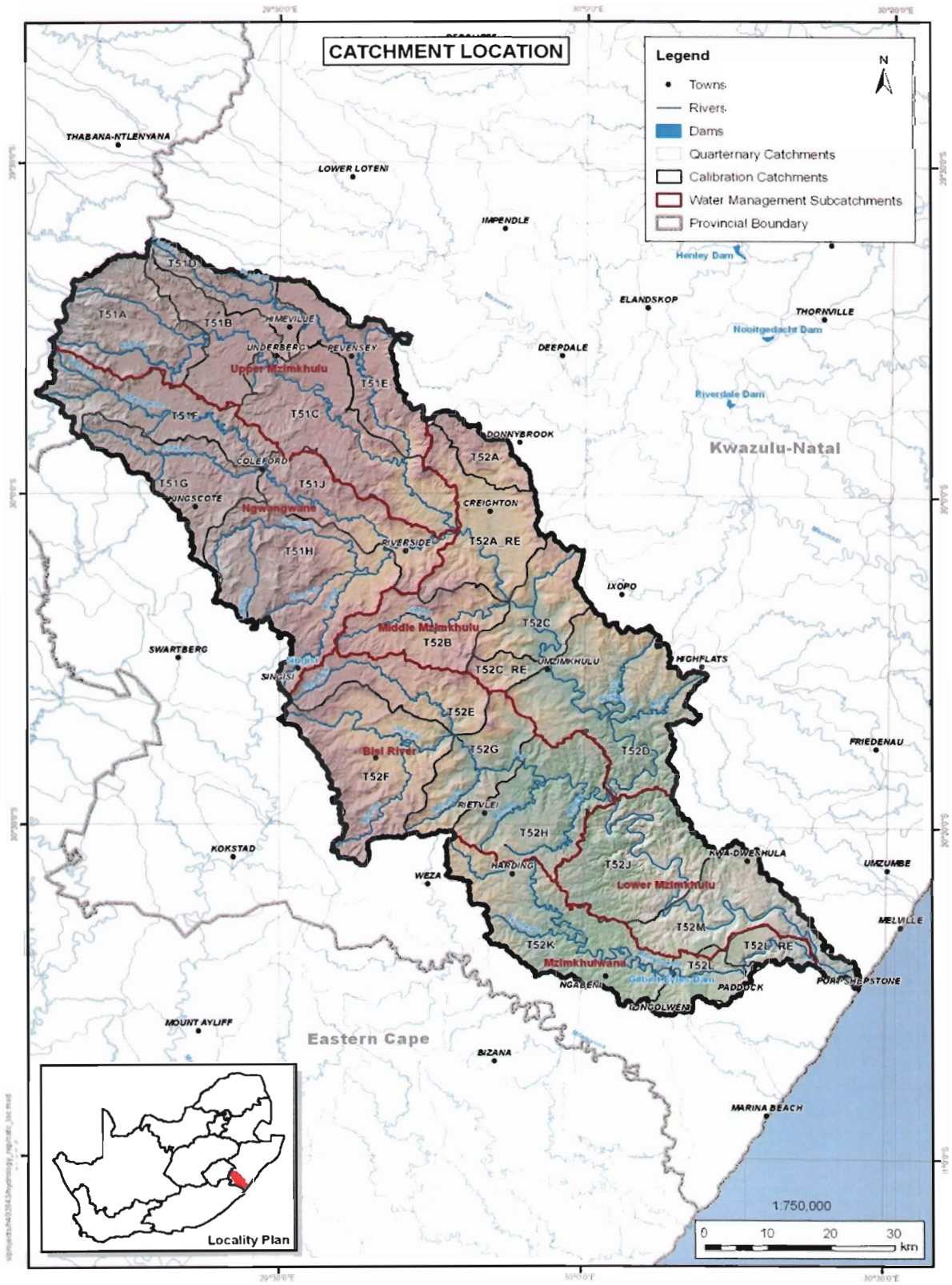

Figure 1: Map showing the location of the Mzimkhulu River catchment

Key Catchment Statistics:

- *Catchment Area: 6 668 km^2;*
- *Natural Mean Annual Runoff (MAR) 1 453 million m^3;*
- *Present Day MAR: 1 176 million m^3 per annum;*
- *Mean Annual Precipitation (MAP): 930 mm; and*
- *Length of main river: 353 km.*

For the purpose of this study, the catchment has been divided into six Water Management Sub-catchments, comprising the Upper Mzimkhulu, the Ngwangwane, the Middle Mzimkhulu, the Bisi, the Mzimkhulwana and the Lower Mzimkhulu.

LAND USE AND WATER USE

The Land Use and Water Requirements Report, Volume 9, deals with current water uses in the catchment, which in turn provide the basis for inputs into the hydrological model. This component of the Study has involved the extraction of data from satellite imagery in each of the 21 quaternary sub-catchments. The present day land use by the various water use sectors is shown in ***Figure 2.***

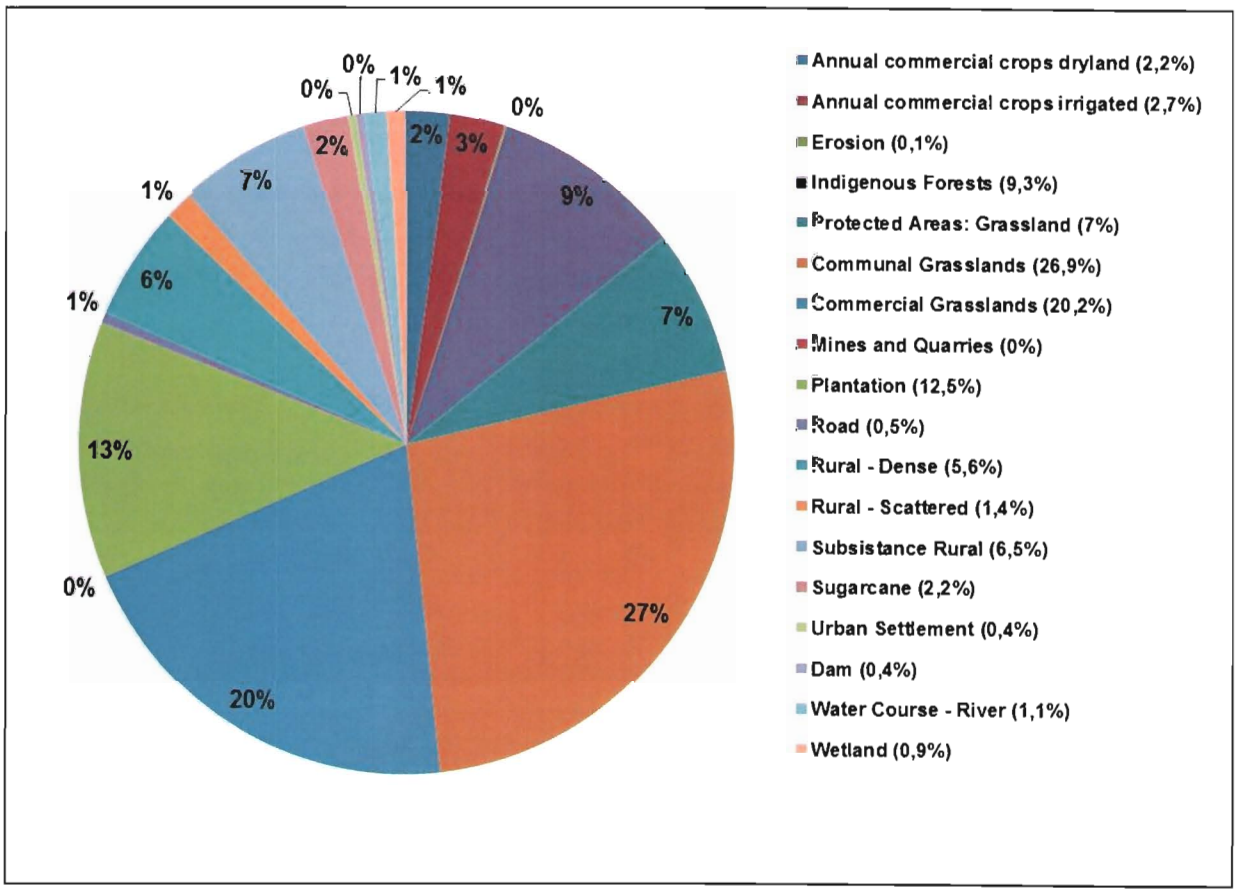

Figure 2: Percentage Land Use

Table 1 *and* ***Figure 3*** *below summarises the estimated total volume of water use by sector, in the Mzimkhulu catchment in 2010. The total estimated current water use is 277,7 million m³/a.*

Table 1: Total volume of water use by sector in 2010

Land Use	Total Water Requirement (Million m³/a)	Demand as percentages of total
Plantation Forestry	112,7	41%
Irrigation	86,6	31%
Alien Vegetation	39,7	14%
Rural, Urban, Industrial and Commercial	28,1	10%
Dryland Sugarcane	6,8	3%
Livestock watering	3,8	1%
Total water requirements	**277,7**	**100%**

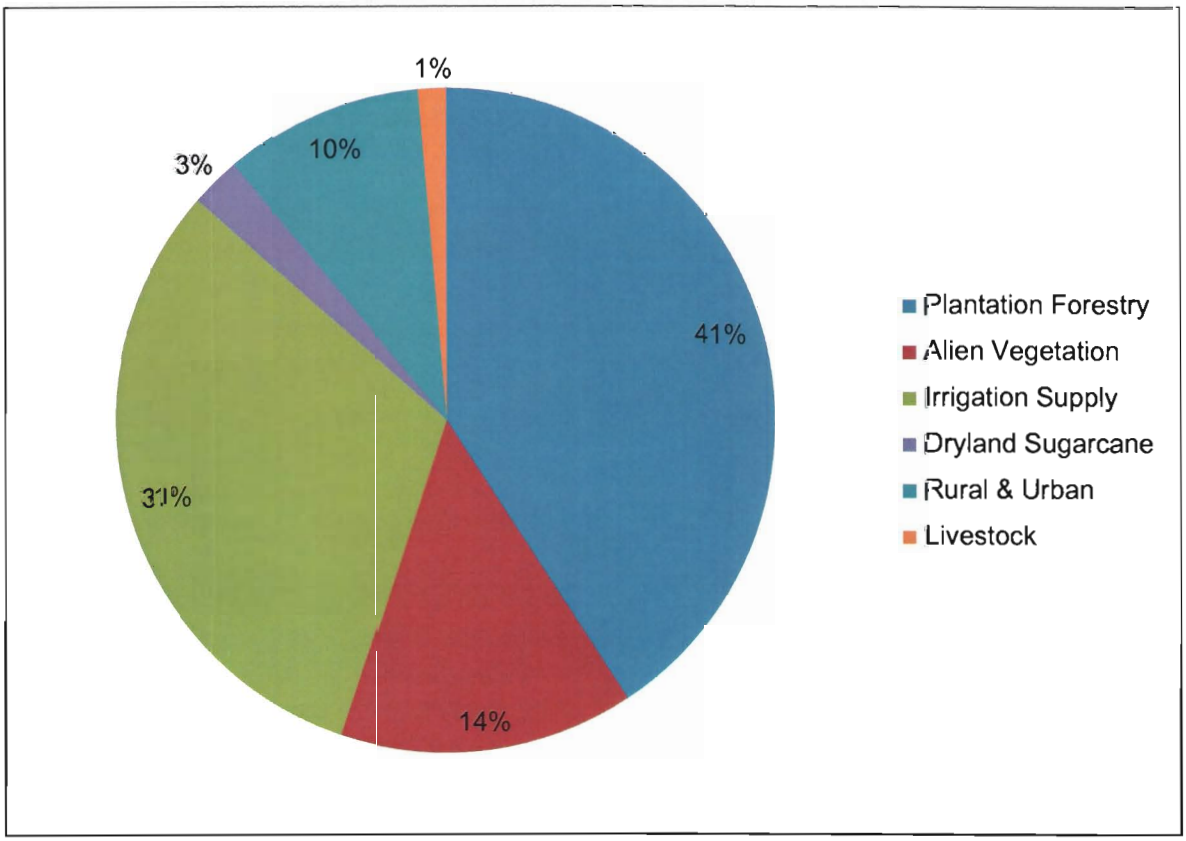

Figure 3: Breakdown of Water Use in the Mzimkhulu Catchment by Sector

POTENTIAL FOR PLANTATION FORESTRY DEVELOPMENT

To determine plantation forestry potential, a negative mapping process was carried out, examining the existing land use and the climatic, topographic and soil conditions required for forestry. Exclusion criteria related to Land Cover, the Ezemvelo KwaZulu-Natal Wildlife (EKZNW) Conservation Plan (C-Plan), Topographical, Hydrological and Agricultural factors were adopted. Plantation forestry growing potential, based on these factors, was established

*and classified, as set out in **Table 2** below. Figures take no cognisance of water availability, which is dealt with in the modelling results.*

Table 2: Plantation Forestry Potential

Suitability	Commercial potential (ha)	Small Grower Potential (ha)
Low	56 170	41 700
Medium	24 673	15 507
High	16 607	12 405
Total	**97 451**	**69 613**

Applying filtering criteria throughout the catchment, and using more conservative criteria where small growers were involved, resulted in potentially suitable areas of:

- *50 350 ha for all growers (inclusive of small growers);*
- *29 400 ha for small growers; and*
- *21 050 ha for the small growers in the Bisi and Middle Mzimkhulu WMSCs.*

In order to assess the impact of developing the additional areas of plantation forestry, four basic future development scenarios, each with a number of sub-scenarios were defined and the water resource implications were modelled. The four scenarios with the following increases in forestry and irrigation were:

i. 29 400 ha of forestry on land suitable for small growers;
ii. 21 050 ha of forestry on land suitable for small growers in the Bisi and Middle Mzimkhulu catchments;
iii. 50 350 ha of forestry throughout the catchment, with 29 400 ha of the land being suitable for small growers and a 20% increase in water use for irrigated agriculture; and
iv. As for Scenario 3 with a large dam to export water.

Projected future water use requirements and EWRs were included for each quaternary catchment. The water resource modelling assessed the impacts of increased land and water use, with and without mitigation provided by one of two dam options, in each scenario.

***Figure 4** provides a spatial view of areas in the catchment with poor, low, medium and high potential for forestry for all growers.*

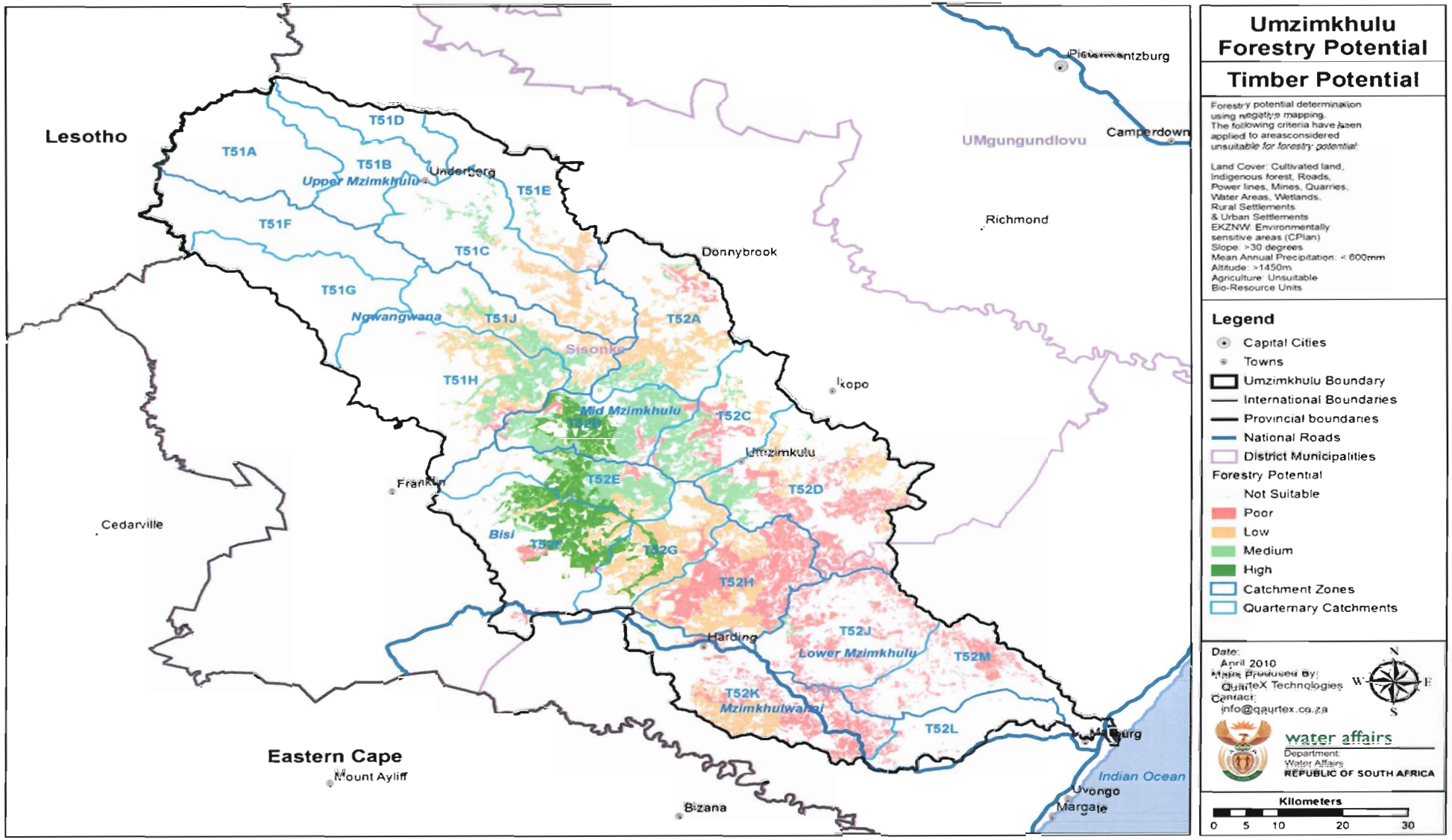

Figure 4: Areas with Potential for new Forestry

HYDROLOGY

The objective of the catchment hydrology task is to present the updated hydrology for the study area, in order to support the determination of existing and potential future water use, to assess the opportunities and water available for future economic development, and to recommend possible schemes for meeting future requirements with a specific focus on the potential for development of plantation forestry in the catchment. Monthly simulated runoff sequences are produced and used in the system yield analyses relating to present and future land-use development scenarios and development options.

The hydrology of the Southern KwaZulu-Natal Pre-Feasibility Study (SKZNPFS) (DWAF, 2002) which was for the period 1925 to 1998 was used as a point of departure and was updated with the latest land and water use information representing the 2007 hydrological year. The Water Resources Simulation Model (WRSM2000) was configured and calibrated with this information in order to generate monthly flow sequences.

Rainfall data is one of the most important data requirements for hydrological modelling and the density of the existing rain station coverage is low. The accuracy and reliability of rainfall information in the catchment could be improved with continued monitoring and maintenance of the existing stations. Re-instatement or re-opening of closed gauges in key areas is recommended, in order to improve the density and coverage of active rainfall stations in the network.

The flow monitoring network in the Mzimkhulu catchment is adequate for a general water resources assessment but should be improved, if significant new socio-economic developments, such as plantation forestry, are planned. It is important that existing flow gauges remain open and continue to be monitored and maintained. Additional flow gauges should be established on the Ngwangwane River just upstream of the confluence with the Mzimkhulu, as well as on the main stem downstream of Umzimkulu town in the lower catchment.

WATER QUALITY

A comprehensive assessment of the water quality situation was not part of the project because such an assessment was undertaken, with data up to 1999, as part of the SKZNPFS (DWAF, 2002). Since then about eight years of additional water quality data have been collected in the catchment and a brief review of the water quality situation was undertaken to determine if the water quality trends described previously have changed, or if new water quality issues have emerged since then. To compare findings, the catchment was divided into three parts and the data was analysed with the WQStat Plus statistical software package.

The study confirmed that the status quo in the upper catchment remained largely unchanged and that the conclusions drawn previously were still valid.

In the middle catchment, the study confirmed the status quo, but specific concerns were expressed about the state of the river near the town of Umzimkulu. It is recommended that a water quality survey be undertaken in that area to identify potential pollution sources and management interventions to address local impacts.

Previously, the finding was that the quality in the Mzimkhulwana River was not as good as that in the other basins. The previous recommendation, to improve monitoring in the lower basin is therefore strongly supported and the DWA is encouraged to review and maintain their water quality monitoring in the Mzimkhulu River catchment in order to track water quality changes as further development of the catchment continues.

RIVERINE ECOLOGICAL WATER REQUIREMENTS

The undammed nature of the Mzimkhulu River has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) programme and the river is ranked as one of the most important for conservation in the region.

The Ecological Water Requirements (EWR) for eight selected riverine sites in the Mzimkhulu catchment, as well as for the estuary, was determined. Although the results of the modelling indicated that the current low flows do not always meet the recommended flows to maintain the Present Ecological State (PES) of the river, the overall conclusion, is that the state of the ecosystem in this catchment is unusually good for such a large river system. The river was also determined to be relatively resilient, the riverine environment being assessed as relatively unresponsive to an increase of up to 30 000 ha of additional forestry.

Before major developments in the catchment are given approval, the extent of the ecological impacts that would occur in smaller tributaries at a local scale need to be assessed.

There are also some uncertainties about the impacted low flows that would result from that additional area of forestry. It is recommended that, as a condition to any development new forestry, the following be undertaken:

- *Review of the calibration of key flow gauges;*
- *Additional EWR studies on smaller tributaries be undertaken and synchronised with these results (in progress via the Resource Directed Measures (RDM) office);*
- *Ongoing ecological monitoring at the EWR sites; and*
- *Resource Quality Objectives (RQO) should be set for the river using the newly published procedure. This would provide clear objectives for future management.*

This on-going monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored.

However the monitoring results are not required before some new plantation forestry can be approved.

Any new licence application for development would need to include information of potential impacts as provided by an Environmental Impact Assessment (EIA) process and potentially a Reserve study, conducted at a local level.

Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively may have a high impact, need to be considered in a larger context. This is especially so for small scale forestry developments. Co-ordination of the management of this larger impact should be the responsibility of DWA with support from the provincial environmental management authority.

ESTUARINE ECOLOGICAL WATER REQUIREMENTS

This study was undertaken without reliable or accurate mouth data for the estuary and when the majority of the work was completed, there was a low overall confidence in the hydrology. Then, near the end of the study, improved flow records were developed, the implications for the estuary were reviewed but the detailed assessments were not repeated.

Flows in the Mzimkhulu estuary are highly seasonal with average winter flows of less than 10 m^3/s and summer averages of about 80 m^3/s. Although shallow, with some intertidal areas in the lower reaches, localised depths of 6 - 8 m occur. Sediments are highly variable temporally and geographically and range from very soft muds to unstable, unconsolidated, coarse sand and gravels. The estuary, in terms of salinity penetration and tidal effects, extends for at least 9,5 km upstream but this is highly dependent on the level of river flow.

Indications are that mouth closure has become more frequent but in the absence of long term monitoring and with the confounding influence of artificial breaching, this finding would have to be treated with caution.

The present major human impacts on the system are; the loss of benthic habitat, resulting from bridge construction with associated rubble deposits and sand mining operations, which, apart from removing habitat, also mobilise fine sediments and contribute to their dispersal and re-distribution by river and tidal currents. Open mouth conditions can be maintained by adequate river flow, which does not necessarily disrupt salinity layering in the upper reaches.

Seven development scenarios based on, the four basic scenarios described above plus those scenarios with dams for mitigation or export of water, and the impacts of the simulated reductions in the water received by the estuary were assessed. Scores indicated that the system could be classified between a B (largely natural with few modifications) and a C (moderately modified).

Allowing the condition of the Mzimkhulu Estuary to decline from its current PES, would have implications, which would have a ripple effect on economic good and services provided by the adjacent marine environment, e.g. the marine fisheries and coastal sediments. Such changes need to be coupled to RQO which need to be set for the estuary using the newly published procedure. This would provide clear objectives for future management.

It is thus strongly recommended that decisions that affect the flow regimes of the Mzimkhulu Estuary carefully consider potential impacts on all users. Given its importance every effort should also be made to implement the measures required to mitigate the non-flow related impacts on the system, such as:

- *eradicate invasive alien vegetation from river banks and floodplains;*
- *remove derelict structures and rehabilitate banks to natural sediments;*
- *prohibit dredge spoil dumping in inappropriate areas;*
- *manage agricultural and industrial practices in the catchment to minimise nutrient and sediment loads entering the estuary; and*

Identified data gaps should also be addressed through improved and on-going monitoring.

GROUNDWATER RESOURCES

The Mzimkhulu River Catchment Water Resources Study was initiated to meet three main objectives, which all directly involve groundwater and its potential to be assessed as an integral part of the resource and its sustainable management:

- *determine the existing and potential future usage of water in the catchment, with reference to the potential of further afforestation;*
- *reassess the hydrology and water supplies available from existing sources; and*
- *investigate schemes for meeting future requirements.*

The following recommendations are made:

- *Groundwater exploration should be carried out from Rietvlei to the north and northwest and be continued:*
  - *Near the Centecow Mission,*
  - *Directly east of Creighton,*
  - *From west-southwest to northwest of Underberg.*
- *Basaltic, doleritic and argillaceous sedimentary rock areas throughout the area should also be investigated for localised water supply.*
- *Shallower soil profiles with increased clay contents could be investigated for localised water supply.*
- *The extreme southern areas of the catchment should not be prioritised for groundwater investigation.*
- *The extreme northern parts of the catchment should only be investigated further if no other viable water resources are available in the area.*

There is significant use of groundwater, primarily in the middle area of the catchment and particularly around Creighton and Underberg.

SURFACE WATER RESOURCES

The objective of the surface water resources task for the Mzimkhulu River Catchment Water Resources Study is to present the updated system yield analysis for the current supply system, as well as for future scheme development options in the catchment. The system was modelled for the period 1920 to 2007 in the WRYM-IMS, using updated hydrology estimates. The model indicated that that the Present day MAR has reduced from a natural state of 1 453 to 1 176 million m^3/a.

The model was configured to include future scheme developments which included five potential dam options and scenarios of increased plantation forestry, irrigation and urban and rural water use. Three scenarios of increased plantation forestry areas were considered:

- *An additional 29 400 ha for small growers throughout the catchment;*
- *An additional 21 050 ha for small growers only in the Bisi and Middle Mzimkhulu catchments; and*
- *An additional 50 350 ha all small and large growers throughout the catchment.*

In addition, a 20% increase in water use by irrigated agriculture was assumed in some scenarios. It was assumed that the future water use by 2030 for rural and urban domestic, industrial and commercial purposes would increase by 60% from current. Potential dam sites were included in the scenarios to provide mitigation for the impacts of increased water demands as a result of additional plantation forestry and irrigation in the catchment by releasing the EWRs for the Gibraltar site in the Lower Mzimkhulu catchment. In addition dams exporting surplus yield were modelled.

The results of the scenario modelling indicate that by providing storage, the impacts of increased plantation forestry and irrigation in the catchment can be mitigated by providing storage while maintaining current EWRs or improving them to meet the PES. Moreover, the dams would provide some surplus yield which could be exported or utilised within the catchment.

PROVIDING ADDITIONAL STORAGE

The development of one or more, new dams to mitigate the impacts, particularly on low flows, of additional forestry, or other water use in the catchment was considered. Reports from previous studies conducted by DWA, Umgeni Water and municipalities were studied. Some 20 possible dam sites had been previously identified on the main stream and tributaries of the Mzimkhulu River, shown in ***Figure 5.***

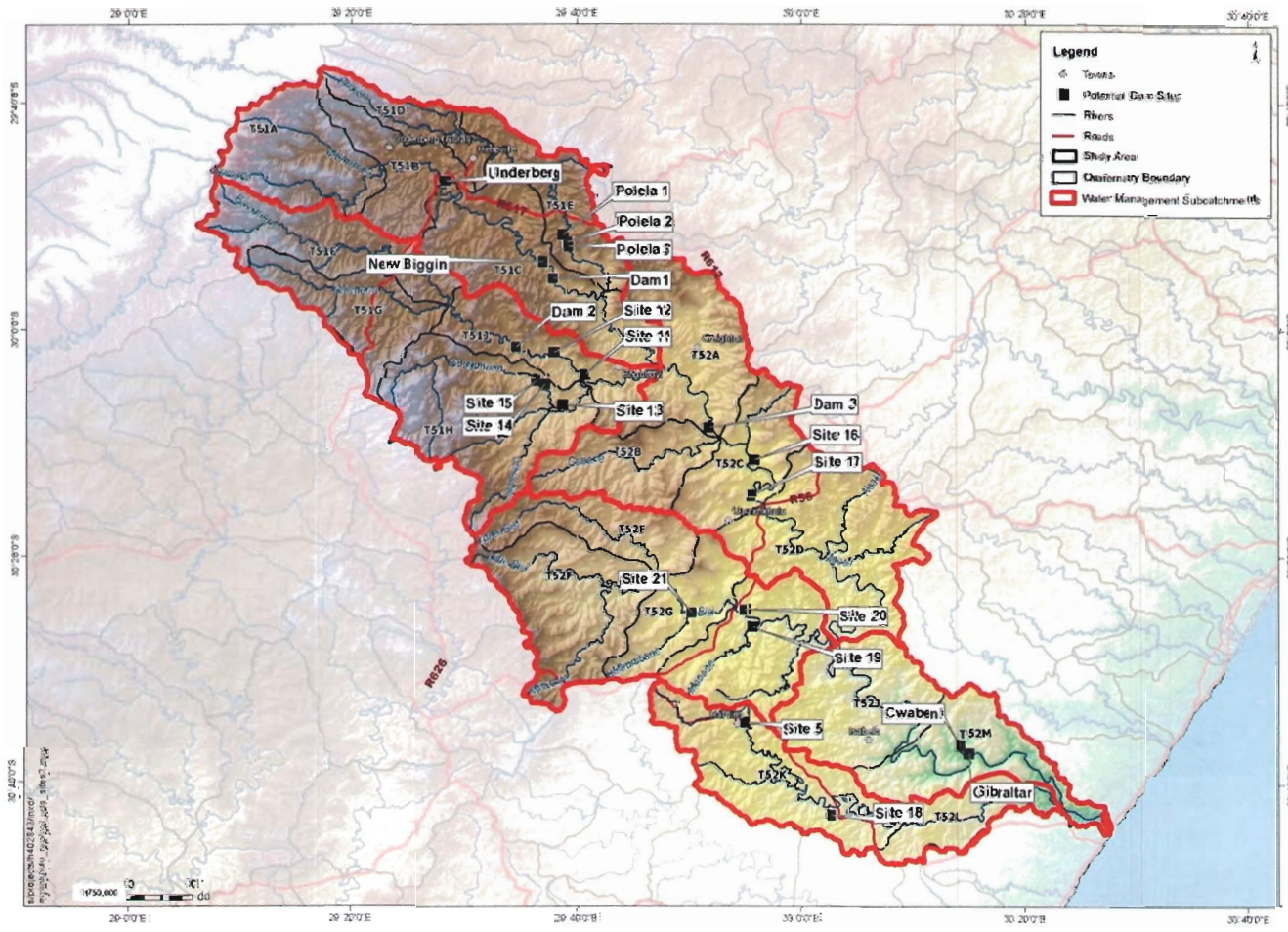

Figure 5: Previously identified Dam Sites

The sites were screened, using various criteria, the overriding one being locality. As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, were regarded as being best positioned to mitigate the impact of forestry on the low flows:

- *Site 12 on the Ngwangwane River, and*
- *Site 19 on the Bisi River.*

To test the impact on the river flows and water available to meet the EWRs a possible large dam with all the surplus yield being exported, a further two sites were selected.

- *Underberg, and*
- *New Biggin.*

CATCHMENT SCENARIOS

When taking into consideration the EWR, there is no historic firm surplus yield from the run of river flows, at quaternary sub-catchment level.

The future scenarios were developed, in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. All known urban and rural demands, projected to 2030, were included. A number of sub-scenarios were run, which are dealt with in the main text of this report and the Management and Development Options Report (WMA 11/T50/00/3009 Volume 2). In Scenarios 1 to 3, below, the dams are sized to meet the present day flows and the EWR at Gibraltar. A 0,5 MAR dam was also modelled, with the surplus yield assumed to be fully utilised or exported.

Future Scenario 1: All Small Growers

Scenario 1 assumes small grower plantation forestry expansion of 29 400 ha, and no increase in irrigated agriculture. Mitigated scenarios sized a dam at Site 12 on the Ngwangwane River, as described above.

The results of the modelling indicated that this relatively large additional plantation forestry development had minimal impact on the present day flows at the Gibraltar EWR site. The present day flows could be restored by a small 10 million m^3 dam (0,04 MAR) at Site 12 on the Ngwangwane River. A larger dam of 45 million m^3 (about 0,2 MAR) would restore the river to meet all EWR flows at Gibraltar. The larger 0,5 MAR dam produced a surplus of 80 million m^3/a.

Future Scenario 2: Small Growers, Bisi

Scenario 2 assumes plantation forestry expansion of 21 050 ha for small growers in the Bisi River catchment, with no increase in irrigated agriculture. Mitigated scenarios sized a dam at Site 19 on the Bisi River.

The results of the modelling indicated that this relatively large additional plantation forestry development had minimal impact on the present day flows at the Gibraltar EWR site. The present day flows could be restored by a dam of just less than 15 million m^3 (0,07 MAR) at Site 19 on the Bisi River. A larger dam of 45 million m^3 (0,2 MAR), on the same site, would restore the river to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 30 million m^3/a.

Future Scenario 3: All Growers, Small and Large

Scenario 3 has an increased forestry area of 50 350 ha, for small and large growers, throughout the catchment, as well as a 20% increase in irrigated agriculture. Mitigated, scenarios were run to size a dam at Site 12 on the Ngwangwane River.

The larger area of additional plantation forestry, had limited noticeable impact on the present day flows at the Gibraltar EWR site and the Bisi site. In this case, the present day flows could be maintained by a small 16,5 million m^3 dam (0,07 MAR) at Site 12 on the Ngwangwane River. A larger dam of 48 million m^3 (0,2 MAR) would be able to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 76 million m^3.

Future Scenario 4: Large Dam Scenario

Scenario 4 explored the impacts on the river and estuarine flows of a significant water resource development, either for export of water or to meet significant new demands. This scenario has the same land and water use as for Scenario 3.

Three cases were modelled, with various combinations of a large 1,0 MAR dam at Underberg, a 1,5 MAR dam at the New Biggin site and smaller dams, at the Bisi and Ngwangwane sites, the latter two, to meet the EWR flows at Gibraltar.

The results indicated that volumes of about 180 million m^3/a from the Underberg site and about 230 million m^3/a from the New Biggin site, could be made available for export, while meeting all EWR flows.

DISCUSSION

At the sites used for the EWR study the Mzimkhulu River was assessed to be in a good condition, somewhat better than expected. The aquatic environment also proved to be fairly resilient, being relatively unaffected by the proposed development of additional forestry and irrigation in the catchment. It emerged that there is limited risk to the environment in allowing a moderate degree of forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows.

Whilst the impact of moderate areas of additional forestry was relatively small at these sites, there may be considerably more severe impacts locally, on some of the smaller tributaries, which will need to be assessed when considering licence applications.

CONCLUSIONS

The overall conclusion is that the state of the ecosystem in this catchment, including the estuary, is generally good and the river is fairly resilient to some additional development in the catchment. By providing storage, the impacts of significant increases in the areas of plantation forestry and increased irrigation would not only be successfully mitigated, but the state of the river could be improved, to fully meet the EWRs at Gibraltar.

The cost estimates of the smallest possible dams at site 12 on the Ngwangwane River and site 19 on the Bisi River to meet all the EWRs at the Gibraltar site, are estimated to be R367 million and R265 million respectively.

Annual costs of redemption of the above loans, over a period of 40 years, at interest rates of 8, 10 and 12% for each of the dams, reduced to a per hectare cost for the three scenarios, vary from R410 to R1 890 depending on areas to be planted and interest rates. Considering that the gross marginal cost of timber production in the catchment, is estimated to be in the order of R2 500/ha/a, provided reasonably large areas of plantation forestry are planted, the mitigation costs of constructing a dam to restore the EWR flows, are within reach.

RECOMMENDATIONS

Short to Medium Term Actions (1 to 5 years)

(a) Water use licensing

- *A further 5 000 ha of afforestation can be planted without undue negative impact. Therefore invite and process licence applications for an initial area of 5 000 ha of plantation forestry in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu Water Management Sub-catchments, with priority being given to small growers.*
- *There is a large amount of alien vegetation in the catchment. Removal of these can be replaced with equivalent afforestation.*
- *Even further afforestation can be done if negative flow impacts are offset with provision of strategically placed storage for releases in dry season.*

(b) Water resource development

- *Investigation of Cwabeni off channel storage must continue in order to have mechanism ready to address dry season water shortages in the short term.*
- *Carry out an initial comparison, including realistic time lines and lifetime economics between the Cwabeni off-channel storage dam and a storage dam on the Ngwangwane and Bisi Rivers, sized to supply Ugu District Municipality's requirements and mitigate the impacts of additional plantation forestry.*
- *Develop groundwater resources for remote rural and urban settlements and where yields are sufficient, also for small scale irrigation to provide food security.*

(c) Water resource management

- *Implement Water Conservation and Demand Management (WCDM).*
- *Validate and verify all registered water use in the catchment and eliminate unlawful use.*
- *Monitor to ensure compliance with licence conditions. Assess any new licence applications for development, considering information on potential impacts as provided by an EIA process and potentially a Reserve study conducted at a local level.*
- *Develop procedures or guidelines to link the removal of invasive alien vegetation to licences for additional forestry.*
- *Educate people in rural areas to prevent over-grazing.*
- *Implement Catchment Management measures, like Working for Wetlands and Working for Water to assist with meeting the Reserve.*

(d) Environmental

- *Initiate a programme to rehabilitate drained wetlands.*
- *Implement on-going ecological monitoring at the EWR sites. Ensure that the ecological state of the river does not deteriorate.*

- *Evaluate the findings of this EWR investigation together with the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from this study will provide information on the Reserve situation in the smaller tributaries.*
- *As soon as possible determine and implement RQO following the newly published procedure, so that there can be clear objectives for the management of the river. Carry out on-going monitoring at the estuary, to allow the effects of development to be properly monitored.*

(e) Hydrological monitoring

- *Review the calibration of key flow gauges.*
- *Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).*

Longer Term Management and Development Options

- *Having implemented the recommended monitoring, assess the impact on stream flow of the water use in the catchment, including that of the first areas of additional forestry, when at least 5 years monitoring is available and the additional forestry has been in place for at least 5 years.*
- *The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.*
- *Reassess the EWR results for the rivers and estuary.*
- *Based on the results for these assessments decide whether or not to invite and process licence applications in batches of 5 000 ha up to say 30 000 ha.*
- *Continue to monitor the inputs to reassess if further licences, potentially up to a total area of 50 000 ha of new plantation forestry can be issued.*
- *Small growers should receive priority.*
- *The impact on the water resource and the environment should continue to be monitored.*
- *Local impacts needs to be evaluated for each application and cumulative effects considered.*
- *If unacceptable impacts are observed and there is still a demand for more plantation forestry, the next recommendation is to undertake a pre-feasibility study to investigate a dam on the Ngwangwane or the Bisi River. The purpose of this dam would be:*
    - *To mitigate as far as possible, the impact of realising the full potential plantation area of 50 000 ha;*
    - *To restore the EWR flows'*
    - *The study should investigate whether there are sites upstream of those modelled on the Ngwangwane and the Bisi Rivers with more favourable capacity to MAR rations;*
    - *To meet the shortfalls at the Ugu's St Helen's Rocks abstraction works on the main river, which could do away with the need for the Cwabeni off-channel dam currently being investigated. This could avoid duplication and save the off-channel pumping costs.*
- *Identify the technical, economic and environmental feasibility of developing a dam.*

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Abbreviations

a	-	annum
BAS	-	Best Attainable State
CBD	-	Central Business District
C-Plan	-	Conservation Planning
DWA	-	Department of Water Affairs (previously DWAF)
DWAF	-	Department of Water Affairs and Forestry
EHI	-	Estuary Health Index
EIA	-	Environmental Impact Assessment
EIS	-	Estuarine Importance Score
EKZNW	-	Ezemvelo KwaZulu-Natal Wildlife
EWR	-	Ecological Water Requirements
GIS	-	Geographical Information System
GRIP	-	Groundwater Resources Information Project
IB	-	Irrigation Board
KZN	-	KwaZulu-Natal
MAP	-	Mean Annual Precipitation
MAR	-	Mean Annual Runoff
msl	-	Mean Sea Level
NFEPA	-	National Freshwater Ecosystem Priority Areas
NWA	-	National Water Act, Act 36 of 1998
PES	-	Present Ecological State
RDM	-	Resource Directed Measures
REC	-	Recommended Ecological Class
RQO	-	Resource Quality Objectives
SANBI	-	South African National Biodiversity Institute
SAPPI	-	South African Pulp and Paper Industry
SKZNPFS	-	Southern KwaZulu-Natal Pre-feasibility Study
WARMS	-	Water Use Authorisation Registration Management System
WCDM	-	Water Conservation and Demand Management
WMSC	-	Water Management Sub-catchment
WR2005	-	Water Resources of South Africa 2005
WRC	-	Water Research Commission
WRSM2000	-	Water Resources Simulation Model 2000
WRYM-IMS	-	Water Resources Yield Model – Information Management System

Scenario keys

U	-	Unmitigated – no dams
M	-	Mitigated by one or more dams
SG	-	Forestry potential for Small Plantation Growers
LG	-	Forestry potential for Large Plantation Growers
A	-	All forestry areas
Irr 20	-	Additional 20% irrigation water use
Bisi	-	Bisi in the Middle Mzimkhulu WMSCs
OCS	-	Off-channel Storage (Cwabeni Dam)

1. INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as the natural river run-off, particularly during the low flow months and in dry periods, was no longer adequate to meet the demands in the lower catchment. There was a concern that the flows might have dropped below the requirements of the Ecological Reserve. This was largely attributed to heavy afforestation and irrigation developments without storage, in various parts of the catchment. The Department was under pressure to grant licences for further afforestation which, if allowed, would exacerbate the situation.

1.1 OBJECTIVES OF THE STUDY

The main objectives of the study as defined in the inception phase are as follows:

- To determine the existing and potential future water use in and from the catchment of the Mzimkhulu River.
- To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry, while also considering other envisaged future requirements.
- To reassess the hydrology and the water supplies available from existing sources, which are mainly run of river, taking the ecological flow requirements into account, in order to determine to what extent the existing sources can meet the existing and potential future usage requirements.
- To recommend possible schemes for meeting future requirements, including potential additional plantation forestry, as well as interventions for moderating existing and potential future usage requirements.

This report describes the assessment of the possible development scenarios and is one of the deliverables in support of meeting these objectives.

1.2 CATCHMENT DESCRIPTION

1.2.1. Overview

The Mzimkhulu River catchment comprises tertiary catchments T51 and T52 with a total catchment area of approximately 6 668 km^2. A map showing the location of the catchment is shown in **Figure 1.1**.

The Mzimkhulu River (the great home of all rivers) rises in the Southern Drakensberg in the Ukhahlamba Drakensberg Park (Garden Castle Forest) at a height of just over 3 000 m in the upper part of Quaternary sub-catchment T51A. It is joined by the Mlambonja and Mzimkhulwana Rivers, after which it flows south of the town of Underberg.

It is later joined by the Pholela and Ngwangwane Rivers.

The upper part of the catchment is characterised by agricultural development, mainly under irrigation and fed by numerous farm dams. The area is serviced by the farming towns of Underberg, Himeville, Creighton and Harding, which have reasonably developed water supply infrastructure. Tourism also plays a large role in the upper catchment, where there are numerous resorts and hotels, many with dams offering boating, trout fishing, hiking, mountaineering, horse riding and golf.

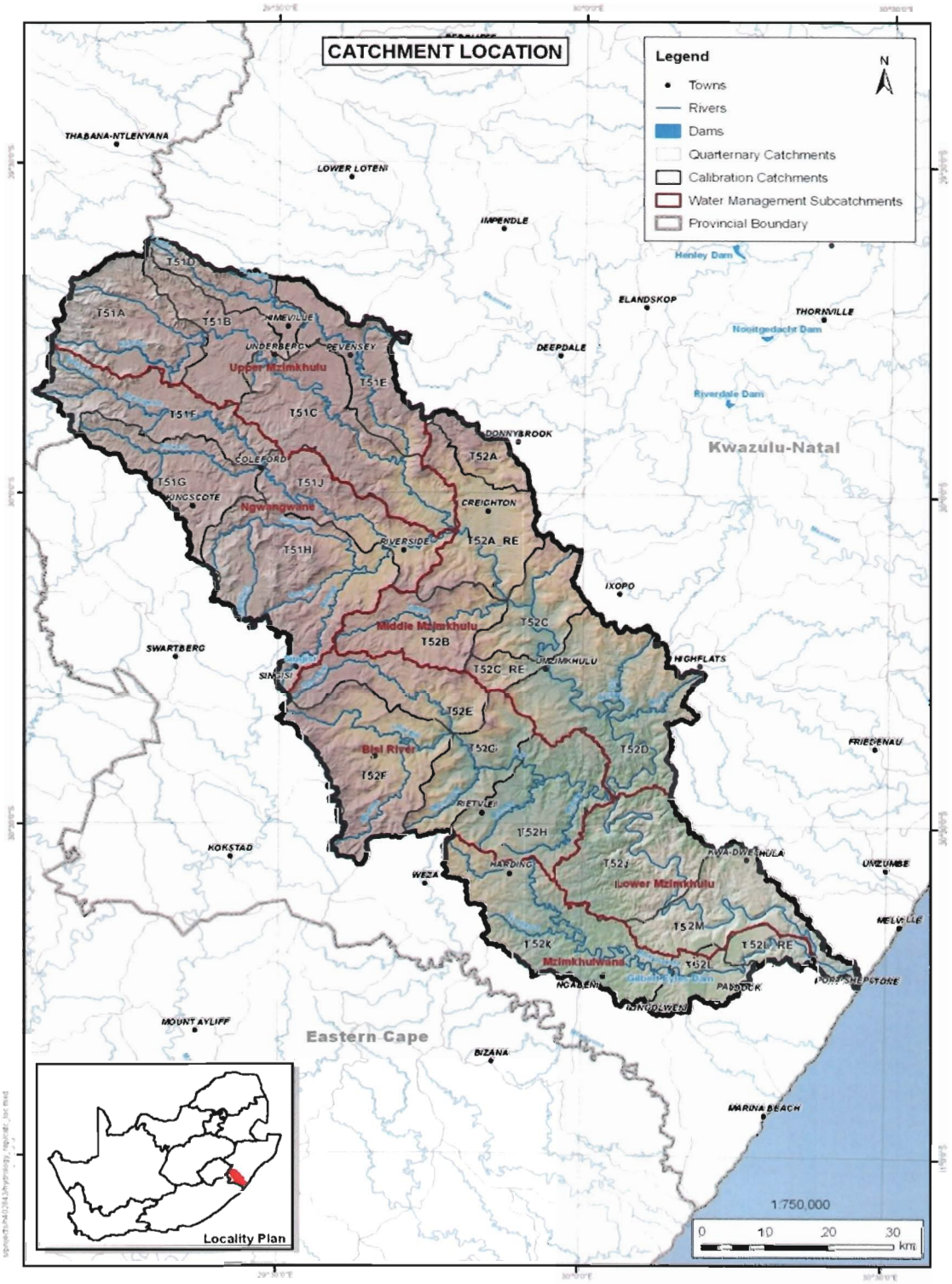

Figure 1.1: Map showing the location of the Mzimkhulu River catchment

Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested. The DWA has put a hold on any further Licences for plantation forestry, because there are water shortages in the lower catchment during low flow periods.

The Mzimkhulu River then flows past the Northern and Eastern sides of the town of Umzimkulu. The Central Business District (CBD) is situated in the flood plain of the river and is subject to periodic flooding. This middle part of the catchment is predominantly rural tribal trust land and formed part of the previously independent Transkei. In this area, there are scattered subsistence rural communities drawing water from run-of-river. There is a great need for poverty alleviation and job creation in this area.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water mostly from local streams, but also from boreholes and springs.

The river then enters a deep gorge, where it is joined by the Bisi River and lower down, the (second) Mzimkhulwana River. The Oribi Flats form a plateau between the gorges of the Mzimkhulu and the Mzimkhulwana Rivers, the latter, emanating from the Oribi Gorge Nature Reserve, a World Heritage Site and well known tourist attraction, with spectacular scenery.

The Mzimkhulu River drains tertiary sub-catchments T51 and T52, then winds its way to the Indian Ocean at Port Shepstone. The estuary used to be navigable, with difficulty, in days gone by and provided a sea link (hence the prefix "Port") with Durban, prior to the construction of the coastal railway line.

1.2.2. Conservation of the "Wild and Scenic" Beauty of the River

The Mzimkhulu River and its tributaries offer a variety of "wild and scenic" sections, and is utilised in many recreational activities specifically for these wild and scenic areas. Recreational use of the catchment includes, canoeing, white water kayaking and rafting, mountain biking, fly-fishing, birding, hiking, horse-riding, climbing and many more. Further several areas of the catchment are characterised by nature reserves and other areas of ecological sensitivity, identified and detailed in the environmental studies. While many areas are conserved for their ecological biodiversity, or ecological functions, supported by the sciences; "Wild and Scenic" incorporates these as well as 'sense of place' (i.e. the emotional experience) of the particular area. 'Sense of place' refers to an interaction between person and place.

With regard to the Mzimkhulu River, "wild and scenic" sense of place is defined as being areas of pristine environment or little disturbance/impacts and areas of natural beauty. It is the specific 'wild and scenic' ambience of these areas that draw the users to these areas. The upper catchments of the Mzimkhulu River and its tributaries are located within the Ukhahlamba Drakensberg Park, a World Heritage Site. This area is preserved as for its pristine, ecological, and historical nature. The entire Drakensberg Mountain Range is considered as "wild and scenic". The sections downstream of the Drakensberg Park to the trout farms upstream of Underberg are undisturbed and should be maintained - the river cuts through ancient rock formations. The dense riparian habitat along the rivers gives

one a sense of being the first explorer to pass under steep stone cliffs and to trample through the forest shadows. The crystal clear water provides habitat to many bird species, invertebrates and wild trout. Also of importance in these upper catchments is the Nsekeni Vlei Wetland, Bushman's Nek area and the Himeville swamp area. These are of ecological importance and contribute significantly towards birdlife biodiversity, ecological functions and areas of scenic beauty. In the middle reaches of the catchment, the river passes through a series of steep gorges, especially below the town of Umzimkulu. Again, this section of the river should be conserved for its wild and scenic beauty, i.e. its identity of being alone with nature, and the recreational interest in this area. In the lower sections of the catchment, the river meanders between towering gorges towards the Indian Ocean, passing through the Oribi region and Oribi Gorge Nature Reserve. This section of the river has been conserved, and its wild and scenic beauty is worthy of further conservation.

Any development within the river catchment will impact on its 'sense of place'. It is noted that the wild and scenic areas are mainly linked to areas already being conserved. Whereas areas already impacted, e.g. water quality impacts due to fish farming and agriculture, draw less interest for recreational use and are regarded as less appealing as they are no longer wild (suggesting undisturbed) and scenic and have an altered sense of place. Therefore any development should be considered for areas already disturbed and impacted, and whose 'sense of place' is associated with development, as opposed to "wild and scenic".

1.2.3. Climate

The Mzimkhulu River catchment falls within the summer rainfall region of South Africa. Rainfall is strongly seasonal with roughly 80% of rainfall occurring from October to March.

1.2.4. Key Statistics

- Catchment Area: 6 668 km^2;
- Natural Mean Annual Runoff (MAR) 1 453 million m^3;
- Present Day MAR: 1 176 million m^3/a;
- Mean Annual Precipitation (MAP): 930 mm; and
- Length of main river: 353 km.

The catchment comprises 21 Quaternary sub-catchments and has been divided into six Water Management Sub-catchments (WMSCs), comprising the following quaternary sub-catchments also shown in **Figure 1.2**:

- Upper Mzimkhulu: T51A, T51B, T51C,T51D, T51E;
- Ngwangwane: T51F, T51G, T51H, T51J;
- Middle Mzimkhulu: T52A, T52B, T52C, T52D;
- Bisi: T52E, T52F, T52G, T52H;
- Mzimkhulwana: T52K, T52L; and
- Lower Mzimkhulu: T52J, T52M.

Figure 1.2: Project Area, showing the Quaternary sub-catchments and the six Water Management Sub-catchments

2.2.2. Human Settlement:

The volumes consumed in urban areas in the catchment (excluding Port Shepstone) amount to 3,0 million m^3/a, based on the population living in these towns. In contrast, rural settlement accounts for 6,2 million m^3/a, which estimate is inclusive of differentials in consumption associated with a range in levels of service. Together, human settlement in the catchment currently accounts for 9,1 million m^3/a. The total water use for Port Shepstone, which is outside the catchment but supplied from it, is 16,7 million m^3/a.

2.2.3. Industry and Commerce:

Volumes consumed for industries and quarries located in rural areas of the catchment amount to 1,52 million m^3/a, whilst that in the urban areas is 53 400 m^3/a in 2009. The consumption figures for commerce are confined to the urban areas and in 2009 were estimated to be 760 000 m^3/a.

2.2.4. Agriculture (dryland and irrigation):

Dryland arable consumption, apart from sugar and plantation forestry, has been treated in the same way as natural grasslands, where consumption has been factored into baseflow as a pre-existing use.

In contrast, irrigation represents a significant water user, based on abstraction from rivers and dams in the catchment. The factors in the land and water use section of the report used in determining irrigation demand on different crop types were derived from the following sources: Irrigation Boards (IB's), the Department of Water Affairs', Water Use Authorisation Registration Management System (WARMS) database and communication with the Department of Agriculture (Section 4.3 Table 35). The final factors used in the modelling were based on those built into the Pitman Model where the above data was used for comparative and verification purposes.

2.2.5. Plantation Forestry Potential:

In order to determine the commercial forestry potential, a negative mapping process was used. The details are contained in the Land Use and Water Requirements Report, *(WMA 11/T50/00/3009, Volume 9*) of this study.

The study examined the existing land use and the climatic, topographic and soil conditions required for forestry and exclusion criteria related to the following factors were adopted:

- Existing land use;
- Ezemvelo KwaZulu-Natal (KZN) Wildlife Conservation Plan (C-Plan);
- Topographical Factors;
- Hydrological Factors; and
- Agricultural Factors.

In addition, the potential of the soils to grow timber was determined, using the soil type, depth, clay content and Bioresource unit slope, giving rise to four classes of

bio resource units, Poor, Low, Medium and High. The areas with soils in the Poor class were excluded. The percentage of suitable soils in each of the other classes and the total area with potential is shown in **Table 2.2**.

Table 2.2: Summary of Plantation Forestry Potential

Suitability	Commercial potential (ha)	Small Grower Potential (ha)	% of suitable land
Low	56 170	41 701	20 – 40%
Medium	24 673	15 507	40 – 60%
High	16 608	12 405	>60%
Total	**97 451**	**69 613**	

Applying further filtering criteria throughout the catchment, and using more conservative criteria where small growers were involved, resulted in potentially suitable areas of:

- 50 350 ha for all growers (inclusive of small growers);
- 29 400 ha for small growers, and
- 21 050 ha for the small growers in the Bisi and Middle Mzimkhulu WMSCs.

Figure 2.3 provides a spatial view of areas in the catchment with poor, low, medium and high potential for forestry for all growers.

2.2.6. Background and inputs to scenarios

In order to assess the impact of developing additional areas of plantation forestry, the Mzimkhulu River system was modelled for the period 1920 to 2007 in the Water Resources Yield Model – Information Management System (WRYM-IMS), using updated hydrology, all known water demands, as well as riverine Ecological Water Requirements (EWRs) to maintain the Present Ecological State (PES), extrapolated to each quaternary sub-catchment for the present day system.

The surplus yields for each quaternary sub-catchment were calculated initially, to determine which catchments might have available yield which could be taken up by the future development of plantation forestry.

Future development scenarios were then developed in order to test the impact of possible future developments within the catchment, on the flows downstream and to test their impact on the EWRs. In all the scenarios, Port Shepstone's projected future (2030) water demand of 27 million m^3/a, from the Mzimkhulu River abstraction works at St Helen's Rock, was taken into account. Projected future land and water use requirements discussed above and in more detail in the Land Use and Water Requirements Report, *(WMA 11/T50/00/3009, Volume 9)*, were modelled and EWRs were included for each quaternary catchment for the PES. Four basic development scenarios were evaluated with the following increases in forestry and irrigation:

i. 29 400 ha of forestry on land suitable for small growers
ii. 21 050 ha of forestry on land suitable for small growers in the Bisi catchment

Agriculture and plantations are the predominant land use in the catchment, covering 67% of the land currently developed for commercial production. Activities include irrigation, dryland cropping, plantation forestry and livestock farming. This is followed by indigenous forests and protected grasslands, covering 16% of the catchment. A further 14% is allocated to human settlement (urban and rural) and transportation infrastructure. The remaining area is attributed to rural industry and water bodies.

Irrigated agriculture covers approximately 20 000 ha and uses just under 90 million m^3 of water per annum. Plantation forestry uses about 113 million m^3/a.

Table 2.1 and **Figure 2.2** summarise the total volume of use in the Mzimkhulu catchment, by sector, in 2010. The total estimated current water use is 277,7 million m^3/a. The highest water users in the catchment are plantation forestry and irrigation, which account for 41% and 31% of annual water use respectively. Irrigation represents a significant water user, based on abstraction from rivers and dams in the catchment. Alien vegetation accounts for 14% and rural, urban, industrial and commercial requirements account for 10%. Of the total, the remaining 4% is made up of demands for dryland sugar and livestock watering

Table 2.1: Summarised Land Use and Water Requirements

Land Use	Total Water Requirement (Million m^3/a)	Demand as percentage of total
Plantation Forestry	112,7	41%
Irrigation	86,6	31%
Alien Vegetation	39,7	14%
Rural, Urban, Industrial & Commercial	28,1	10%
Dryland Sugarcane	6,8	3%
Livestock watering	3,8	1%
Total water use	**277,7**	**100%**

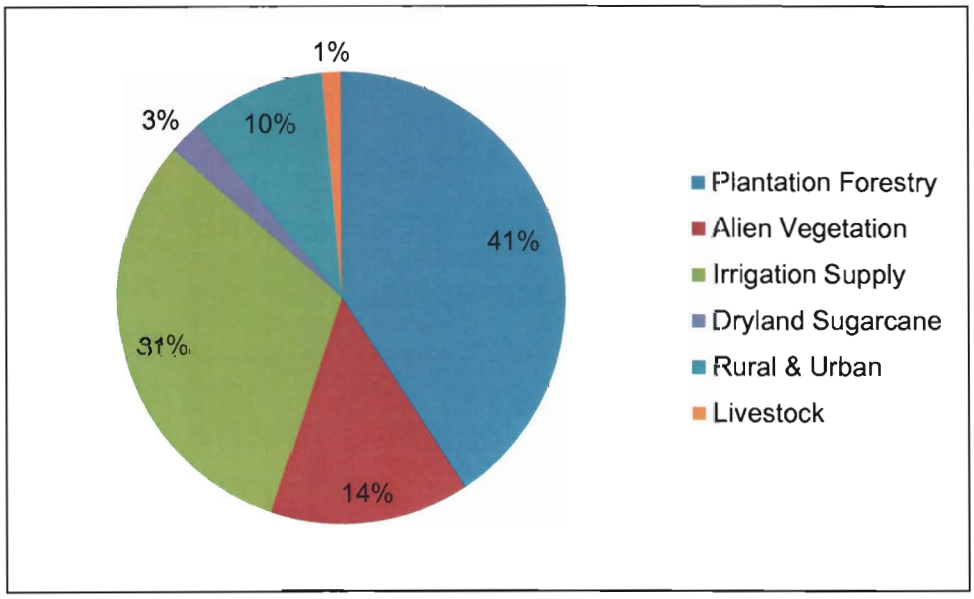

Figure 2.2: Breakdown of Water Use in the Mzimkhulu Catchment by Sector

2. LAND USE AND WATER USE

2.1 INTRODUCTION

This report presents the land and water use components of the Mzimkhulu River Catchment Water Resources Study. The report deals with current water uses in the catchment, which in turn provides the basis for inputs into the hydrological model.

The land use component of the Mzimkhulu River Catchment Water Resources Study has involved the extraction of data from satellite imagery in each of the 21 quaternary sub-catchments, which comprise the catchment. Further investigation was required into each of the identified land uses, in order to establish water use for each of the classes of land use.

Different methodologies were developed as the project progressed, to enable members of the land use and hydrological teams to extract relevant data from a wide variety of different sources. This report provides an explanation of the methods used and the outputs produced on current water use in the Mzimkhulu River catchment.

2.2 SUMMARY OF KEY OUTPUTS

2.2.1. Land use

The volumes of water consumed by the various water use sectors in the catchment are discussed in the Land Use and Water Requirements Report, *(WMA 11/T50/00/3009 Volume 9)*. The present day land use is shown in **Figure 2.1**.

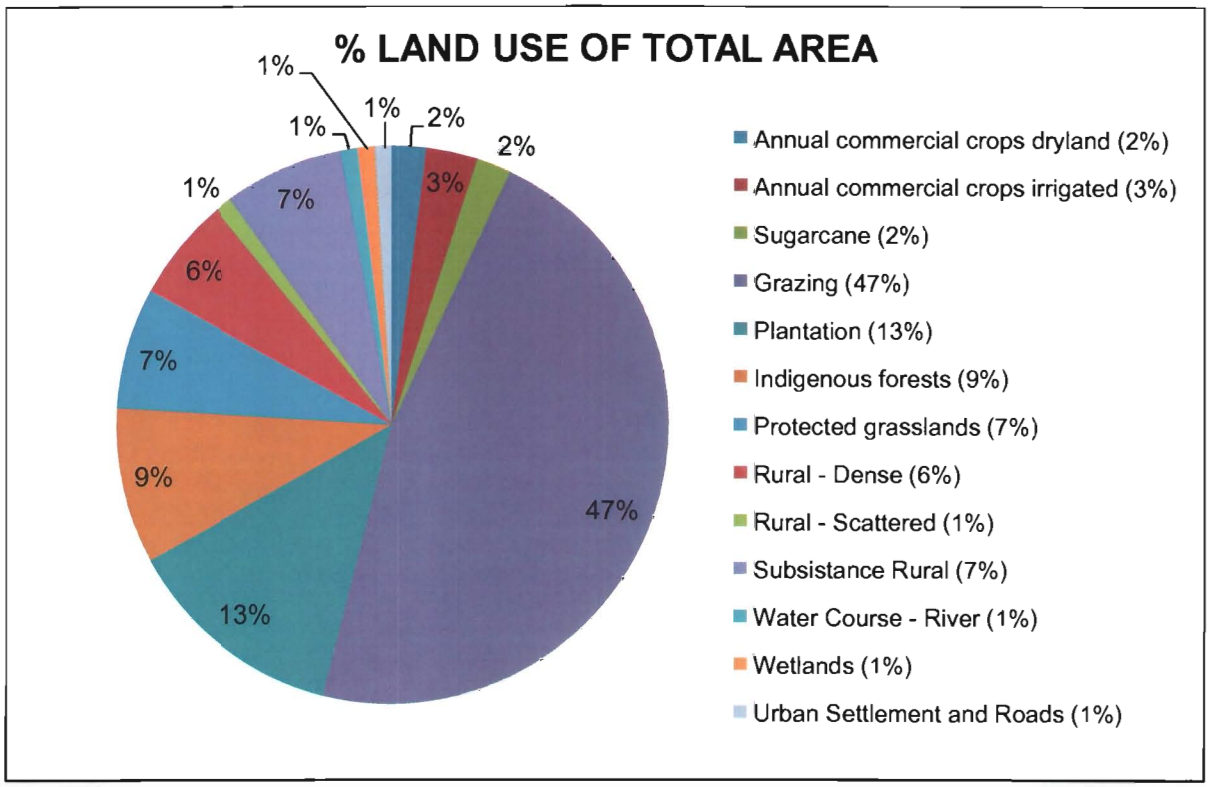

Figure 2.1: Percentage Land Use of total Area

iii. 50 350 ha of forestry throughout the catchment, with 29 400 ha of the land being suitable for small growers and a 20% increase in water use for irrigated agriculture.
iv. As for Scenario (iii) with a large dam to export water.

Each has a number of sub-scenarios as shown in **Table 2.3**, giving a total of 15 future development scenarios. More details are given in Chapter 9 and in the Management and Development Options Report *(WMA 11/T50/00/3009, Volume 2)*.

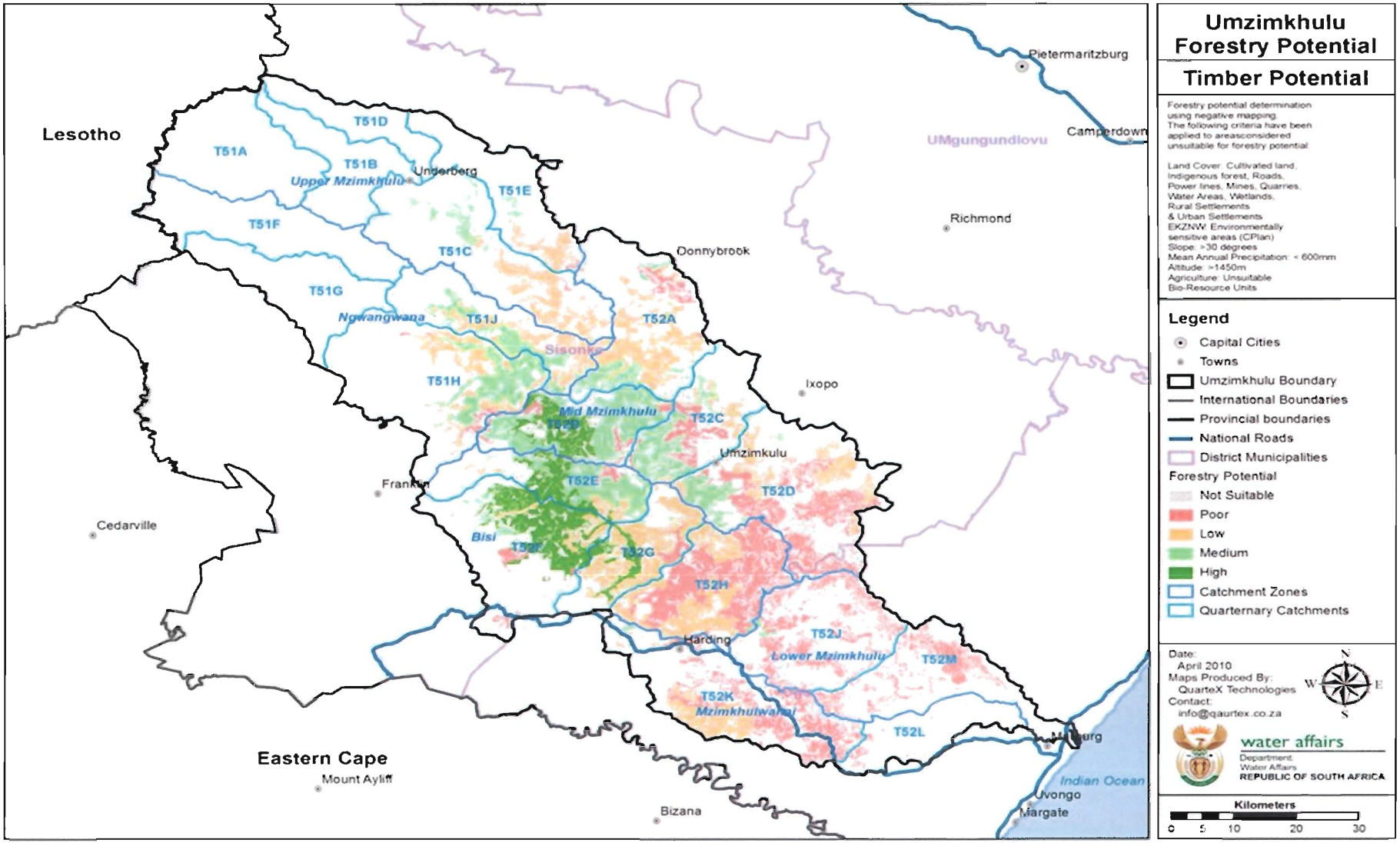

Figure 2.3: Areas with Potential for new Forestry

Table 2.3: Summary of Future Development Scenarios

Scenario	FS 1U_OCS (SG A)	FS 1M 1 (SG A)	FS 2M 2 (SG Bisi)	FS 3U OCS (LG A + Irr 20)	FS 4a (M: LG A)	FS 3M 1 (LG A + Irr 20)	FS 4c (M: LG A Full)	FS 4c (M: LG A Low)
River EWR Scenario Number	1	2	3	4	5	-	6	7
Estuary EWR Scenario number	3	4	5	6	2	7	1	-
increased forestry	29 400 ha	29 400 ha	21 050 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha
increased demand from irrigated agriculture	NIL	NIL	NIL	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)
Cwabeni OCS	Yes (and No)	No	No	Yes (and No)	No	No	No	No
Dam at site 12 (Ngwangane)	No	0,5 MAR Operated to meet all EWRs at Gibraltar in all months		None	0,17 MAR Operated to support the dam at site 19 to meet all EWRs in all months at Gibraltar – surplus yield exported	0,5 MAR Operated to meet EWRs at Gibraltar and surplus yield exported		
Dam at site 19 (Bisi)	No	No	0,18 MAR Operated to meet all EWR flows in all months at Gibraltar	No	0,18 MAR Operated to meet all EWR in all months at Gibraltar – surplus yield exported	No	0,5 MAR Operated to meet all EWRs in all months at Creighton and Gibraltar. Surplus yield exported or used.	0,5 MAR Operated to meet EWRs in low flow months at Creighton and Gibraltar. Surplus yield exported or used.
Dams for water use or export					1,0 MAR at Underberg All yield exported out of the basin. Export 180 million m^3/a.		1,5 MAR dam at New Biggin All yields exported out of basin. Export 227 million m^3/a.	1,5 MAR All yields exported out of basin. Export 227 million m^3/a

NOTES:

1. In all scenarios the base is present day infrastructure, forestry and irrigation agriculture.
2. In all scenarios the growth in urban and rural domestic water use is a 30% increase up to 2030 and includes the coastal strip, supplied by Port Shepstone, with seasonal demands.
3. Scenario 4b was defined but not modelled.

3. HYDROLOGY

3.1. INTRODUCTION

The objective of the catchment hydrology task for the Mzimkhulu River Catchment Water Resources Study is to present the updated hydrology for the study area in order to support the determination of existing and potential future water use, to assess the opportunities and water available for future economic development, and to recommend possible schemes for meeting future requirements with a specific focus on the potential for development of plantation forestry in the catchment. Monthly simulated runoff sequences are produced which are used in the system yield analyses relating to present and future land-use development scenarios and scheme development options.

3.2. GENERAL APPROACH

The hydrology of the Southern KwaZulu-Natal Pre-Feasibility Study (SKZNPFS) (DWAF, 2002) which was for the period 1925 to 1998, was used as a point of departure and it was updated with the latest land and water use information, representing the 2007 hydrological year. The Water Resources Simulation Model (WRSM2000) was configured and calibrated with this information in order to generate monthly flow sequences using the following approach:

- Capturing and processing spatial data for use in the Pitman model including rainfall, evaporation, irrigated areas and crop types, afforested areas and alien vegetation areas, water demands, abstractions and return flows, transfers and farm dam information.
- Sub-catchment configuration informed by previous studies and availability of spatial data and observed flow gauge data.
- Calibration of the Pitman model in WRSM2000.
- Produce long term naturalised flow sequences.

3.3. RESULTS

A summary of the calibration results for the Mzimkhulu River sub-catchments is shown in **Table 3.1**. Wherever possible the calibrated flows are based on longer flow records, than in previous studies and the naturalised flow sequences (1920-2007) for the Mzimkhulu River sub-catchments appear to compare well with the estimates from the previous study (SKZNPFS), with a difference of 11% in the T51 tertiary catchment and 5% in the T52 tertiary. There are larger differences on a quaternary level and these can be attributed to inter alia, changes in land use areas and more up to date land use information, longer observed flow records on which to calibrate, different combinations of rainfall stations, updated software and techniques for streamflow reductions and calculation of irrigation demands. The Natural and Present Day MARs per quaternary sub-catchment are shown in **Table 3.2**.

Table 3.1: Summary of Mzimkhulu River sub-catchment calibration results

Flow Gauge	MAP (mm)	Catchment area (km^2)	Patched observed MAR (million m^3/a)	Calibration period
T5H004	1 229	534	240,15	1960-2007
T5H003	1 234	139	66,20	1964-2007
T5H005	958	97	24,69	1956-1991
T5H007	999	3 589	1 003,22	1956-1977
T5H002	899	870	153,46	1998-2007
T5H012	811	531	33,13	1980-2007

Table 3.2: Natural and Present Day MARs per quaternary sub-catchment

Quaternary sub-catchment	Natural MAR: Incremental	Present-Day MAR: Incremental	Incremental Present Day MAR as a % of Natural MAR	Natural MAR: Cumulative	Present-Day MAR: Cumulative	Cumulative Present Day MAR as a % of Natural MAR
	(million m^3/a)	(million m^3/a)	(%)	(million m^3/a)	(million m^3/a)	(%)
T51A	157	149	94,9%	157	149	94,9%
T51B	87	74	85,1%	244	224	91,8%
T51C	117	88	75,2%	487	415	85,2%
T51D	66	60	90,9%	66	60	90,9%
T51E	60	44	73,3%	126	104	82,5%
T51F	117	100	85,5%	117	100	85,5%
T51G	91	81	89,0%	91	81	89,0%
T51H	123	112	91,1%	123	112	91,1%
T51J	52	45	86,5%	383	339	88,5%
T52A	94	65	69,1%	964	819	85,0%
T52B	50	44	88,0%	50	44	88,0%
T52C	48	32	66,7%	1 063	894	84,1%
T52D	29	22	75,9%	1 092	916	83,9%
T52E	56	44	78,6%	56	44	78,6%
T52F	97	71	73,2%	97	71	73,2%
T52G	65	56	86,2%	218	172	78,9%
T52H	28	24	85,7%	246	196	79,7%
T52J	35	31	88,6%	1 372	1 143	83,3%
T52K	33	23	69,7%	33	23	69,7%
T52L	15	11	73,3%	48	34	70,8%
T52M	33	29	87,9%	1 453	1 206	83,0%
T51 total	**870**	**753**	**86,6%**	**870**	**753**	**86,6%**
T52 total	**582**	**452**	**77,7%**	**1 453**	**1 206**	**83,0%**
Total	**1 453**	**1 206***	**83,0%**	**1 453**	**1 206***	**83,0%**

* The Present Day simulated MAR according to the WRYM-IMS = 1 176 million m^3/a

3.4. CONCLUSIONS AND RECOMMENDATIONS

The key objective of this task was to update and extend the naturalised streamflows and water requirements to the 2007 hydrological year to take forward to the system model for scenarios analysis, which has been achieved.

Rainfall data is one of the most important data requirements for hydrological modelling and the density of the existing rain station coverage is low. The accuracy and reliability of rainfall information in the catchment could be improved with continued monitoring and maintenance of the existing stations. Re-instatement or re-opening of closed gauges in key areas, specifically in the low-lying areas of the Ngwangwane and Middle Mzimkhulu catchments is recommended, in order to improve the density and coverage of active rainfall stations in the network.

The flow monitoring network in the Mzimkhulu catchment is adequate for a general water resources assessment, but should be improved if significant new socio-economic developments, such as plantation forestry, are planned. It is important that existing flow gauges remain open and continue to be monitored and maintained. It would be useful to monitor flows for the tributary of the Ngwangwane River, just upstream of the confluence with the Mzimkhulu, as well as on the main stem downstream of Umzimkulu town in the lower catchment. The quality of the observed data is fairly good for most flow gauges however the records are relatively short because many of the gauges were closed during the independence of the Transkei and re-opened afterwards.

4. WATER QUALITY

A comprehensive assessment of the water quality situation was not envisaged as part of the project because such an assessment was undertaken, with data collected up to 1999, as part of the SKZNPFS (DWAF, 2002). Since then, about eight years of additional water quality data have been collected in the catchment and a brief review of the water quality situation was undertaken to determine if the water quality trends described previously, have changed, or if new water quality issues have emerged since then. To compare findings, the catchment was divided into three parts, shown in **Figure 4.1**, and the data was analysed with the WQStat Plus statistical software package.

4.1. UPPER BASIN

It was previously found that *"the land use and the water quality data both indicate good water quality with no significant signs of pollution, or any adverse trends in water quality. Treatment of abstracted water should not pose any problem. No additional monitoring is considered necessary due to the fact that water pollution is unlikely. The current water quality data available is considered sufficient at this stage".* This study confirmed that the status quo remained largely unchanged in the upper basin and that the conclusions drawn previously were still valid.

4.2. MIDDLE BASIN

It was previously found that *"the data indicate good water quality with no signs of pollution and should not be difficult to treat to potable water standards. There is a greater percentage of agricultural activity and urban land that warrants additional data collection to improve assessment of water quality. Sampling at the DWAF site T5H007Q01 or at a site on the river above Umzimkulu town is recommended."* This study confirmed the status quo but specific concerns were expressed about the state of the river near the town of Umzimkulu. It is recommended that a water quality study be undertaken in that area to identify potential pollution sources and management interventions to address local impacts.

4.3. LOWER BASIN

It was previously found that *"the overall water quality in the Mzimkhulwana River is not as good as that in Basins 1 and 2, which could be due to agricultural activities. The prediction would be poorer water than in the upper basins. The water quality is considered to be moderate and should be suitable for consumption after treatment. Sampling of the Mzimkhulu River above its confluence with the Mzimkhulwana River is recommended. Additionally, the Mzimkhulwana River should be sampled either at the DWAF site (T5H012Q01) or just before its confluence with the Mzimkhulu River."* In the lower basin (Basin 3) water quality monitoring stopped in 1996 making it impossible to draw meaningful conclusions about a possible change in status.

A previous recommendation to improve monitoring in the lower basin is strongly supported and the DWA is encouraged to review and maintain their water quality monitoring in the Mzimkhulu River catchment in order to track water quality changes as further development of the catchment continues.

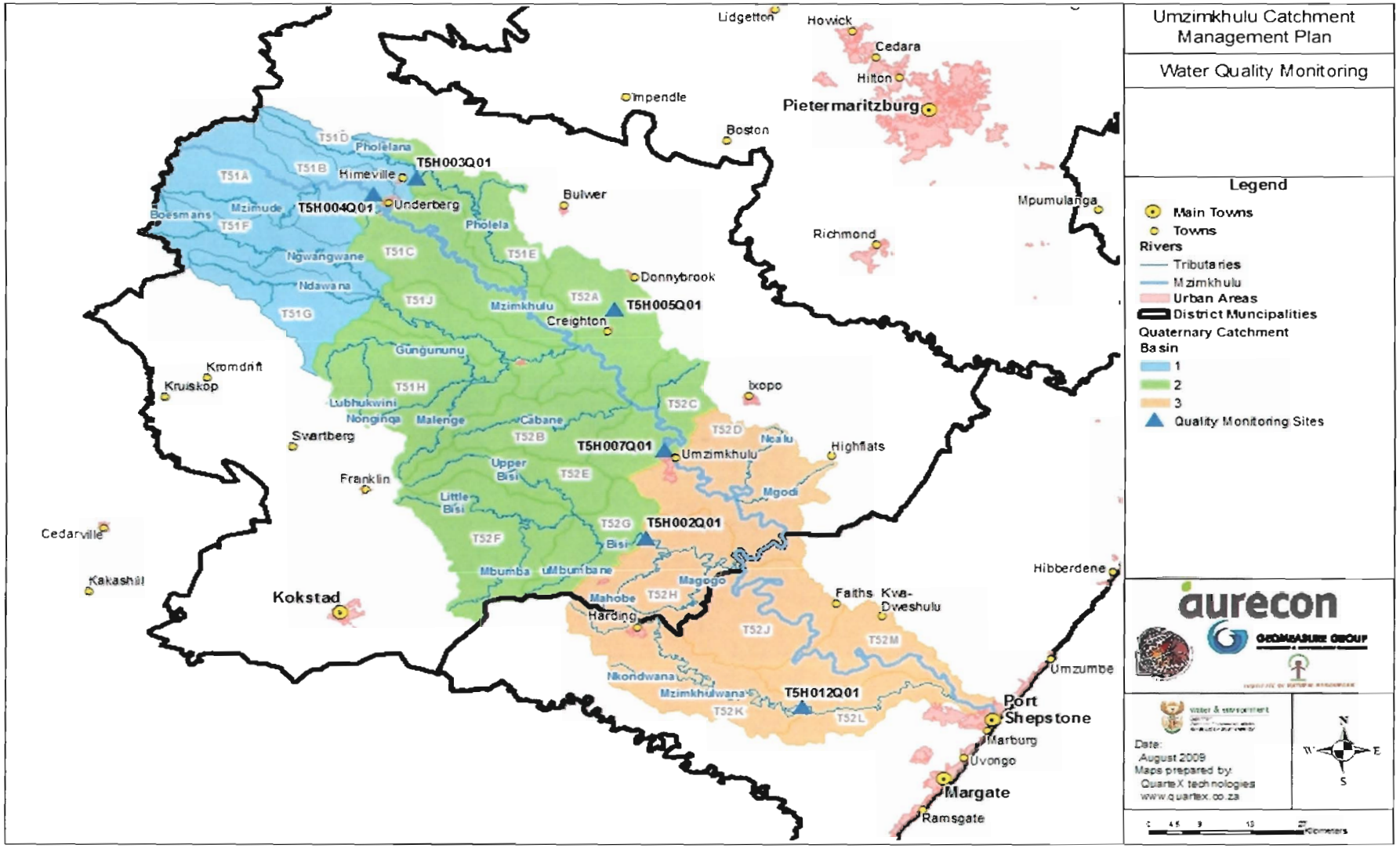

Figure 4.1: Map of the Mzimkhulu River catchment showing the three basins and water quality monitoring network

5. RIVERINE ECOLOGICAL WATER REQUIREMENTS

5.1 INTRODUCTION

The Riverine Ecological Water Requirements are dealt with in detail in the Riverine Ecological Water Requirements Report, *(WMA 11/T50/00/3009, Volume 5)* of this Study. This investigation was initiated by pressure for expansion of, in particular, the forestry industry, with numerous applications for planting additional forestry having been put on hold, pending the findings of this study. There was a prior perception that the resources in the catchment were already overdeveloped, based largely on the fact that water resources had become limiting at the lower end of the river, where Port Shepstone at times does not have adequate supplies. The Mzimkhulu River Catchment Water Resources Study was required to assess the availability of water and the pressures being placed on this water, in the different parts of the catchment.

Against this background, the objective of the river EWR (or Reserve) determination was to quantify the requirements of the river environment for a quantity of water, as is required by the National Water Act, Act 36 of 1998, (NWA). The Ecological Reserve is considered by the NWA to be one of only two rights to access to water; the other being the basic human needs Reserve. The rationale behind this is that the EWR represents the actual resource, and to damage this would be to damage the potential for other users to have access to the water.

The study commenced in 2009 and the field work and scenario assessment were completed in early 2011. The work was based on the 2010 hydrology and modelling of the impacts of future development scenarios on the flow regimes. On 12 March 2011 revised hydrology became available and the impact of the future developments on the flow regimes was re-assessed. The implications of the possible development scenarios using the 2010 hydrology on which the EWR work was based and an assessment of the implications of the March 2011 flow regimes are discussed below.

5.2 APPROACH TO THE DETERMINATION OF THE EWR FOR THE RIVER

The approach that has been followed is essentially to reproduce the methods that have been applied previously to other catchments and thus have been approved by the Resource Directed Measures (RDM) office of DWA. While these methods have been seen to evolve over time, the most recent examples of the Vaal and Crocodile West EWR determinations have been used to illustrate the latest thinking.

The EWR determination has been carried out with a mixture of approaches, with the INTERMEDIATE approach applied to five of the sites and the RAPID III approach applied to the remaining three sites. The former approach undertakes the investigation at a greater level of detail, entailing a more extensive survey as well as two visits to each site. The latter approach is confined to a single site survey using a reduced number of methods. The latter naturally has a lower confidence in terms of the results that are produced. The EWR sites are shown in **Figure 5.1**.

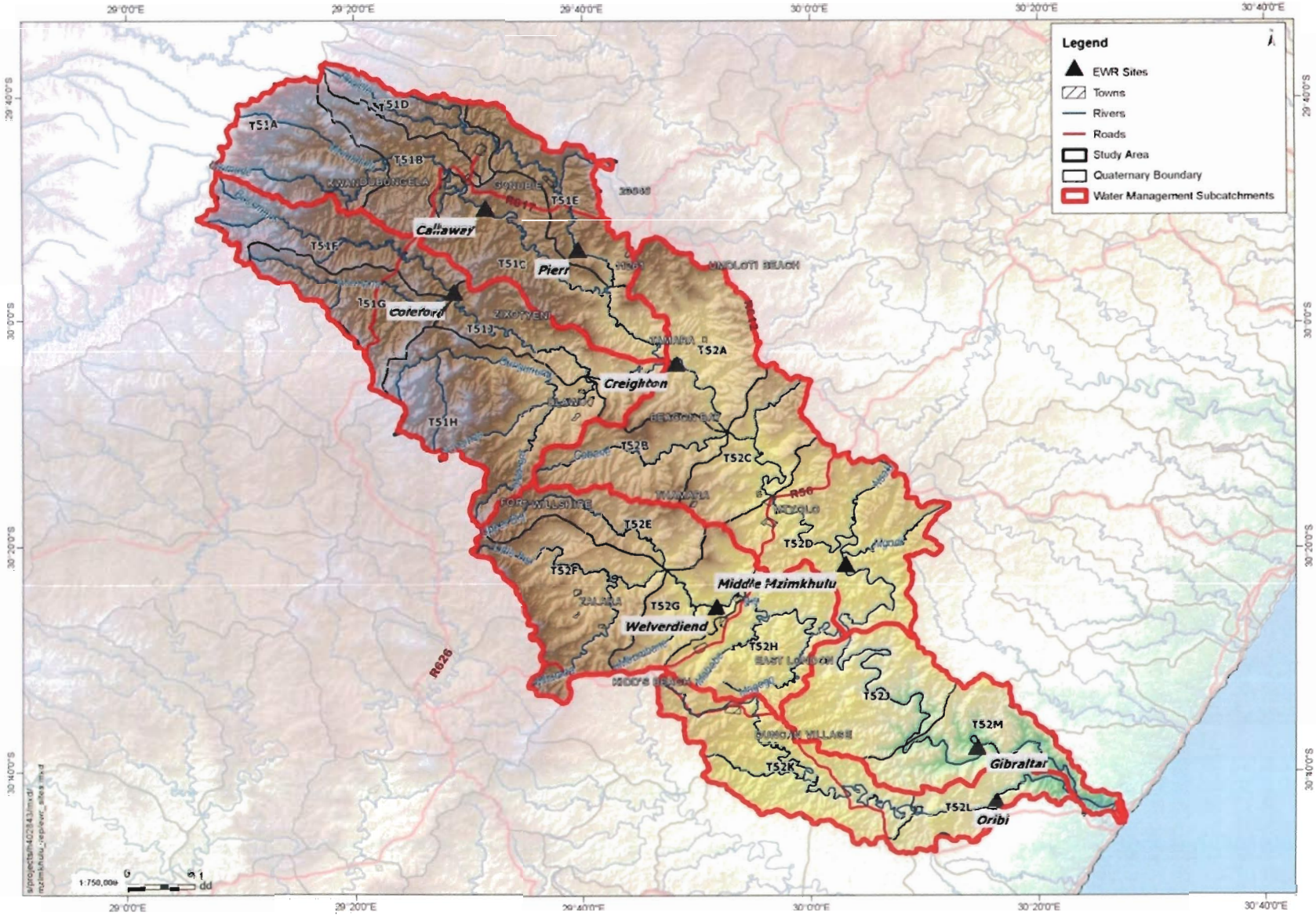

Figure 5.1: Location of EWR sites

5.3 THE PRESENT ECOLOGICAL STATE OF THE MZIMKHULU RIVER

Surveys were conducted twice at five of the sites and once for three of the sites, where intensive ecological data and information was collected to describe the PES of the river and its major tributaries. The results of this investigation are summarised in **Table 5.1**.

Essentially the main river and its tributaries are in a "B category" or higher indicating that the ecosystem is in a near natural or only slightly transformed state. This, despite the fairly heavy developments that have taken place in the upper catchment and the degradation of many parts of the catchment due to poor land-use practices, particularly in the middle parts of the catchment. It has to be cautioned though, that this conclusion could be misleading as the investigation was carried out on the main-stem river as well as the downstream, larger portions of some of the main tributaries. No investigation was carried out where the tributary size is small, and where local impacts may be severe. For example, small streams amongst extensive forestry plantations or irrigation schemes, may present a different story. However, the results do indicate that the river overall, its main artery, remains in good condition.

Despite the developments that have taken place, the water quality remains relatively good. This is largely due to the nature of the developments in the catchment which are generally non-polluting and because of the relative isolation of settlements from open water. Possibly the greatest risk from a water quality point of view lies in the town of Umzimkulu which discharges effluent of questionable quality directly to the river. A more important reason for the degradation that has taken place is the large amounts of water being removed from the water resource. While the minimal degradation suggests that these volumes of water were surplus to the needs of the ecosystem, it is probably that the point where more serious degradation will start to happen is being approached.

5.4 DETERMINATION OF THE ECOLOGICAL WATER REQUIREMENTS

A process was followed to determine the EWR for the sites being investigated, and also to extrapolate this to the remaining quaternary catchments which were not investigated. This determination describes the quantity of water, its volume and timing of flow that is necessary to maintain the ecosystem in a defined condition. In this study the first assessment was the water required to maintain the river in its PES. It was found that only a portion of the available water was necessary to maintain the river in this state, as summarised in **Table 5.1**. This ranged from 21 to 43% of the natural flow in the tributaries to between 21 to 30% for the main Mzimkhulu River. The assessment breaks this down to show the amount of water that is needed during the low flow seasons (i.e. the maintenance baseflow) as well as in the form of floods. It also considers the reduced volume that is needed to sustain the river during drought periods, which in semi-arid regions such as this are necessary for the maintenance of biodiversity in rivers.

5.5 ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

A number of possible development scenarios were developed by other parts of this Mzimkhulu River Catchment Water Resources Study and are presented in detail in other volumes. Essentially, the development scenarios entailed the development of between 20 000 and 50 000 ha of forestry in the areas most suitable for forestry development (mainly the mid-altitude parts of the catchment), as well as the development of additional

irrigation with an increase in water use by that sector of 20%, mostly in the upper reaches of the catchment. A number of dam options were also investigated; some considered merely providing mitigation for the forestry and irrigation developments, and others as water storage reservoirs to supply consumptive users.

The ecological consequences of a number of these scenarios were assessed in much the same way that the EWR for the present flow situation was assessed using the 2010 flow scenarios. The impact of possible scenarios is described in terms of the change in the flow regime in the river, as represented at the different EWR sites, and the implications of this for the different parts of the ecosystem. This was assessed based on the present situation and an understanding of the ecosystem. A summary of the ecological impacts of the various scenarios is provided in **Table 5.2**. A full description of what each of these scenarios entails and what consequences were predicted is available in Chapter 4. The key aspects of each scenario were given in Table 2 of Volume 5 of this Study. In brief, four scenarios, FS 1U_OCS (SG A); FS 1M 1 (SG A); FS 2M 1 (SG Bisi) and FS 3U OCS (LG A + Irr 20), describe situations where there is an increasing amount of forestry and/or irrigation in the catchment together with strategically placed small dams designed to provide only for the EWR in the main river. It can be seen from **Table 5.2** for the 2010 flow scenarios that, in all of these situations, the ecological consequences are minor.

Three scenarios FS 4a (M: LG A); FS 4c (M: LG A Full) and FS 4c (M: LG A Low), describe situations where there is maximum development as well as the construction of a large dam on the main stem Mzimkhulu River as well as in some cases on a tributary. Various combinations of dams were modelled to provide mitigation of the EWR and also to store water for use in the catchment or to be exported. These are the only scenarios where it is anticipated there would be a significant drop in the ecological state of the river, as a result of these developments.

Probably the main reason for the limited impact of development and the prediction that the river will remain in a relatively good condition is that a large portion of the river flow falls on the pristine Ukhahlamba Drakensberg Mountains from where it flows unimpeded to the sea.

Table 5.1: Summary of the Ecological Water Requirements for the Mzimkhulu River and Tributaries

Quaternary catchment	River	EWR site number	EWR site name	Level	PES	REC	EIS	Natural MAR (n) (million m^3)	% MAR (n) Maintenance Low Flow	% MAR (n) Maintenance High Flow	% MAR (n) EWR	% Drought Low Flow
T51C	Mzimkhulu	EWR2i	Callaway	Intermediate	B	B	M	261	13	12	25	5
T52A	Mzimkhulu	EWR3i	Creighton	Intermediate	B	B	M	870	20	3	23	4
T52D	Mzimkhulu	EWR5i	Middle Mzimkhulu	Intermediate	B	B	M	1 085	16	6	22	5
T52M	Mzimkhulu	EWR6i	Gibraltar	Intermediate	A/B	A/B	M	1 384	25	5	30	6
T51E	Pholela	EWR9r	Pierr	Rapid 3	B/C	B/C	M	110	19	10	29	7
T51F	Nwangwane	EWR8r	Coleford	Rapid 3	C	C	M	117	12	10	22	6
T52G	Bisi	EWR14r	Welverdiend	Rapid 3	A/B	A/B	M	195	31	12	43	12
T52L	Mzimkulwana	EWR17i	Oribi	Intermediate	B	B	H	43	18	12	30	6

Table 5.2: Summary of the anticipated ecological consequences of seven different water development scenarios planned for the Mzimkhulu River Catchment: based on 2010 flow scenarios

Light green with ✓:	PES and REC EcoStatus for all components is not reduced.
Dark Green with ✓:	PES and REC EcoStatus for some components is reduced but not the overall category.
Purple with X:	PES and REC EcoStatus is reduced

EWR site	Scenarios for development						
	FS1U_OCS	FS1M1	FS2M1	FS3U_OCS	FS4a	FS4c_full	FS4c_low
Mzimkhulu River							
MzEWR2i	✓	✓	✓	✓	X	✓	✓
MzEWR3i	✓	✓	✓	✓	X	X	X
MzEWR5i	✓	✓	✓	✓	X	X	X
MzEWR6i	✓	✓	✓	✓	X	X	X
Ngwangwane River							
MzEWR8r	✓	✓	✓	✓	✓	✓	✓
Pholela River							
MzEWR9r	✓	✓	✓	✓	✓	✓	✓
Bisi River							
MzEWR14r	✓	✓	✓	✓	✓	✓	✓
Mzimkhulwana River							
MzEWR17i	✓	✓	✓	✓	✓	✓	✓

Notes: Details of the scenarios are summarised in Chapter 4 of Volume 5 and in detail, in Volume 2 of this Study. An X sign indicates where the ecological category has been reduced, while the ✓ indicates where the category has remained the same.

When the March 2011 flow scenarios become available for the various development scenarios the two predicted flow regimes for each development scenario were compared but without re-running the models that gave rise to the ecological consequences. However, as the magnitude of the changes brought about by the March 2011 flow scenarios were small and probably within the confidence limits of the original assessment, it was determined that there would not be any significant changes to the conclusions that were determined using the 2010 flow scenarios.

It has to be cautioned again, that these consequences do not describe the entire picture. This is mainly as the sites where the consequences are described are on the main Mzimkhulu River and on the larger tributaries. The sites on the tributaries are also generally above the sites of potential dam construction, meaning that the ecological impacts did not consider the impacts of the dams on the tributaries themselves. There is thus a zone of unknown ecological impact, below the prospective dams and above the confluence with the main river. The sites are also confined to the larger portions of the river, and thus do not reflect the potential impacts on the small tributaries where localized impacts may be severe. It is strongly recommended that where major developments are planned, that local EWR / Reserve assessments are carried out.

5.6 CONCLUSIONS AND RECOMMENDATIONS

The overall conclusion of this EWR investigation is that the state of the ecosystem in this catchment is generally good, ranging from an A/B to a B. For a large river system, it is

unusual for South Africa, to have a river in such good condition. The river also proves to be relatively resilient, being relatively unresponsive to the proposed developments of forestry and irrigation in the catchment. This resilience is based on a combination of the presently good condition of the river, the good water quality, which is not expected to deteriorate much, and the lack of special or unique aspects in the components of the ecosystem. This is supported by the continuous flow of good quality and quantity of water from the headwaters in the pristine Ukhahlamba Drakensberg Mountains and the presently undammed nature of the river. The developments that propose a large dam to be constructed on the mainstem Mzimkhulu, have the largest potential impact on the ecosystem, with those dams planned for tributaries having much less impact. Avoiding construction of dams on the mainstem river, would also support conservation initiatives, where the undammed nature of the Mzimkhulu River has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) (South African National Biodiversity Institute (SANBI), 2008) programme and the river is ranked as one of the most important for conservation in the region.

There are a number of limitations to this assessment which have been described in the report. While none of these constitute a "fatal flaw" in the investigation, there are some areas of uncertainty that should be resolved before major developments in the catchment are given approval. There are also uncertainties about the extent of the ecological impacts that would occur in smaller tributaries at a local scale. While the project has taken the overall catchment impacts into consideration, these local impacts need to be assessed as part of any development plan.

It is recommended that, as a condition of allowing any new forestry or irrigation development the following are undertaken:

- Review of the calibration of key flow gauges, as discussed in the Surface Water Resources Report *(WMA 11/T50/00/3009, Volume 8).*
- Ongoing ecological monitoring at the EWR sites, especially the RAPID III sites, and upgrading them to intermediate category.
- Ongoing monitoring at the Estuary, as discussed in the Estuarine Ecological Water Requirements *(WMA 11/T50/00/3009, Volume 6).*

This ongoing monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored, but the monitoring results are not required before some new plantation forestry can be approved.

However the monitoring results are not required before some new plantation forestry can be approved.

Any new licence application for development would need to include information of potential impacts as provided by an Environmental Impact Assessment (EIA) process and potentially a Reserve study conducted at a local level. The Reserve information provided in this report cannot be construed to cater for all local level situations.

Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively, may have a high impact, need to be considered in a larger context. This is especially so for small scale forestry developments. Co-ordination of the management of this larger impact should be the responsibility of DWA with support from the provincial environmental management authority.

6. ESTUARINE ECOLOGICAL WATER REQUIREMENTS

6.1 ASSUMPTIONS AND LIMITATIONS

This study was undertaken with the following assumptions and limitations:

- The historical information describing the situation of mouth closure in the estuary is poor, this is due to the lack of reliable historical water level records but this is also confounded by the artificial breeching of the mouth. A water level recorder was installed after the monitoring programme was complete and only two months prior to the EWR workshop at the end of the study; and
- The overall confidence in the hydrodynamics of the estuary, and therefore the overall assessment, is Low. This is because of:
    - The lack of historical water level records;
    - The lack of good records of the state of the mouth (open or closed) and the artificial breaching; and
    - The lack of a flow record just upstream of the estuary.

Criteria for confidence limits attached to statements in this study were as follows:

Table 6.1: Criteria for confidence limits

LIMIT	DEGREE OF CONFIDENCE
Very Low	If no data were available for the estuary or similar estuaries (i.e. < 40% certain)
Low	Limited data were available and estimates could be out by >60% (40% certain of estimate)
Medium	If reasonable data were available for the estuary and estimates could be out by 20-60% (i.e. 40-80% certain of estimate).
High	If good data were available for the estuary and estimates are probably not more than 20% out (i.e. >80% certain of estimates)

The accuracy of the predicted abiotic states for the Mzimkhulu Estuary (and hence biotic characteristics) and the distribution of these states under the Reference condition, present state and different flow scenarios, depends largely on the accuracy of the simulated runoff data and measured flow data.

Geographical boundaries

The geographical boundaries for the Mzimkhulu River Estuary are:

Downstream boundary : Estuary mouth (30°44'21.68"S, 30°27'27.52"E);
Upstream boundary : 9,5 km from the mouth to the extent of tidal influence; and
Lateral boundaries : 5 m contour above Mean Sea Level (msl) along each bank.

6.2 PRESENT ECOLOGICAL STATUS OF THE MZIMKHULU ESTUARY

6.2.1 Overview

A present day MAR of 1 176 million m^3/a, which constitutes 81% of the natural MAR of 1 453 million m^3 per annum places the Mzimkhulu River in the top three KwaZulu-Natal rivers, exceeded only by the Thukela and slightly ahead of the

Mkomazi. With a regionally very large catchment of about 6 700 km^2, flows are highly seasonal with average winter lows of less than 10 m^3/s and summer averages of about 80 m^3/s. Although shallow with some intertidal areas in the lower reaches, the localised depths of 6 - 8 m upstream and downstream of the freeway and the low level Archibald bridge, it is presently the deepest estuary north of the Mtamvuna and south of the Kosi coastal lakes. Sediments, as might be expected from the annual flow ranges and the periodic floods with flows of 5 500 - 6 500 m^3/s, are highly variable temporally and geographically and range from very soft muds to unstable, unconsolidated, coarse sand and gravels. The estuary, in terms of salinity penetration and tidal effects, extends for at least 9,5 km upstream but this will clearly be highly dependent on the level of river flow.

Mouth closure has historically occurred, although the significance of the coastal bridge and its position on the substantial south extending berm at the mouth in this process is moot. Major floods such as that in 1959 washed the bridge away while the 1987 flood removed almost the entire berm. Artificial breaching has historically been carried out, primarily to protect the local golf course which lies on the flood plain on the north bank immediately upstream of the mouth. Anecdotal observations suggest that closure has become more frequent but in the absence of a long term monitoring and as no other reliable records exist this would have to be treated with extreme caution.

The biota of the Mzimkhulu Estuary will be highly constrained by the natural flow, salinity and sediment variability in the system and this is confirmed by the admittedly sparse historical data and the more extensive sampling carried out in 2009 and 2010. The estuary channel is typically steep sided so there is very little development of intertidal areas and any associated fauna and flora. Despite the mouth being allegedly generally open in the past, there is no historical evidence of mangroves in the system. Mangroves are not immune to floods and the alleged magnitude of past floods would have been quite sufficient to remove any colonising trees.

The present major human impacts on the system are the loss of benthic habitat resulting from bridge construction and associated rubble deposits in the mid region, coupled with the long standing activities of the sand mining operators downstream and upstream of the freeway and Archibald bridges. It is also arguable that the sand mining activities, apart from removing habitat, also mobilise fine sediments and contribute to their dispersal and re-distribution by river and tidal currents. There do not appear to be any significant anthropogenic effects on water quality as regards ecosystem function but problems apparently arise with potability as water is currently drawn from the upper reaches of the estuary. Open mouth conditions will be maintained by adequate river flow which does not necessarily disrupt salinity layering in the upper reaches. Following closure, it appears that layering can break down and deeper more saline water mixes with surface fresh water which is then drawn off for use in Port Shepstone and the Sugar Mill.

6.2.2 Estuary health index and importance

The Estuary Health Index (EHI) scores for the Mzimkhulu Estuary are shown in **Table 6.2**. In its present state the EHI was scored at 79 and accordingly given a B

category status (scoring range 76 - 90) on a scale from A to F reflecting a system "largely natural with few modifications".

Table 6.2: Estuarine Health Index Scores allocated to the Mzimkhulu Estuary

Variable	Weight	Score	Weighted Score
Hydrology	25	84	21
Hydrodynamics and mouth condition	25	78	20
Water quality	25	72	18
Physical habitat alteration	25	75	19
Habitat Health Score			**77**
Microalgae	20	90	18
Macrophytes	20	80	16
Invertebrates	20	70	14
Fish	20	80	16
Birds	20	80	16
Biotic Health Score			**80**
ESTUARINE HEALTH SCORE			**79**
Present Ecological Status			**B**

On a national scale Estuarine Importance is "highly important", "important" or is indicated as having "low to average importance". As shown in **Table 6.3**, the Mzimkhulu Importance Score was 84 falling in the range 81-100 of "highly important".

The Estuarine Importance Scores (EIS) allocated to the Mzimkhulu Estuary were as follows:

Table 6.3: Estuarine Importance Scores

Criterion	Score	Weight	Weighted score
Estuary Size	80	15	12
Zonal Rarity Type	30	10	3
Habitat Diversity	100	25	25
Biodiversity Importance	76	25	19
Functional Importance	100	25	25
ESTUARINE IMPORTANCE SCORE			**84**

This was based largely on the estuary's role as a nursery ground, as a movement corridor and as a conduit for catchment derived detritus, nutrients and sediments to the coastal zone.

6.3 RECOMMENDED ECOLOGICAL CLASS

The recommended Ecological Reserve Category (REC) represents the level of protection assigned to an estuary.

For estuaries, the first step is to determine the 'minimum' REC, based on its PES. The relationship between EHI Score, PES and minimum REC is set out in the table below.

Table 6.4: Relationship between EHI Score, PES and minimum REC

EHI Score	PES	Description	Minimum REC
91-100	A	Unmodified, natural	A
76-90	B	Largely natural with few modifications	B
61-75	C	Moderately modified	C
41-60	D	Largely modified	D
21-40	E	Highly degraded	-
0-20	F	Extremely degraded	-

PES dictates the minimum REC. The degree to which PES needs to be elevated depends on the level of **importance** and level of **protection or desired** protection of a particular estuary:

Table 6.5: Level of importance and level of protection / desired protection of a particular estuary

Current/desired protection status and estuary importance	Recommended Ecological Reserve Category	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D category

* BAS = Best Attainable State

In addition to being categorised as a 'Highly Important estuary', the Mzimkhulu Estuary is also required to be under partial protection and at an REC of B as part of the core set of estuaries to achieve the country's biodiversity targets (Turpie, Wilson and van Niekerk 2010) as well as being characterised as irreplaceable on the KZN Systematic Conservation Plan. Therefore, according to the guidelines for assigning a recommended REC, the condition of the estuary should be elevated to a Category A or the Best Attainable State (BAS).

6.4 EVALUATION OF THE WATER USE SCENARIOS

Seven scenarios were considered, all based on the 2010 hydrology and simulated reductions in the water received by the estuary below the present level of 81% on natural MAR. It should be noted that the time at which the mouth closes and the length of mouth closure are particularly significant for the estuary. The closure is influenced by the monthly flow distribution and does not necessarily correlate with the MAR. Unmitigated and mitigated scenarios were considered since, unlike the river, the reduction in floods

caused by the dams can be very significant for the estuary, and ranged from 60% to 80% of the reference MAR.

These generated EHI scores between 74 and 79 which left the system on the borderline (75-76) between B and C (moderately modified) with four retaining a B status and two (Scenarios 1 and 6) dropping to a C. The results are summarised in **Table 6.6**.

Table 6.6: Summary of the 2010 estuary flow scenarios evaluated in this study

Scenario name	Estuary Scenario No.	MAR (million m^3)	Percentage MAR remaining	Est. Health Score Index	Ecology reserve categories
Natural		1 452,5	100,0		
Present		1 199,5	82,6	79	B
FS4c	1	865,4	59,6	74	B-
FS4a	2	955,6	65,8	75	C+
FS1U_0CS	3	1 165,0	80,2	76	B-
FS1M1	4	1 078,3	74,2	79	B
FS2M1	5	1 139,0	78,4	79	B
FS3U_OCS	6	1 130,5	77,8	74	C
FS3M1	7	1 051,6	72,4	78	B

6.5 RECOMMENDED ECOLOGICAL WATER REQUIREMENT

The evaluation of the Water Use Demand Runoff Scenarios is used to derive the recommended EWR. Thus the recommended EWR is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will ensure the estuary remains in the Ecological Reserve Category.

Given the changes to flow which have already occurred, it would be impractical to improve the condition of the Mzimkhulu Estuary to a Category of A. Using flow alone, the condition could be improved by 8% (from 79 to 87%). Even if, non-flow related mitigation measures, such as reducing agricultural impacts on the floodplain, reducing the application of fertilizers in the catchment and were also implemented the condition would not reach a Category A.

Thus, the BAS for the estuary is a Category B.

Most of the scenarios evaluated in this study, resulted in a decrease in the EHI score for the Mzimkhulu Estuary. This was due mainly to the reduction in both low flows and floods resulting in a change in the mouth status as well as the physico-chemical states within the system.

These results were reassessed in light of the changes made to the hydrology data during March 2011. This sensitivity analysis indicated that the percentage change from the previous hydrological modelling were all less than 2% and should therefore not change the findings of the previous assessment significantly. The revised hydrology indicated that the Present State is slightly different as both low flow states (1: Closed mouth and 3:

intermittent closed) are now occurring less often (approximately 0,5%). There is a small concern in that State 1, the closed mouth state, increase by nearly 2% from the Present day situation under flow scenarios, FS1RU and FS3RU. However, because the river inflow ranges that are estimated to cause mouth closure were of low confidence it is very difficult to quantify exactly how significant these changes were in the overall picture. Additionally, as the changes lie within the confidence ranges which were place on the estuarine assessment the original findings remain valid. This is particularly true for the abiotic assessment but it should be noted that the effect of this small change may be amplified through the biological components by up to 5% i.e. the scores assigned may change by this margin resulting in a slight overall change to the scoring. The distributions of monthly flows for three scenarios are shown in **Tables 6.7** to **6.10**.

Table 6.7: Summary of the abiotic states that can occur in the Umzimkulu Estuary

Colour Key		
State	**Flow Range (m^3/s)**	**Description**
State 1: Closed	<0,5	Further reduction in freshwater flow and less frequent opening results in a more uniform, but fairly saline system. Zone A becomes brakish (~5), and salinities in Zones B, C and D reaches 15, 25 and 25, respectively.
State 2: Intermittent closed	0,5 – 3	The system show stronger marine influence compared with State 3 due to reduced freshwater inflow and regular breaching. Zone A remains fresh (~1), but salinities in Zones B, C and D reaches 10, 20 and 30, respectively.
State 3: Open, marine	3 – 5	Only Zone A remains fresh. Limited saline intrusion into Zone B (salinity ~5). Zones C receives sone saline intrusion (~15), while Zone D receives significant saline intrusion (~30)
State 4: Open, brackish	5 – 20	Zones A and B are fresh, with limited saline intrusion into Zone C (salinity ~5). Zone D is subject to saline intrusion (salinity ~20)
State 5: Open, fresh	>20	All zones are fresh, with limited saline intrusion into bottom waters of zone D during high tides

Table 6.8: Summary of the monthly flow (in m^3/s) distribution under Scenario FS1M1)

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99	77,9	142,9	187,2	202,4	239,2	390,3	138,2	108,0	71,6	27,3	15,6	70,3
90	20,3	54,0	96,3	129,2	167,8	128,1	76,4	30,5	12,3	11,6	8,4	8,1
80	13,4	32,4	78,6	101,1	110,6	107,3	58,4	18,6	9,9	6,9	5,7	6,2
70	10,4	25,6	61,7	81,2	97,5	85,2	48,1	16,1	8,6	6,4	5,5	6,0
60	9,2	20,7	44,7	68,5	84,8	74,6	37,5	13,8	7,8	5,8	5,0	5,7
50	8,3	17,7	35,1	62,6	74,6	62,4	32,2	12,0	6,7	5,1	4,2	5,1
40	6,8	15,2	30,8	56,7	69,7	53,4	29,4	10,0	5,3	3,9	3,5	4,2
30	5,0	11,0	22,4	45,7	55,2	48,7	25,7	8,0	3,9	2,8	2,8	3,1
20	3,3	6,9	17,6	30,7	40,8	35,9	17,9	6,3	2,7	2,0	1,8	2,2
10	2,2	3,7	8,7	21,9	30,5	25,0	13,5	4,9	2,1	1,7	1,3	1,6
1	1,8	2,1	2,9	7,4	10,9	9,5	5,1	2,8	1,8	1,4	1,2	1,3

Table 6.9: Summary of the monthly flow (in m^3/s) distribution under Scenario FS2M1

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99	77,6	146,8	191,1	207,4	235,7	392,1	140,8	109,9	73,0	27,5	17,3	68,1
90	20,5	63,5	110,5	132,5	168,1	130,0	77,9	32,2	13,6	12,6	7,8	6,9
80	14,3	36,1	84,9	109,3	112,6	107,5	59,1	20,3	10,2	6,7	5,7	6,2
70	10,8	28,9	68,7	88,5	100,1	87,3	48,9	17,7	8,6	6,4	5,5	6,0
60	9,2	24,9	53,3	75,3	89,9	77,9	39,5	15,4	7,8	5,8	5,0	5,7
50	8,3	19,7	40,4	70,6	82,4	66,3	33,6	13,4	6,7	5,1	4,2	5,1
40	6,8	16,3	35,9	60,7	72,6	56,7	30,4	10,6	5,3	3,9	3,5	4,2
30	5,0	12,0	25,7	53,5	59,9	50,6	26,6	8,	4,1	2,8	2,5	3,1
20	3,3	6,6	20,6	37,4	45,8	37,8	19,5	7,2	2,9	2,0	1,8	2,2
10	2,2	3,1	9,7	28,2	33,8	27,4	14,9	5,3	2,2	1,7	1,3	1,6
1	1,8	2,0	2,9	10,0	14,5	11,7	5,8	3,5	1,8	1,4	1,2	1,3

Table 6.10: Summary of the monthly flow (in m^3/s) distribution under Scenario FS3M1

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99	74,9	139,5	184,3	199,2	235,7	386,8	136,5	106,9	70,1	26,7	15,0	68,8
90	19,2	51,5	93,4	125,7	164,5	125,7	75,2	30,1	11,8	11,3	7,9	7,5
80	12,7	31,3	75,8	98,9	108,9	105,7	57,3	18,2	9,7	6,7	5,7	6,2
70	10,0	24,1	59,7	79,6	95,3	83,8	47,2	15,7	8,5	6,4	5,5	6,0
60	9,2	19,5	43,7	66,4	83,8	73,5	36,8	13,3	7,8	5,8	5,0	5,7
50	8,3	16,4	33,5	60,7	72,8	61,4	31,1	11,5	6,7	5,1	4,2	5,1
40	6,8	13,9	29,7	55,1	72,8	52,6	28,7	9,5	5,3	3,9	3,5	4,2
30	5,0	9,8	21,2	43,8	68,1	47,4	25,0	7,9	3,9	2,8	2,5	3,1
20	3,3	5,8	16,2	29,4	54,9	35,1	17,2	5,9	2,7	2,0	1,8	2,2
10	2,2	3,3	7,8	20,8	39,8	24,1	12,9	4,5	2,1	1,7	1,3	1,6
1	1,8	2,0	2,9	7,0	10,3	9,0	4,6	2,5	1,8	1,4	1,2	1,3

In addition operational guidelines are provided to assist in setting management objectives regarding important aspects of estuarine condition such as mouth state and water chemistry and these should be used in conjunction with the recommended water use scenarios to ensure that the estuary remains within the desired REC.

Allowing the condition of the Mzimkhulu Estuary to decline from its current PES has the following implications:

- Reduced numbers of estuarine dependent fish and invertebrate species, particularly those that use the estuary as a spawning and nursery ground.
- Reduced cueing effect to estuarine dependent invertebrate and fish species, and a possible reduction in diversity and abundance of fish in the estuary and along the coast.
- The estuary has also been selected for full protection at a provincial level and partial protection at a national level and changes to the status of the estuary will affect the core set of estuaries selected to satisfy biodiversity conservation targets.

These are also likely to have a ripple effect on economic good and services provided by the adjacent marine environment, e.g. the marine fisheries and coastal sediments.

Thus, it is strongly recommended that decisions that affect the flow regimes of the Mzimkhulu Estuary carefully consider potential impacts on all users. Given its importance

every effort should also be made to implement the measures required to mitigate the non-flow related impacts on the estuarine system particularly:

- eradicate invasive alien vegetation (especially dense stands of bamboo and eucalyptus) from river banks and floodplains;
- remove derelict, redundant and old quays, jetties, wharfs and revetments; and rehabilitate banks to natural sediments;
- prohibit dredge spoil dumping (from lower main channel as well as marina) in inappropriate areas; and
- manage agricultural and industrial practices in the catchment to minimise nutrient and sediment loads entering the estuary;

6.6 RESOURCE MONITORING PROGRAMME

The status of baseline data currently available for different abiotic and biotic components in the Mzimkhulu Estuary, after completion of this project is summarised in the *Estuarine Ecological Water Requirements Report (WMA 11/T50/00/3009 Volume 6)* of this study. Short term detailed data are available for most abiotic and biotic components. The report does, however, identify a number of important data gaps that, if addressed, would improve the confidence of this and any future reserve determination studies.

7. GROUNDWATER RESOURCES

The report: Groundwater Resources is contained in (*WMA 11/T50/00/3009, Volume 4*) of the study.

7.1. BACKGROUND

The Mzimkhulu River Catchment Water Resources Study was initiated to meet three main objectives, which all directly involve groundwater and its potential to be assessed as an integral part of the resource and its sustainable management:

- determine the existing and potential future usage of water in the catchment, with reference to the potential of further afforestation;
- reassess the hydrology and water supplies available from existing sources; and
- investigate schemes for meeting future requirements.

7.2. OBJECTIVES

The broad objectives of this component were to assess the potential groundwater resources of the catchment in an attempt to relate borehole yields to geological formations, including water quality and potential for recharge, as well as identifying potential aquifer formations and related structural features. Once accomplished, this would allow for the assessment of the potential for further groundwater development to supply rural and domestic use requirements, specifically in the rural areas of the middle and lower parts of the Mzimkhulu River catchment.

7.3. METHODOLOGY

Relevant groundwater data, which were either collected from the field area or were sourced from in-house data bases and regional databases (Groundwater Resources Information Project – GRIP), were utilised in conjunction with geographical information systems (GIS) and digital mapping data to establish an understanding of the groundwater system in the Mzimkhulu River catchment.

The yields of existing boreholes are shown on **Figure 7.1.** There is significant use of groundwater, primarily in the middle area of the catchment and particularly around Creighton and Underberg.

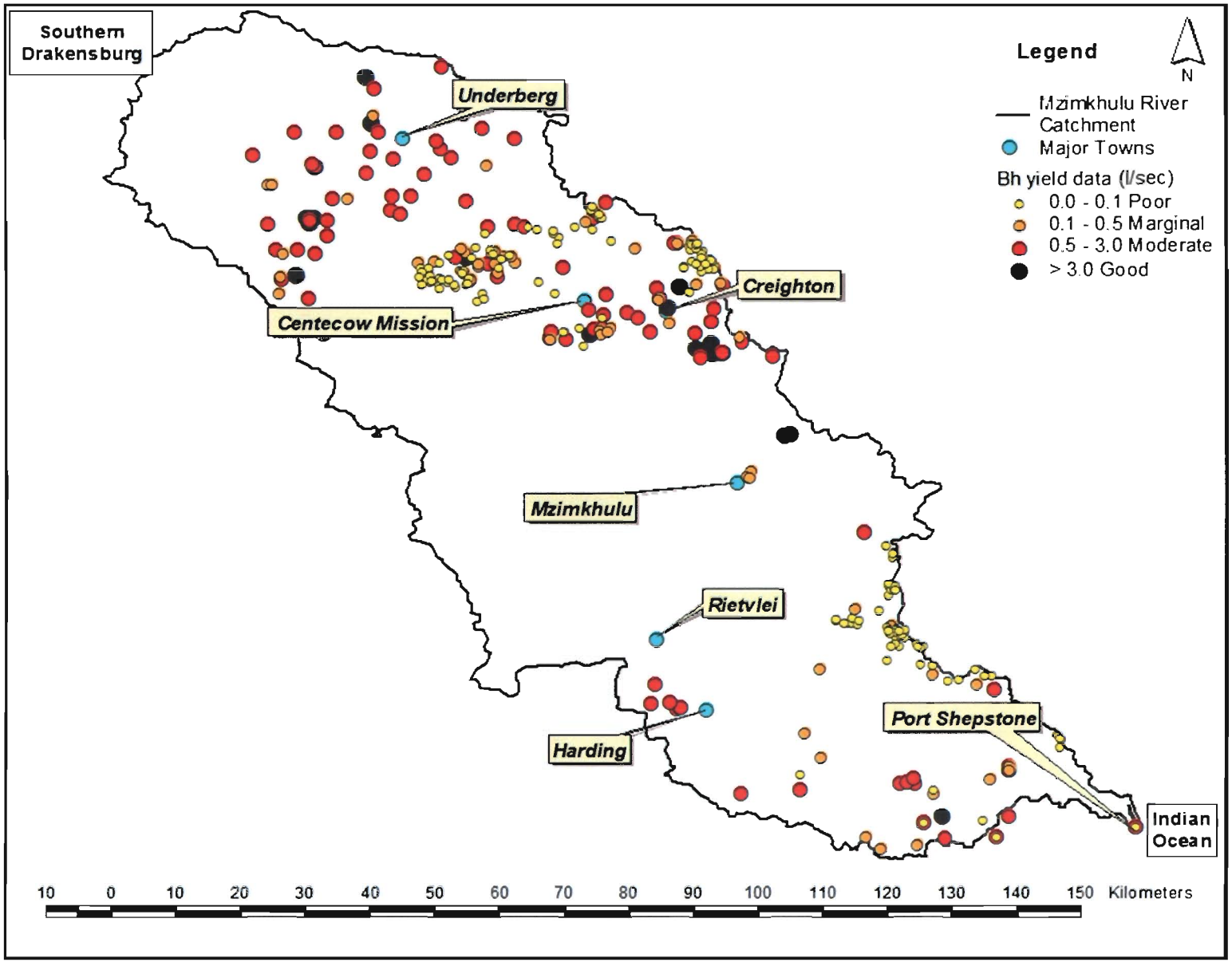

Figure 7.1: Borehole Yield Map

Typically then, the occurrence and availability of groundwater was determined by employing the following factors:

- Topography and drainage;
- Rainfall and climate data;
- Population data (indicative of current usages);
- Vegetation types and consequent water requirements;
- Petrology (aquifer types);
- Geological structures;
- Soils (potential, depths and clay content);
- Groundwater yields;
- Recharge areas; and
- Depth to groundwater.

Physical and chemical groundwater data and the afore-mentioned associated data were mapped out within the catchment such that the availability and occurrence of groundwater could be investigated. The data / maps were 'over-layered' with the ultimate purpose of this practice to identify the areas within the Mzimkhulu River catchment that could be investigated for the supply of greater volumes of chemically suitable groundwater, and the geological structures / lithology these areas correlate to.

7.4. CONCLUSIONS

The following conclusions were made:

- Elevated groundwater yields occur to the north of Rietvlei, directly east of Creighton and from west-southwest to northwest of Underberg.
- Rainfall recharges the shallow aquifers in these areas and it is intercepted by the boreholes in the catchment.
- Populations (both rural and urban) are situated within these areas, such that groundwater supply to these communities appears viable.
- The principle high-yielding geological formations are the Drakensberg basalts, the Karoo dolerites and the closely-bedded argillaceous Karoo Supergroup rocks.
- Dolerite dyke and sill contacts and observed lineaments act as the main pathways for groundwater movement and to a certain extent, storage
- Areas underlain by shallower soil profiles and soils with increased clay content typically exhibit higher yields.
- Magnesium (Mg), nitrate (NO_3) and fluoride (F) are the only potentially problematic determinants in the groundwater, with these three 'peaking' in the southern areas of the Mzimkhulu River catchment.

7.5. RECOMMENDATIONS

The following recommendations are made:

- Groundwater exploration should be carried out from Rietvlei to the north and northwest and be continued:
  - near the Centecow Mission,
  - directly east of Creighton,
  - from west-southwest to northwest of Underberg.

- Basaltic, doleritic and argillaceous sedimentary rock areas throughout the area should also be investigated for localised water supply.
- Shallower soil profiles with increased clay contents could be investigated for localised water supply.
- The extreme southern areas of the catchment should not be prioritised for groundwater investigation.
- The extreme northern parts of the catchment should only be investigated further if no other viable water resources are available.
- There is significant use of ground water, primarily in the middle area of the catchment and particularly around Creighton and Underberg.

8. SURFACE WATER RESOURCES

The objective of the Report, Surface Water Resources *(WMA 11/T50/00/3009, Volume 3)*, of the Mzimkhulu River Catchment Water Resources Study, is to present the updated system yield analysis for the current supply system as well as for future scheme development options in the catchment.

The WRYM-IMS has been used to update the Mzimkhulu River system configuration to include present day land and water use, for the period 1920 to 2007, as well as the EWR for each quaternary catchment.

The model was then configured to include future scheme developments which included five potential dam options and scenarios of increased plantation forestry, irrigation and urban and rural water use. Areas for potential forestry development were determined through a negative mapping approach which assessed the catchment according to timber growing potential characteristics. Three scenarios of increased plantation forestry areas were considered:

- An additional 29 400 ha for small growers throughout the catchment;
- An additional 21 050 ha for small growers only in the Bisi catchments; and
- An additional 50 350 ha for small and large growers throughout the catchment.

In addition a 20% increase in water use by irrigated agriculture was assumed in some scenarios. It was assumed that the future water use by 2030 for rural and urban domestic, industrial and commercial purposes would increase by 60% from current. Potential dam sites were included in the scenarios to provide mitigation for the impacts of increased water demands as a result of additional plantation forestry and irrigation in the catchment by releasing the EWRs for the Gibraltar site in the Lower Mzimkhulu catchment. In addition dams exporting surplus yield were modelled.

Initially the detailed assessment of the impacts of the different scenarios on the EWR sites in the catchment were determined using the 2010 hydrology and the 2010 flow scenario results are presented in Appendix B of Report, Riverine Ecological Water Requirements *(WMA 11/T50/00/3009, Volume 5)*. When the March 2011 hydrology became available, the effects of the most important development scenarios were re-modelled and the new results are presented in the body of Report, Volume 5. The results of the scenario modelling indicate that the impacts of increased plantation forestry and irrigation in the catchment can be mitigated by providing storage while maintaining current EWRs or improving them to meet the PES. Moreover, the dams would provide some surplus yield which could be exported or utilised within the catchment.

9. MANAGEMENT AND DEVELOPMENT OPTIONS

Various options for expansion of forestry were considered in future development scenarios as discussed below. Future infrastructure developments were also taken into account in assessing the future water demands on the catchment.

- The proposed Cwabeni off-channel Dam, about 20 km upstream of Ugu District Municipality's abstraction point at St. Helen's Rocks, to address sporadic shortages in supply to Port Shepstone.
- Future water exports, to the Mhlabatshane Regional Water Supply Scheme, which will require a small volume water to be exported to the adjacent catchment, as from 2015.
- The possibility of future augmentation of the Mgeni System, via the Mkomazi River;
- Increased supply to the coastal towns and resorts to the north and south of Port Shepstone.
- Any increase in urban an irrigation water use or plantation forestry areas, would reduce the river flows, particularly the low flow. Any significant export of water would also change the flow regimes. It is probable that these would have a negative impact on the environment which was assessed.

9.1 WATER RESOURCE MANAGEMENT AND INTERVENTIONS

9.1.1. Development Options – Providing Additional Storage

The development of one or more, new dams to mitigate the impacts, particularly on low flows, of additional forestry, or other water use in the catchment was considered. Reports from previous studies conducted by DWA, Umgeni Water and municipalities were studied. Some 22 possible dam sites had been previously identified on the main stream and tributaries of the Mzimkhulu River, shown in **Figure 9.1**.

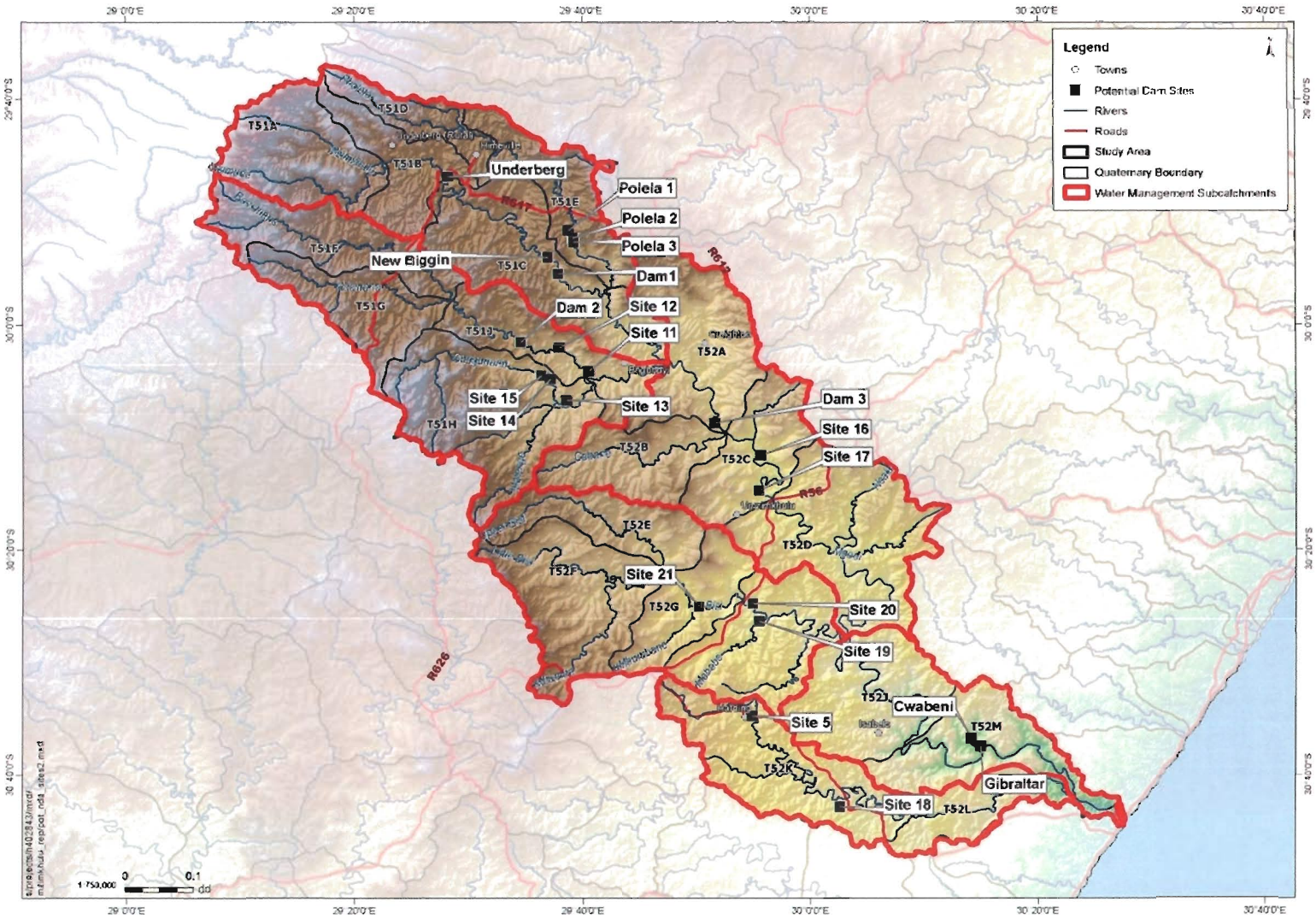

Figure 9.1: Previously identified Dam Sites

The sites were screened, using various criteria, the overriding one being locality. As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, were regarded as being best positioned to mitigate the impact of forestry on the low flows:

- Site 12 on the Ngwangwane River, and
- Site 19 on the Bisi River.

To test the impact on the river flows and water available to meet the EWRs a possible large dam with all the surplus yield being exported, a further two sites were selected.

- Underberg, and
- New Biggin

9.2 CATCHMENT SCENARIOS

Present day land and water use requirements and the riverine EWRs to maintain the PES, extrapolated to each quaternary sub-catchment for the present day system were imposed on the system. Two scenarios were run for the present supply system, with and without the Cwabeni off-channel storage, which is currently being investigated. When taking into consideration the EWR, there is no historic firm surplus yield from the run of river flows, at quaternary sub-catchment level.

The future scenarios were developed, in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. All known urban and rural demands, projected to 2030, were included.

9.2.1. Future Scenario 1: All Small Growers

Scenario 1 assumes small grower plantation forestry expansion of 29 400 ha, and no increase in irrigated agriculture. A number of sub-scenarios were run, with and without the off-channel storage at Cwabeni, as well as mitigated scenarios with a dam at Site 12 on the Ngwangwane River, sized and operated to meet either the EWR or the present day flows at Gibraltar. A 0,5 MAR dam was also modelled, with the surplus yield assumed to be fully utilised or exported.

The results of the modelling indicated that this relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site. These flows could be restored by a small dam of about 10 million m^3 dam (0,04 MAR) storage at Site 12 on the Ngwangwane River. A larger dam of 45 million m^3 (0,2 MAR), would meet all recommended EWR flows at Gibraltar. The larger 0,5 MAR dam produced a surplus of about 80 million m^3/a.

9.2.2. Future Scenario 2: Small Growers, Bisi

Scenario 2 assumes plantation forestry expansion of 21 050 ha for small growers in the Bisi and Middle Mzimkhulu River catchments, with no increase in irrigated agriculture. A dam at Site 19 on the Bisi River was included to mitigate the impacts of increased plantation area. Three scenarios were run with the dam to

size it to meet either the EWR flows or to meet the present day flows at Gibraltar and a 0,5 MAR dam, operated to meet the EWR at Gibraltar, with the surplus yield assumed to be fully utilised or exported.

From the results of the modelling runs, as mentioned above, this relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site, but did impact on the low flows at the Bisi EWR site. In this scenario, the present day flows at Gibraltar could be restored by a small dam of just less than 15 million m^3 dam (0,07 MAR) at Site 19 on the Bisi River. A larger dam of 45 million m^3 (0,2 MAR), on the same site, would restore the river to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of about 30 million m^3/a.

9.2.3. Future Scenario 3: All Growers, Small and Large

Scenario 3 has an increased forestry area of 50 350 ha, for small and large growers, throughout the catchment, as well as a 20% increase in the water supplied to irrigated agriculture. Two unmitigated scenarios were run, with and without the off-channel storage at Cwabeni. Three mitigated, scenarios were run to size a dam at Site 12 on the Ngwangwane, the first just large enough to meet the EWR flows, the second to meet the present day flows at Gibraltar and the third being a 0,5 MAR dam, operated to meet all the EWR flows at Gibraltar, with the surplus yield assumed to be fully utilised or exported.

From the results of the modelling runs, the larger area of additional plantation forestry had a noticeable impact on the present day flows at the Gibraltar EWR site and the Bisi site. In this case, the present day flows could be maintained by a relatively small 16,5 million m^3 dam (0,07 MAR) at Site 12 on the Ngwangwane River. A larger dam of 48 million m^3 (0,2 MAR) would be able to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 76 million m^3.

9.2.4. Future Scenario 4: Large Dam Scenario

Scenario 4 was developed in order to explore the impacts on the river and estuarine flows of a significant water resource development, either for export of water or to meet significant new demands. This scenario has the same land and water use as for Scenario 3.

Three cases were modelled, with various combinations of a large 1,0 MAR dam at Underberg, a 1,5 MAR dam at the New Biggin site and small dams, ranging from 0,17 to 0,5 of the MAR at the Bisi and Ngwangwane sites, the latter two, to meet the EWR flows at Gibraltar.

The results indicated that volumes of 180 million m^3/a, from the Underberg site and 228 million m^3/a from the New Biggin site, could be made available for export, while meeting all EWR flows.

9.3 DISCUSSION

At the sites used for the EWR study the Mzimkhulu River has assessed to be in a good condition, somewhat better than expected. The aquatic environment also proved to be fairly resilient, being relatively unaffected by the proposed development of additional forestry and irrigation in the catchment. It emerged that there is limited risk to the environment in allowing a moderate degree of forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows.

The developments, in which a large dam is constructed on the mainstem Mzimkhulu, have the largest potential impact on the ecosystem, with those dams planned for tributaries having much less impact. Avoiding construction of dams on the mainstem river, would also support conservation initiatives, where the undammed nature of the Mzimkhulu River has been recognised by the NFEPA (SANBI, 2008) programme and the river is ranked as one of the most important for conservation in the region.

The scope of the project made provision for a limited number of EWR sites. These sites are on the main Mzimkhulu River and on the larger tributaries. Whilst the impact of moderate areas of additional forestry was relatively small at these sites, there may be considerably more severe impacts locally, on some of the smaller tributaries, which will need to be assessed when considering licence applications.

9.4 CONCLUSIONS

The overall conclusion is that the state of the ecosystem in this catchment, including the estuary, is generally good and the river is fairly resilient to some additional development in the catchment. By providing storage, the impacts of significant increases in the areas of plantation forestry and increased irrigation, would not only be successfully mitigated, but the state of the river could be improved, to fully meet the EWRs at Gibraltar. Additional storage would also provide some surplus yield, which could be exported or used. A large storage dam could be considered to export water to a neighbouring catchment or the surplus used to boost additional development within the catchment.

The cost estimates of the possible dams at site 12 on the Ngwangwane River and site 19 on the Bisi River were based on the smallest possible dams to meet all the EWR requirements at the Gibraltar site. On each of the sites, a dam with storage volume of 42 million m^3 was assumed for costing purposes and costs are estimated to be R367 million and R265 million respectively.

Annual costs of redemption of the above loans, over a period of 40 years, at interest rates of 8, 10 and 12% for each of the dams, were reduced to a per hectare cost for the three scenario, as shown **Table 9.1**.

Table 9.1: Cost of capital per hectare to create additional storage to mitigate impact of additional plantation forestry

Scenario (ha)	Ngwangwane (Rand)			Bisi (Rand)		
	8%	10%	12%	8%	10%	12%
21 050	1 350	1 620	1 890	976	1 170	1 360
29 400	970	1 160	1 350	700	840	970
50 350	560	680	790	410	490	570

If one was to add the irrigation expansion, this would add about 3 000 ha and reduce the costs in the table by about 15% for the 21 050 ha scenario and 6% for the 50 350 ha scenario.

The gross marginal cost of timber production in the catchment, is estimated to be in the order of R2 500/ha/a. As can be seen from **Table 9.1**, provided reasonably large areas of plantation forestry are planted, the mitigation costs of constructing a dam to restore the EWR flows, are within reach.

9.5 RECOMMENDATIONS

9.5.1. Short to Medium Term Actions (1-5 Years), to support socio-economic development in the catchment, and to maintain or improve the level of assurance of supply to water users in the catchment while maintaining the EWR flows:

(a) Water use licensing

- A further 5 000 ha of afforestation can be planted without undue negative impact. Therefore invite and process licence applications for an initial area of 5 000 ha of plantation forestry in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu Water Management Sub-catchments, with priority being given to small growers.
- There is a large amount of alien vegetation in the catchment. Removal of these can be replaced with equivalent afforestation.
- Even further afforestation can be done if negative flow impacts are offset with provision of strategically placed storage for releases in dry season.

(b) Water resource development

- Investigation of Cwabeni off channel storage must continue in order to have mechanism ready to address dry season water shortages in the short term.
- Carry out an initial comparison, including realistic time lines and lifetime economics between the Cwabeni off-channel storage dam and a storage dam on the Ngwangwane and Bisi Rivers, sized to supply Ugu District Municipality's requirements and mitigate the impacts of additional plantation forestry.
- Develop groundwater resources for remote rural and urban settlements and where yields are sufficient, also for small scale irrigation to provide food security.

(c) Water resource management

- Implement Water Conservation and Demand Management (WCDM).
- Validate and verify all registered water use in the catchment and eliminate unlawful use.
- Monitor to ensure compliance with licence conditions. Assess any new licence applications for development, considering information on potential impacts as provided by an EIA process and potentially a Reserve study conducted at a local level.
- Develop procedures or guidelines to link the removal of invasive alien vegetation to licences for additional forestry.
- Educate people in rural areas to prevent over-grazing.
- Implement Catchment Management measures, like Working for Wetlands and Working for Water to assist with meeting the Reserve.

(d) Environmental

- Initiate a programme to rehabilitate drained wetlands.
- Implement on-going ecological monitoring at the EWR sites. Ensure that the ecological state of the river does not deteriorate.
- Evaluate the findings of this EWR investigation together with the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from this study will provide information on the Reserve situation in the smaller tributaries.
- As soon as possible determine and implement RQO following the newly published procedure, so that there can be clear objectives for the management of the river. Carry out on-going monitoring at the estuary, to allow the effects of development to be properly monitored.

(e) Hydrological monitoring

- Review the calibration of key flow gauges.
- Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).

9.5.2. Longer Term Management and Development Options

- Having implemented the recommended monitoring, assess the impact on stream flow of the water use in the catchment, including that of the first areas of additional forestry, when at least 5 years monitoring is available and the additional forestry has been in place for at least 5 years.
- The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.
- Reassess the EWR results for the rivers and estuary.
- Based on the results for these assessments decide whether or not to invite and process licence applications in batches of 5 000 ha up to say 30 000 ha.
- Continue to monitor the inputs to reassess if further licences, potentially up to a total area of 50 000 ha of new plantation forestry can be issued.
- Small growers should receive priority.

- The impact on the water resource and the environment should continue to be monitored.
- Local impacts needs to be evaluated for each application and cumulative effects considered.
- If unacceptable impacts are observed and there is still a demand for more plantation forestry, the next recommendation is to undertake a pre-feasibility study to investigate a dam on the Ngwangwane or the Bisi River. The purpose of this dam would be:

    - To mitigate as far as possible, the impact of realising the full potential plantation area of 50 000 ha;
    - To restore the EWR flows'
    - The study should investigate whether there are sites upstream of those modelled on the Ngwangwane and the Bisi Rivers with more favourable capacity to MAR rations;
    - To meet the shortfalls at the Ugu's St Helen's Rocks abstraction works on the main river, which could do away with the need for the Cwabeni off-channel dam currently being investigated. This could avoid duplication and save the off-channel pumping costs.

- Identify the technical, economic and environmental feasibility of developing a dam.

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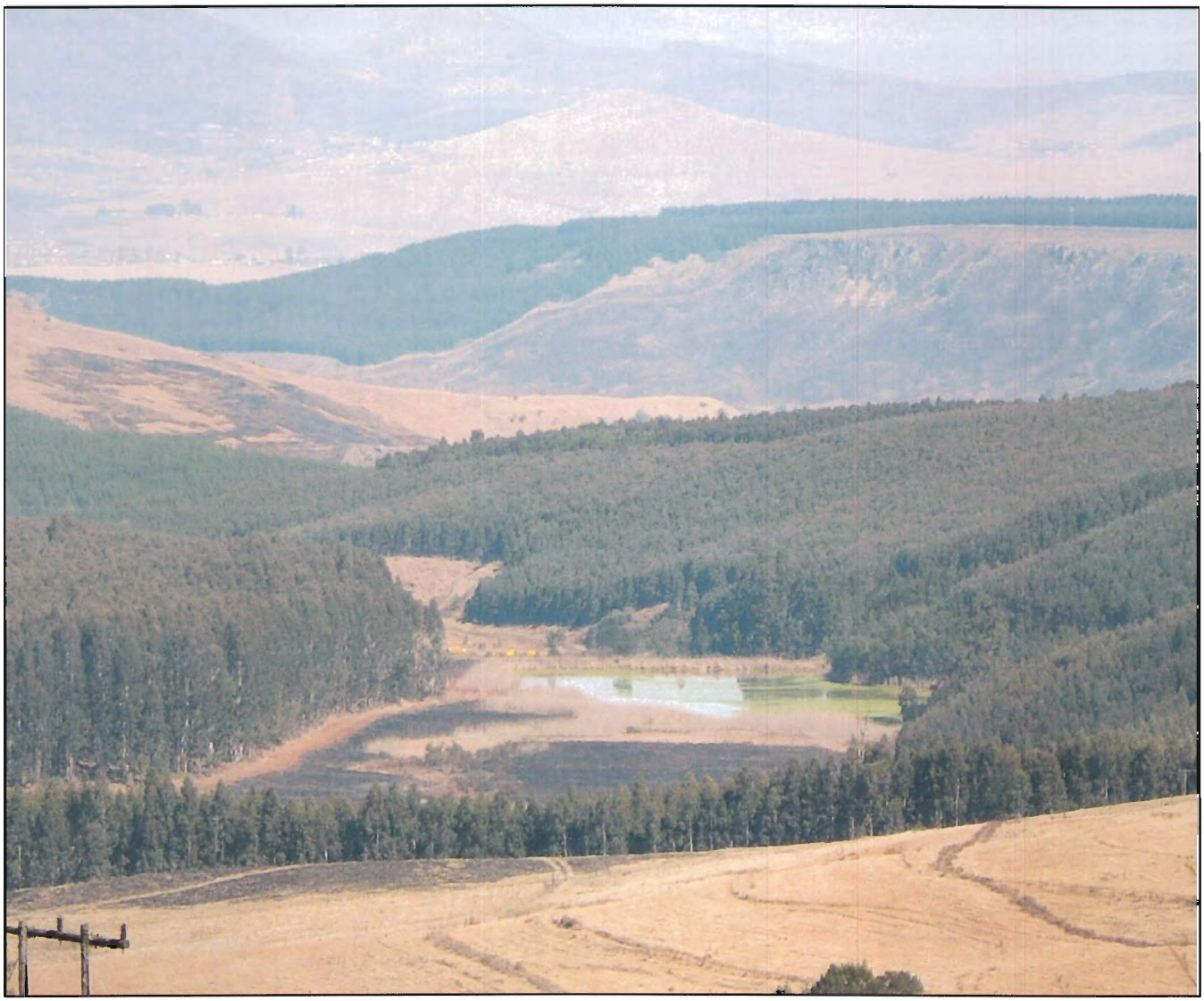

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Management and Development Options Report

Original

FINAL REPORT

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Management and Development Options Report

Report no.: WMA 11/T50/00/3009 Volume 2

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PROJECT NAME	:	**MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY (WP9900)**
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AUTHORS	:	J.C. Perkins
REPORT STATUS	:	Final Report
REPORT NO.	:	WMA 11/T50/00/3009 Volume 2
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Submitted by:

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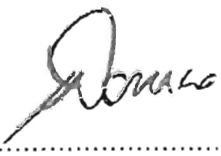
31 March 2011
(Date)



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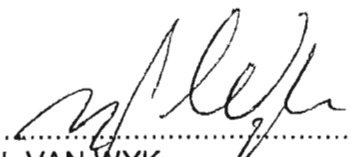

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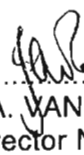

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LIST OF REPORTS	
Title	**Report Number**
Main Report	WMA 11/T50/00/3009 Volume 1
Management and Development Options	**WMA 11/T50/00/3009 Volume 2**
Surface Water Resources	WMA 11/T50/00/3009 Volume 3
Groundwater Resources	WMA 11/T50/00/3009 Volume 4
Riverine Ecological Water Requirements	WMA 11/T50/00/3009 Volume 5
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Hydrology	WMA 11/T50/00/3009 Volume 8
Land Use and Water Requirements	WMA 11/T50/00/3009 Volume 9

Executive Summary

INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as the natural river run-off was no longer adequate to meet the demands in the lower catchment. There was a concern that the flows may have dropped below the requirements of the Ecological Reserve. This was attributed to heavy afforestation and irrigation developments without adequate storage, in various parts of the catchment. The Department was under pressure to grant licences for further afforestation, which could exacerbate the situation.

The main objectives of the study, as defined in the inception phase are as follows:

- *To determine the existing and potential future water use;*
- *To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry;*
- *To reassess the hydrology and the water supplies available from existing sources; and*
- *To recommend possible schemes for meeting future requirements, including potential additional plantation forestry.*

The objective of this report is to consider possible water resource management and development options, the environmental and future consumptive water requirements. The implications for the water resource of possible development scenarios are then assessed.

The Mzimkhulu River catchment comprises 21 Quaternary sub-catchments which have been grouped into six Water Management Sub-catchments (WMSCs), shown in ***Figure 1****.*

Figure 1: Project Area, showing the Quaternary sub-catchments and the six Water Management Sub-catchments

ENVIRONMENTAL WATER REQUIREMENTS

The Ecological Water Requirements (EWRs) for eight selected riverine sites in the Mzimkhulu catchment, as well as for the estuary, were determined. The results of the modelling indicated that the current low flows, are, in most cases, less than ideal to meet the recommended flows to maintain the Present Ecological State (PES) of the river. However the state of the river appears to be stable.

The current state of the estuary and the impact of the additional forestry development were studied separately and are discussed in the Report: Estuarine Environmental Water Requirements, Volume 6 of the series. From the rapid level reserve study, it was concluded that the estuary is still in a good condition. The flow scenarios assessed, indicated that three future scenarios could be put forward, which will keep the system in a definite B category. However it was also found that, with time, the estuary was getting shallower and mouth closures were becoming more frequent. This has led to salinity building up in the estuary, as far upstream as St Helen's Rocks, at times, seriously affecting the quality of the Illovo Sugar Mill's water supply.

WATER RESOURCES

The surface water resources of the Mzimkhulu River, which has a present day MAR of 1 203 million m^3, are fed by the Mzimkhulwana, the Pholela, the Bisi, and the Ngwangwane Rivers, as well as a second Mzimkhulwana River.

Total water use in the catchment amounts to nearly 278 million m^3/a. There are no major storage dams in the catchment, but combined storage capacity of farm dams in the catchment totals some 54 million m^3. About 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested.

The upper part of the catchment is characterised by irrigated agriculture, while the middle part of the catchment is predominantly rural tribal trust land. In the lower middle reaches, there are a number of rural water supply schemes, drawing water mostly from local streams, boreholes and springs. The Ugu District Municipality draws water for Port Shepstone from the Lower Mzimkhulu WMSC.

CURRENT AND FUTURE SURFACE WATER USE

Agriculture and forestry are the predominant land uses in the catchment, with irrigation using just under 90 million m^3/a, and plantation forestry, about 113 million m^3/a. Total current (2009) urban and rural consumption (including Port Shepstone), amounts to 28 million m^3/a, and is expected to rise to 44,7 million m^3/a, by 2030. Rural settlements rely, to a large extent, on groundwater.

***Table 1** below, summarises the water use in the Mzimkhulu catchment, by sector.*

Table 1: Current Water Use by Sector

Land Use	Total Water Use (2010) (Million m^3/a)	Use as a percentage of total
Plantation Forestry	*112,7*	*41%*
Irrigation	*86,6*	*31%*
Alien Vegetation	*39,7*	*14%*
Rural, Urban, Industrial & Commercial	*28,1*	*10%*
Sugarcane	*6,8*	*3%*
Livestock watering	*3,8*	*1%*
Total water use	***277,7***	***100%***

The Surface Water Resources Study (Volume 3) has indicated that the present day Mean Annual Runoff (MAR) has reduced from a natural state of 1 453 to 1 206 million m^3/a.

Projected growth in future water demand, is discussed in the Land Use and Water Requirements Report (WMA 11/T50/00/3009, Volume 9) and further refined in the Surface Water Resources Report (WMA 11/T50/00/3009, Volume 3). All known rural and urban demands were projected to 2030 for modelling purposes.

There is widespread agricultural potential within the catchment and as it is unknown where expansion would take place, for the purpose of modelling the future scenarios, provision was made for all existing water use by irrigation, to increase by 20% by 2030.

Various future developments were also taken into account in assessing the future water demands on the catchment.

- *The proposed Cwabeni off-channel Dam, about 20 km upstream of Ugu's abstraction point at St Helen's Rocks, to address sporadic shortages in supply to Port Shepstone;*
- *Future water exports, to the Mhlabatshane Regional Water Supply Scheme, which will require a small volume water to be exported to the adjacent catchment, as from 2015;*
- *The possibility of future augmentation of the Mgeni System, via the Mkomazi River; and*
- *Increased supply to the coastal towns and resorts to the north and south of Port Shepstone.*

GROUNDWATER SITUATION

The Groundwater situation in the Mzimkhulu River catchment is discussed in the Groundwater Resources Report (WMA 11/T50/00/3009, Volume 4). Recommendations are made that exploration should continue in certain areas and guidelines are given as to the types of formation and profiles which should be investigated for localised water supply.

POTENTIAL FOR PLANTATION FORESTRY DEVELOPMENT

In order to determine the Commercial Forestry Potential, a negative mapping process was used. The details are contained in Volume 9 of this study.

The study examined various types of land cover and exclusion criteria, related to the following factors were adopted:

- *Land Cover;*
- *Ezemvelo KwaZulu-Natal (KZN) Wildlife Conservation Plan (C-Plan);*
- *Topographical Factors;*
- *Hydrological Factors; and*
- *Agricultural Factors.*

Applying filtering criteria throughout the catchment, and using more conservative criteria where small growers were involved, resulted in potentially suitable areas of:

- *An additional 50 350 ha for small and large growers throughout the catchment;*
- *An additional 29 400 ha for small growers throughout the catchment, and*
- *An additional 21 050 ha for small growers only in the Bisi Catchments.*

***Figure 2** provides a spatial view of areas in the catchment with poor, low, medium and high potential for forestry for all growers.*

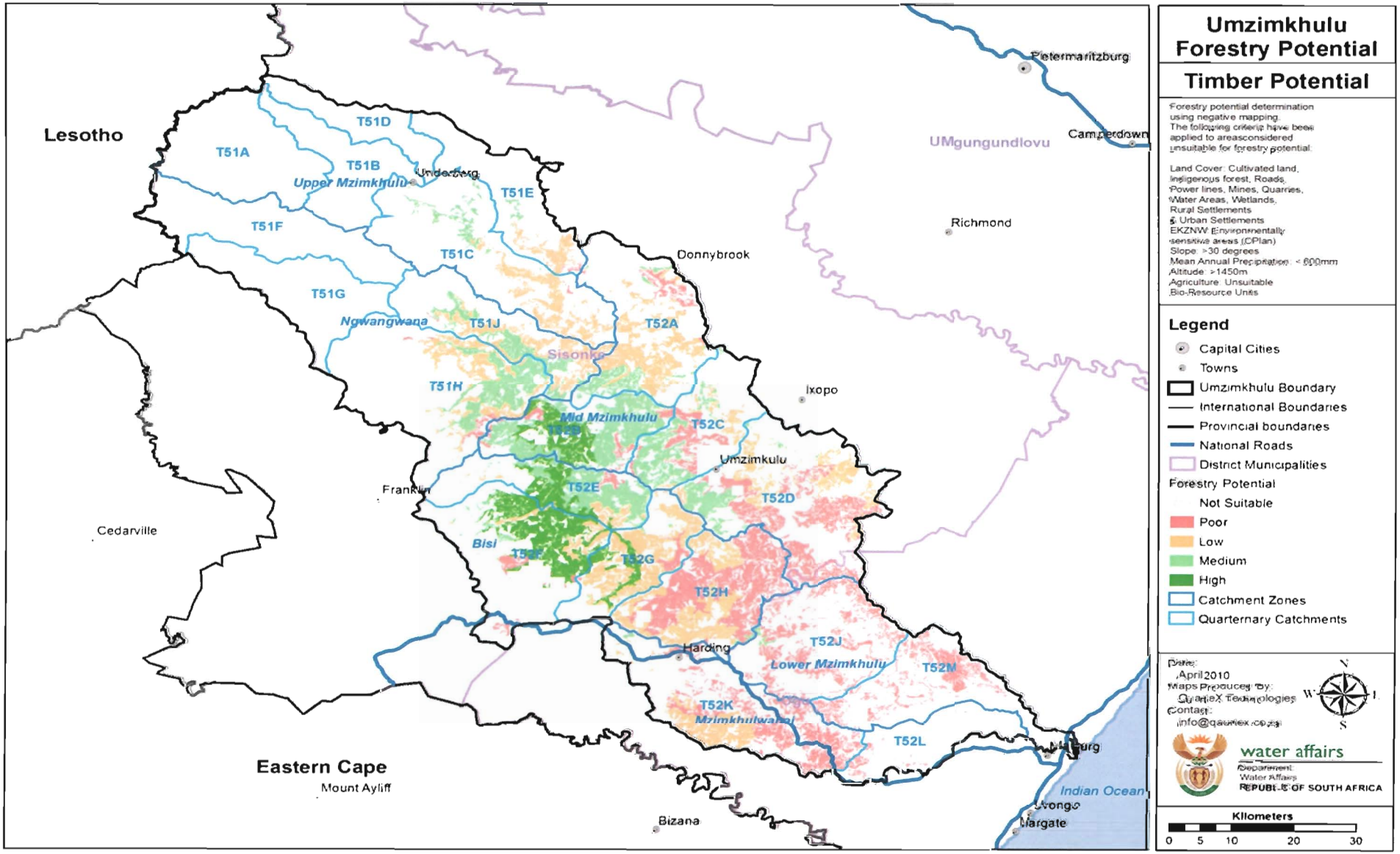

Figure 2: Areas with Potential for new Forestry

WATER RESOURCE MANAGEMENT AND INTERVENTIONS

The Mzimkhulu River, as a water resource, needs to be managed in a sustainable manner. After meeting the legal commitment to both the Basic Human Needs as well as the Ecological Reserve, allocations need to be made responsibly to ensure that the EWRs are not compromised. Numerous management options are discussed in the report and are summarised in the paragraph dealing with Recommendations, Short to Medium Term Actions.

DEVELOPMENT OPTIONS – PROVIDING ADDITIONAL STORAGE

Reports from previous studies conducted by the Department of Water Affairs, Umgeni Water and Municipalities were studied. Some 20 possible dam sites had been previously identified on the Main stream and tributaries of the Mzimkhulu River, shown in ***Figure 3.***

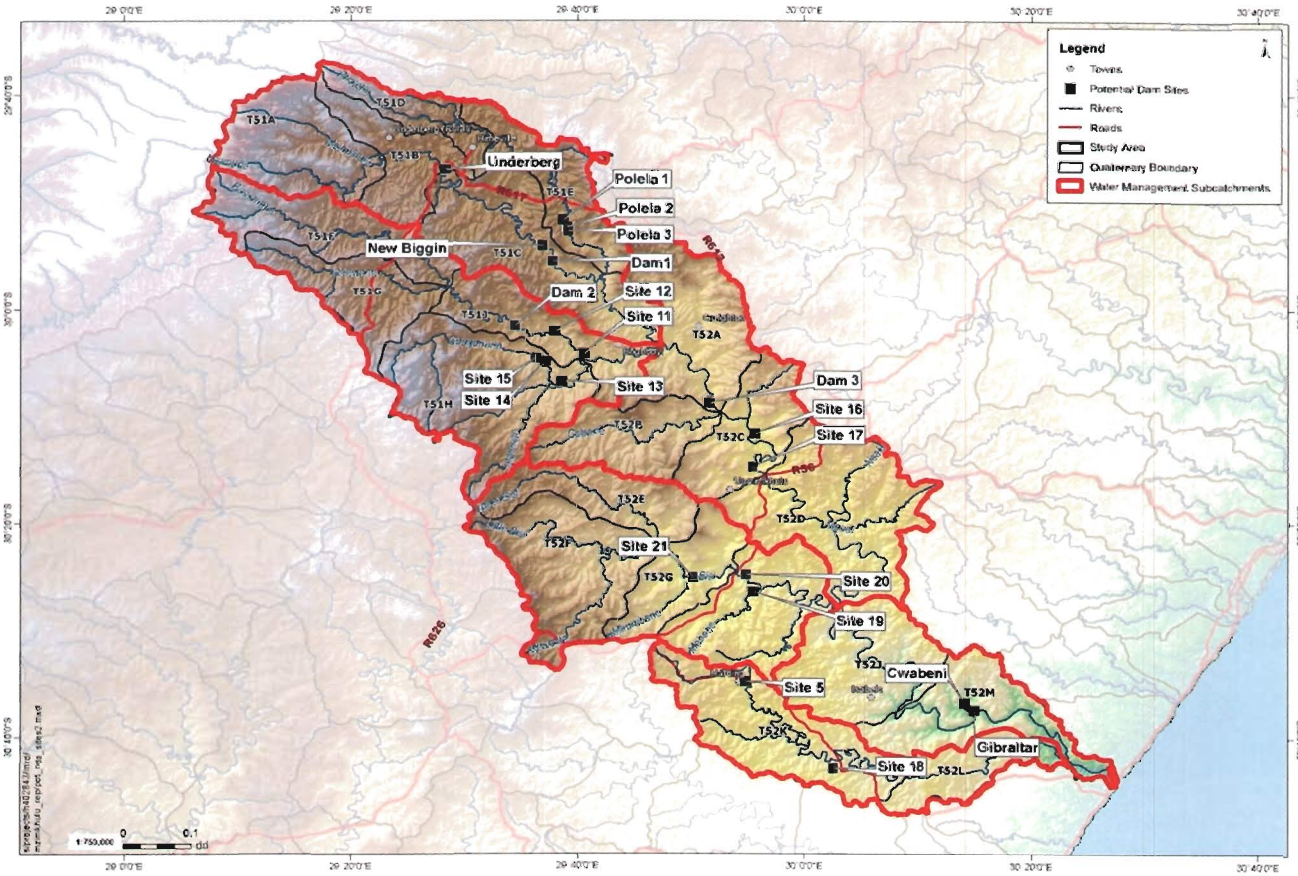

Figure 3: Previously identified Dam Sites

The sites were screened, using various criteria, the overriding one being locality. As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, were regarded as being best positioned to mitigate the impact of forestry on the low flows. Sites selected are:

- *Site 12 on the Ngwangwane River, and*
- *Site 19 on the Bisi River.*

To test the impact on the river flows and water available to meet the EWRs a possible large dam with all the surplus yield being exported, a further two sites were selected:

- *Underberg; and*
- *New Biggin.*

CATCHMENT SCENARIOS

The Mzimkhulu River system was modelled for the period 1920 to 2007 in the Water Resources Yield Model-Integrated Management System (WRYM-IMS), using updated hydrology estimates.

Present day land and water use requirements and the riverine EWRs, to maintain the PES, extrapolated to each quaternary sub-catchment for the present day system were imposed on the system. Two scenarios were run for the present supply system, with and without the Cwabeni off-channel storage, which is currently being investigated. When taking into consideration the EWR, there is no historic firm surplus yield from the run of river flows, at quaternary sub-catchment level.

The future scenarios were developed, in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. All known urban and rural demands, projected to 2030, were included.

FUTURE SCENARIO 1: ALL SMALL GROWERS

Scenario 1 assumes small grower plantation forestry expansion of 29 400 ha, and no increase in irrigated agriculture. A number of sub-scenarios were run, with and without the off-channel storage at Cwabeni, as well as mitigated scenarios to size a dam at Site 12 on the Ngwangwane River, operated to meet either the EWR or the present day flows at Gibraltar. A 0,5 MAR dam was also modelled, with the surplus yield assumed to be fully utilised or exported.

The results of the modelling indicated that this relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site. These flows could be restored by a small dam of about 10 million m^3 (about 0,04 MAR) storage at Site 12 on the Ngwangwane River. A larger dam of about 45 million m^3 (about 0,2 MAR), would meet all recommended EWR flows at Gibraltar. The larger 0,5 MAR dam, produced a surplus of about 80 million m^3/a.

FUTURE SCENARIO 2: SMALL GROWERS, BISI

Scenario 2 assumes plantation forestry expansion of 21 050 ha for small growers in the Bisi River catchment, with no increase in irrigated agriculture. A dam at Site 19 on the Bisi River was included to mitigate the impacts of increased plantation area. Three scenarios were run with the dam, to size it to meet either the EWR flows or to meet the present day flows at Gibraltar and a 0,5 MAR dam, operated to meet the EWR at Gibraltar, with the surplus yield assumed to be fully utilised or exported.

From the results of the modelling runs, as mentioned above, this relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site but did impact on the low flows at the Bisi EWR site. In this scenario, the present day flows at Gibraltar could be restored by a small dam of just less than 15 million m^3 (0,07 MAR), at Site 19 on the Bisi River. A larger dam of about 45 million m^3 (about 0,2 MAR), on the same

site, would restore the river to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of about 30 million m^3/a.

FUTURE SCENARIO 3: ALL GROWERS, SMALL AND LARGE

Scenario 3 has an increased forestry area of 50 350 ha, for small and large growers, throughout the catchment, as well as a 20% increase in the water supplied to irrigated agriculture. Two unmitigated scenarios were run, with and without the off-channel storage at Cwabeni. Three mitigated scenarios were run to size a dam at Site 12 on the Ngwangwane, the first just large enough to meet the EWR flows, the second to meet the present day flows at Gibraltar and the third being a 0,5 MAR dam, operated to meet all the EWR flows at Gibraltar, with the surplus yield assumed to be fully utilised or exported.

From the results of the modelling runs, the larger area of additional plantation forestry had a noticeable impact on the present day flows at the Gibraltar EWR site and at the Bisi Site. In this case, the present day flows could be maintained by a relatively small 16,5 million m^3 dam (0,07 MAR) at Site 12 on the Ngwangwane River. A larger dam of about 48 million m^3 (0,2 MAR) would be able to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 76 million m^3.

FUTURE SCENARIO 4: LARGE DAM SCENARIO

Scenario 4 was developed in order to explore the impacts on the river and estuarine flows of a large scale water resource development, either for export of water or to meet significant new demands. This scenario has the same land and water use as for Scenario 3.

Three cases were modelled, with various combinations of a large 1,0 MAR dam at Underberg, a 1,5 MAR dam at the New Biggin site and small dams, ranging from 0,17 to 0,5 of the MAR at the Bisi and Ngwangwane sites, the latter two, to meet the EWR flows at Gibraltar.

The results indicated that volumes of about 180 million m^3/a, from the Underberg site and about 230 million m^3/a from the New Biggin site, could be made available for export, while meeting all EWR flows.

DISCUSSION

At the sites, used for the EWR study, the Mzimkhulu River has been assessed to be in a good condition, somewhat better than expected. The aquatic environment also proved to be fairly resilient, being relatively unaffected by the proposed development of additional forestry and irrigation in the catchment. It emerged that there is limited risk to the environment, in allowing a moderate amount of plantation forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows.

The developments, in which a large dam is constructed on the main stem of the Mzimkhulu, have the largest potential impact on the ecosystem, with those dams planned for tributaries, having much less impact. Avoiding construction of dams on the main stem river would also support conservation initiatives, where the undammed nature of the Mzimkhulu River has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) programme and the river is ranked as one of the most important for conservation in the region.

The scope of the project made provision for a limited number of EWR sites. These sites are on the main Mzimkhulu River and on the larger tributaries. Whilst the impact of up to 29 400 ha of additional forestry was limited at these sites, there may be considerably more severe impacts locally, on some of the smaller tributaries, which will need to be assessed when considering licence applications. There is some uncertainty about the impacts on the riverine environment of Scenario 3, with about 50 000 ha of additional forestry, together with additional irrigation. Further studies are recommended before such large scale developments are considered.

There are a number of limitations to this assessment which have been described in the Riverine Ecological Water Requirements Report (WMA 11/T50/00/3009, Volume 5). While none of these constitute a "fatal flaw" in the investigation, there are some areas of uncertainty that should be resolved before major developments in the catchment are given approval. The greatest uncertainties revolve around the accuracy of the predicted reductions in flow, with increasing forestry, especially in the Bisi catchment, which also happens to be the catchment, most likely to be developed for forestry.

CONCLUSIONS

The overall conclusion is that the state of the ecosystem in this catchment, including the estuary, is generally good and the main Mzimkhulu river appears to be fairly resilient to the first level of plantation forestry (29 400 ha) development in the catchment. However, there are some uncertainties about the impact with the greatest uncertainty being the impacts on small tributaries which are likely to be severely impacted in the dry season. These were not part of this investigation.

On the larger tributaries, where the dam sites are located, the study did not consider the possible impacts of the dams themselves on the tributaries before the confluence with the main river. Given these uncertainties, it is recommended that a phased approach should be adopted to allowing additional plantation forestry, with careful monitoring of the river to detect and avoid a change of state. By providing storage, the impacts of increased plantation forestry and irrigation would not only be successfully mitigated, but the state of the main Mzimkhulu River could be improved, to meet all EWRs at Gibraltar. Additional storage would also provide some surplus yield, which could be exported or used if a large storage dam is to be considered to export water to a neighbouring catchment within the catchment.

The cost estimates of the possible dams at site 12 on the Ngwangwane River and site 19 on the Bisi River were based on the smallest possible dams to meet all the EWR requirements at the Gibraltar site. On each of the sites, a dam with storage volume of 42 million m^3 was assumed for costing purposes and costs are estimated to be R367 million and R265 million, respectively.

Annual costs of redemption of the above loans, over a period of 40 years, at interest rates of 8, 10 and 12% for each of the dams, were reduced to a per hectare cost for the three scenarios, as shown in ***Table 2****.*

Table 2: Cost of capital per hectare to create additional storage to mitigate the impact of additional plantation forestry

Scenario (ha)	Ngwangwane (Rand)			Bisi (Rand)		
	8%	10%	12%	8%	10%	12%
21 050	1 350	1 620	1 890	976	1 170	1 360
29 400	970	1 160	1 350	700	840	970
50 350	560	680	790	410	490	570

If one was to add the irrigation expansion, this would add about 3 000 ha and reduce the costs in the table by about 15% for the 21 050 ha scenario and 6% for the 50 350 ha scenario.

The gross marginal cost of timber production in the catchment, is estimated to be in the order of R2 500/ha/a. As can be seen from ***Table 2****, provided reasonably large areas of plantation forestry are planted, the mitigation costs of constructing a dam to restore the EWR flows, are within reach.*

RECOMMENDATIONS

SHORT TO MEDIUM TERM ACTIONS (1-5 YEARS)

The following actions should be undertaken:

Environmental

- *Implement on-going ecological monitoring at the EWR sites, especially the RAPID III sites, and upgrading them to Intermediate category, and determine if the ecological state of the river is deteriorating or not.*
- *As soon as possible determine and implement Resource Classification Objectives following the newly published procedure, so that there can be clear objectives for the management of the river.*
- *Establish Intermediate EWR sites and gauge flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu WMSC. Monitor flows at these points and at the Gibraltar EWR site continuously. Maintain regular river health monitoring at these EWR sites.*
- *Carry out on-going monitoring of the estuary, as discussed in the Estuarine Ecological Water Requirements Report (WMA 11/T50/00/3009, Volume 6). This on-going monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored.*
- *Evaluate the findings of this EWR investigation in the light of the new data which is gathered, including that from the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from that study will provide information on the Reserve situation in the smaller tributaries.*
- *Extend the current Wetland Rehabilitation Project to drained and degraded wetlands, wetlands, currently not receiving attention.*

Hydrological Monitoring

- *Review the calibration of key flow gauges, as discussed in the Hydrology Report (WMA 11/T50/00/3009, Volume 8).*
- *Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).*

Water Resource Management

- *Implement Water Conservation and Demand Management measures. If estimated losses in urban and domestic use in the catchment could be halved, the savings could be up to 7 million m^3/a.*
- *Validate and verify all registered water use in the catchment and eliminate unlawful use. If 5% of the current irrigation use of 90 million m^3/a, is unlawful, this could free up about 4,5 million m^3/a. Similarly, removal of illegal plantation forestry, could free up between 5 and 6 million m^3/a.*
- *Monitor to ensure compliance with licence conditions, to ensure amongst others, that abstraction volumes are not being exceeded and plantation areas are not being exceeded.*
- *Identify and remove alien vegetation. Removing a quarter of the estimated area, could boost the available water by 10 million m^3/a.*
- *Maintain water quality monitoring in the catchment and recommence water quality monitoring in the Lower Mzimkhulu.*
- *Educate people in rural areas to prevent over-grazing.*
- *Institute catchment conservation measures, including wetland rehabilitation and removal of alien vegetation, which will assist in meeting the Reserve.*

Water Use Licensing

- *Invite and process licence applications for an initial area of up to 5 000 ha of plantation forestry in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu WMSCs with priority being given to small growers. Applications in other sub-catchments could also be considered. Local impacts of all applications need to be evaluated.*
- *There is a large amount of alien vegetation in the catchment. Removal of these can be replaced with equivalent afforestation.*
- *Ensure that any new licence application for development includes information of potential impacts as provided by an EIA process and potentially a Reserve study, conducted at a local level. The Reserve information provided in this report cannot be construed to cater for all local level situations. Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively may have a high impact, need to be considered in a larger context. This is especially the case for small scale forestry developments. Co-ordination of the management of these larger impacts should be the responsibility of DWA with support from the Provincial Environmental management authority.*

Water Resource Development

- *Investigation of Cwabeni off channel storage must continue in order to have mechanism ready to address dry season water shortages in the short term.*
- *Carry out an initial comparison, including realistic time lines and lifetime economics between the Cwabeni off-channel storage dam and a storage dam on the Ngwangwane and Bisi Rivers, sized to supply Ugu District Municipality's requirements and mitigate the impacts of additional plantation forestry.*

- *Develop Groundwater Resources for remote rural and urban settlements and where yields are* sufficient, also for small scale irrigation to provide food security.

LONGER TERM MANAGEMENT AND DEVELOPMENT OPTIONS

- *The EWR studies should be revisited following on-going EWR monitoring and implementation of a maximum of 5 000 ha of new plantation forestry.*
- *Having monitored the impact of the first 5 000 ha of additional forestry over a period of 5 to 10 years, if the impact does not appear significant, as indicated by the flow regimes and ecological monitoring, invite and process licence applications in batches of 5 000 ha, for the balance of the potential area of 30 000 ha of plantation forestry, in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu WMSCs.*
- *The hydrology should be updated and the model recalibrated, paying particular attention to the Bisi catchment.*
- *Small growers should receive priority.*
- *The impact on the water resource and the environment should continue to be monitored. Applications in other sub-catchments could also be considered.*
- *Local impacts needs to be evaluated for each application and cumulative effects considered.*
- *If unacceptable impacts are observed, then undertake a pre-feasibility study to investigate the possibility of a dam on the Ngwangwane or the Bisi River. The purpose of either of these dams would be:*
  - *to mitigate the impact of realising the full potential plantation area of 50 000 ha;*
  - *to restore the EWR flows;*
  - *to investigate whether there are sites upstream of those modelled on the Ngwangwane and the Bisi Rivers with a more favourable capacity to MAR ratios;*
  - *to meet the shortfalls at the Ugu's St Helen's Rocks abstraction works on the main river, this could do away with the need for the Cwabeni off-channel dam currently being investigated. This could avoid duplication and save the off-channel pumping costs.*
- *Identify the technical, economic and environmental feasibility of developing a dam.*

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Abbreviations

BMP	-	Best Management Practises
C-Plan	-	Conservation Plan
CFP	-	Commercial Forestry Potential
DWAF	-	Department of Water Affairs and Forestry
DWA	-	Department of Water Affairs
EIA	-	Environmental Impact Assessment
ER	-	Ecological Reserve
EWR	-	Ecological Water Requirements
FSL	-	Full Supply Level
IB	-	Irrigation Board
IDP	-	Integrated Development Plan
KZN	-	KwaZulu-Natal
MAP	-	Mean Annual Precipitation
MAR	-	Mean Annual Run-off
masl	-	mean average sea level
NFEPA	-	National Freshwater Ecosystem Priority Areas
NWA	-	National Water Act
PES	-	Present Ecological State
ppm	-	Part per million
RES	-	Recommended Ecological State
SANBI	-	South African National Biodiversity Institute
SDM	-	Sisonke District Municipality
UW	-	Umgeni Water
WARMS	-	Water Use Authorisation Registration Management System
WCDM	-	Water Conservation and Demand Management
WMSC	-	Water Management Sub-catchment
WRC	-	Water Research Commission
WRM	-	Water Resource Management
WRYM-IMS	-	Water Resources Yield Model – Integrated Management System
WUA	-	Water User Associations

Scenario keys

U	-	Unmitigated – no dams
M	-	Mitigated by one or more dams
SG	-	Forestry potential for Small Plantation Growers
LG	-	Forestry potential for Large Plantation Growers
A	-	All forestry areas
Irr 20	-	Additional 20% irrigation water use
Bisi	-	Bisi in the Middle Mzimkhulu WMSCs
OCS	-	Off-channel Storage (Cwabeni Dam)

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1. INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as the natural river run-off, particularly during the low flow months and in dry periods, was no longer adequate to meet the demands in the lower catchment. There was a concern that the flows might have dropped below the requirements of the Ecological Reserve. This was largely attributed to heavy afforestation and irrigation developments without storage, in various parts of the catchment. The Department was under pressure to grant licences for further afforestation which, if allowed, would exacerbate the situation.

1.1. OBJECTIVES OF THE STUDY

The main objectives of the study, as defined in the inception phase, are as follows:

- To determine the existing and potential future water use in and from the catchment of the Mzimkhulu River.
- To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry, while also considering other envisaged future requirements.
- To reassess the hydrology and the water supplies available from existing sources, which are mainly run of river, taking the ecological flow requirements into account, in order to determine to what extent the existing sources can meet the existing and potential future usage requirements.
- To recommend possible schemes for meeting future requirements, including potential additional plantation forestry, as well as interventions for moderating existing and potential future usage requirements.

This report describes the assessment of the possible development scenarios and is one of the deliverables in support of meeting these objectives.

1.2. OBJECTIVES OF THIS REPORT

As part of the above study objectives, this report examines the impact of possible future development scenarios on the river system. This includes meeting all known demands, including Ecological Water Requirements (EWR) up to 2030, potential additional plantation forestry, with particular emphasis on small growers, as well as additional irrigation development. The effect of measures to mitigate the impacts of the possible development scenarios, are modelled and the results discussed. Management interventions for moderating existing and potential future water requirements are also examined.

1.3. STUDY AREA

The Mzimkhulu River catchment comprises the 21 Quaternary sub-catchment areas that feed and form part of the Mzimkhulu River Basin, situated in KwaZulu-Natal (KZN). For the purpose of this study, the project area has been divided into six Water Management Sub-catchments (WMSCs), shown in **Figure 1.1**, below:

- Upper Mzimkhulu (5 Quaternary sub-catchments);
- Ngwangwane (4 Quaternary sub-catchments);
- Mid Mzimkhulu (4 Quaternary sub-catchments);
- Bisi (4 Quaternary sub-catchments);
- Lower Mzimkhulu (2 Quaternary sub-catchments); and the
- Mzimkhulwana (2 Quaternary sub-catchments).

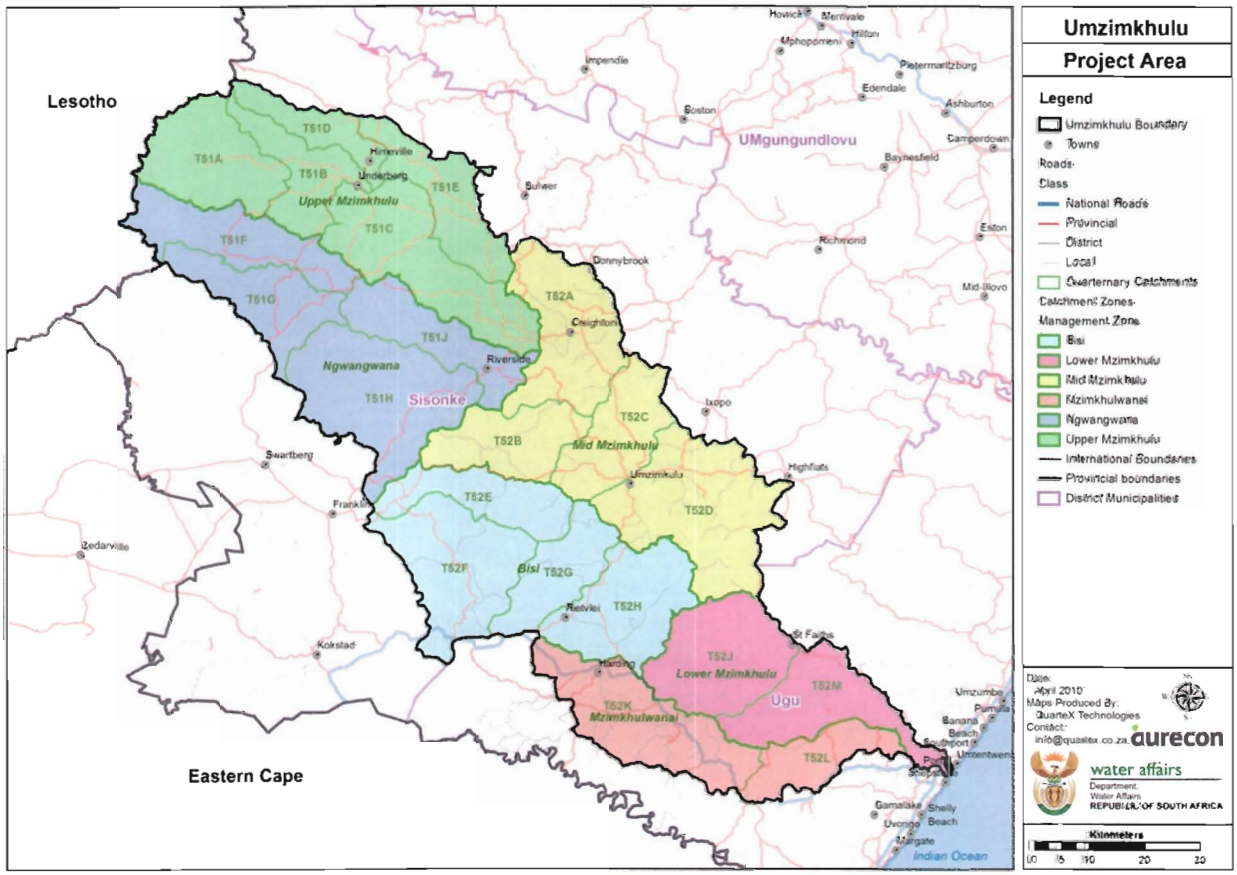

Figure 1.1: Project Area, showing the Quaternary sub-catchments and the six Water Management Sub-catchments

Key Statistics of the Catchment:

- Catchment Area: 6 668,55km^2;
- Mean Annual Runoff (MAR) (Natural): 1 453 million m^3;
- Mean Annual Runoff (Present day): 1 206 million m^3;
- Mean Annual Precipitation (MAP): 930 mm; and
- Length of main river course: 353 km.

2. DEVELOPMENT OBJECTIVES AND VISION

2.1. DEVELOPMENT OBJECTIVES

In any environment, if a resource is not used in a sustainable manner, it will lead to the degradation of the resource and ultimately to its demise. This is particularly true in the riverine environment. The objective of this study has been to identify development opportunities, particularly for forestry development, assess the implications of the potential developments for the water resource and the environment and ascertain whether the water requirements of the developments remain within the bounds of sustainability. In the cases where potential use exceeds the level of sustainability, physical steps are proposed to mitigate the impact on the resource.

In terms of the National Water Act (NWA) 1998, the only right to water is the Reserve. Both the Basic Human Needs as well as the Ecological Reserve need to be met at all times, in order to ensure a sustainable water resource. In order to achieve a balance, the people living in the catchment need to have symbiotic relationship with the catchment and its water resources. This will not happen, unless they have food security and live above the poverty line.

Main development objectives are:

- Plantation forestry development, primarily small by scale emerging growers, as well as large scale commercial companies (Sappi, Mondi, Hans Merenski etc.).
- Irrigation development of small scale irrigators, promoting food security, as well as expansion of commercial irrigation.
- Expansion of urban and industrial development attracted to the catchment by the assurance of sufficient water, in order to enable and promote new development.

2.2. RESOURCE PROTECTION

Key elements of resource protection are protecting the quantity and quality of water required by the environment and ensuring that land use activities do not adversely affect the resource.

The objective of the river EWR, or Reserve determination, was to quantify the flow regime, required by the riverine environment. Determining the Reserve is required by the National Water Act (1998). The rationale behind this is that the environmental water requirements define the flows and water quality required to maintain the ecosystems and the resource. Damage to the ecosystem would jeopardise the potential for other users to have access to the water. Initial indications were that the resources in the catchment were already over-developed, based largely on the fact that water resources appeared stressed at the lower end of the river, where Port Shepstone at times, did not have adequate supplies.

During the stakeholder consultation process, it emerged that there were locations in the catchment where land use activities were leading to the degradation of the resource. These included:

- over-grazing, leading to erosion and subsequent pollution of the river; and
- draining of wetlands for cultivation, thus losing the sponge effect which sustains low flows.

Wetlands are of high importance for the conservation of biodiversity both regionally and nationally. A number of threatened fauna occur in wetlands within the catchment, particularly in the Mpur forestry area, in the Upper Bisi catchment. Three wetlands have been identified, two in quaternary catchment T52E and one in T52F, with various interventions, which are discussed in Paragraph 6.2.

Without proper protection and management of the resource, it will deteriorate and will no longer function in a sustainable way, to be beneficial to the users. The most effective method of controlling and managing the resource is the licensing process. The first step would be to ensure that all water use, including plantation forestry, is lawful. This would involve Validation and Verification of water use, discussed later in this report. All new licences issued, should take particular cognisance of the environmental and Reserve considerations set out in section 27(1) of the NWA. EWR requirements, in particular need to be specified. It is also vital that monitoring takes place to ensure compliance with licence conditions.

2.3. WATER SUPPLY TO ALLEVIATE POVERTY, IMPROVE THE QUALITY OF LIFE, PROMOTE SUSTAINABLE DEVELOPMENT AND JOB CREATION

2.3.1. Urban and rural domestic supply

Population numbers in both urban and rural areas are increasing and it is estimated that water demand will increase by approximately 60% by 2030 due to increasing population and increasing per capita consumption. A similar increase in water use in the rural areas has been assumed, largely due to increase in per capita water use. It is vital that this demand in the urban areas be catered for, in order not to stunt economic growth. A reliable water resource will enable District and Local Municipalities to provide water for sustainable development, thus promoting job creation, leading to poverty alleviation and improved quality of life. A sustainable water resource is also required to improve household food security.

2.3.2. Irrigation supply

Irrigated agriculture is the second largest water user in the catchment, comprising some 20 000 ha, using about 90 million m^3/a. The implications of a 20% increase in water use in this sector, with and without mitigation measures, are examined.

2.3.3. Plantation forestry

The largest water user in the catchment, is plantation forestry, comprising some 83 200 ha using about 113 million m^3/a. There is considerable potential for expansion, particularly in the Bisi and Middle Mzimkhulu WMSCs. This area was formerly part of the then Transkei and later became part of the Eastern Cape. It now forms part of KwaZulu-Natal. See **Figure 2.1**. As it was rather remote from the previous seats of government, it was neglected and there is widespread poverty in the area. There is thus a huge need for social upliftment and creation of jobs. Srnall grower plantation forestry could form part of this upliftment.

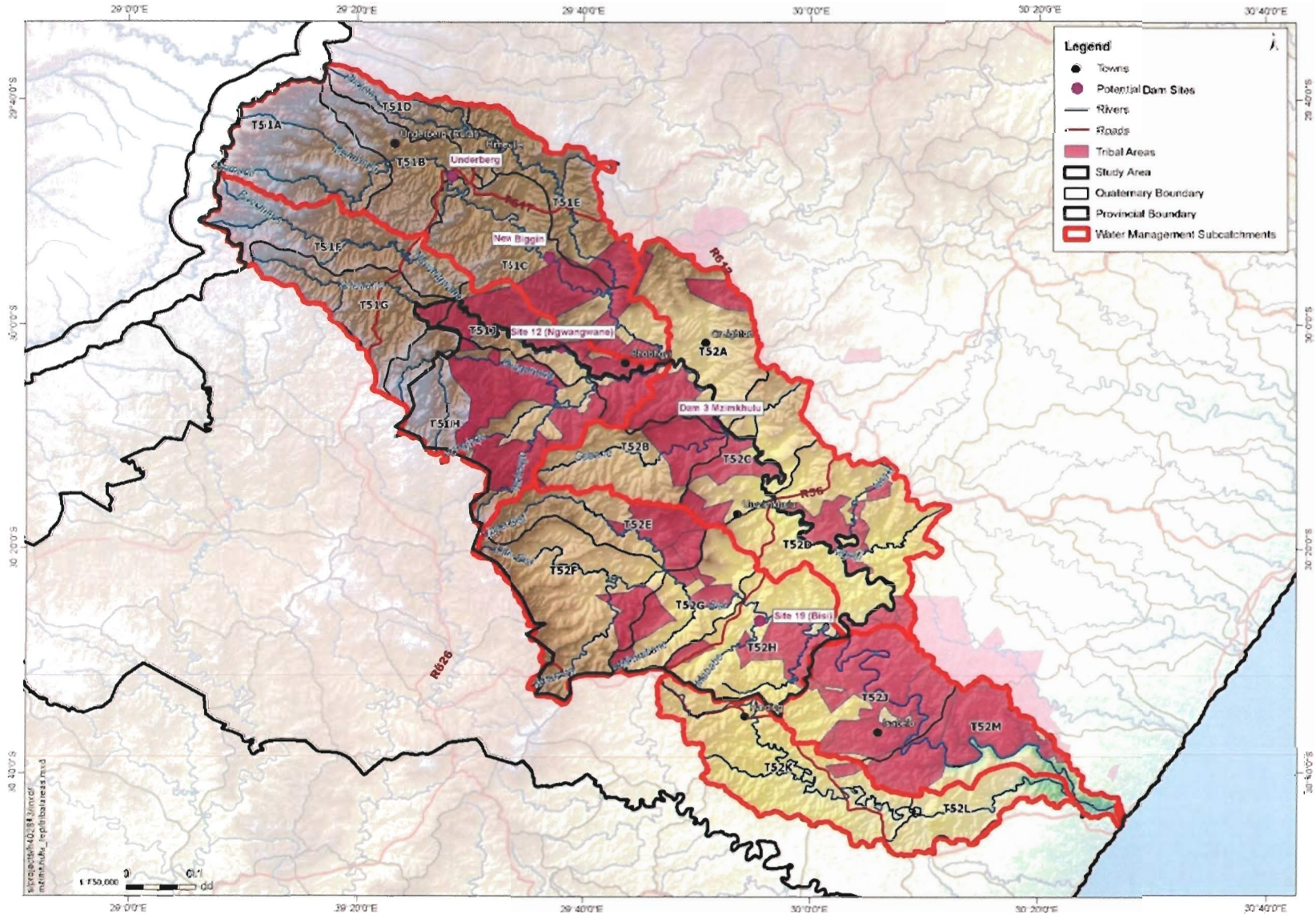

Figure 2.1: Tribal Areas and old Provincial Boundaries

3. ECOLOGICAL WATER REQUIREMENTS

3.1. INTRODUCTION

The EWRs for eight riverine sites in the Mzimkhulu Catchment were determined. The location of the sites is shown in **Figure 3.1** below.

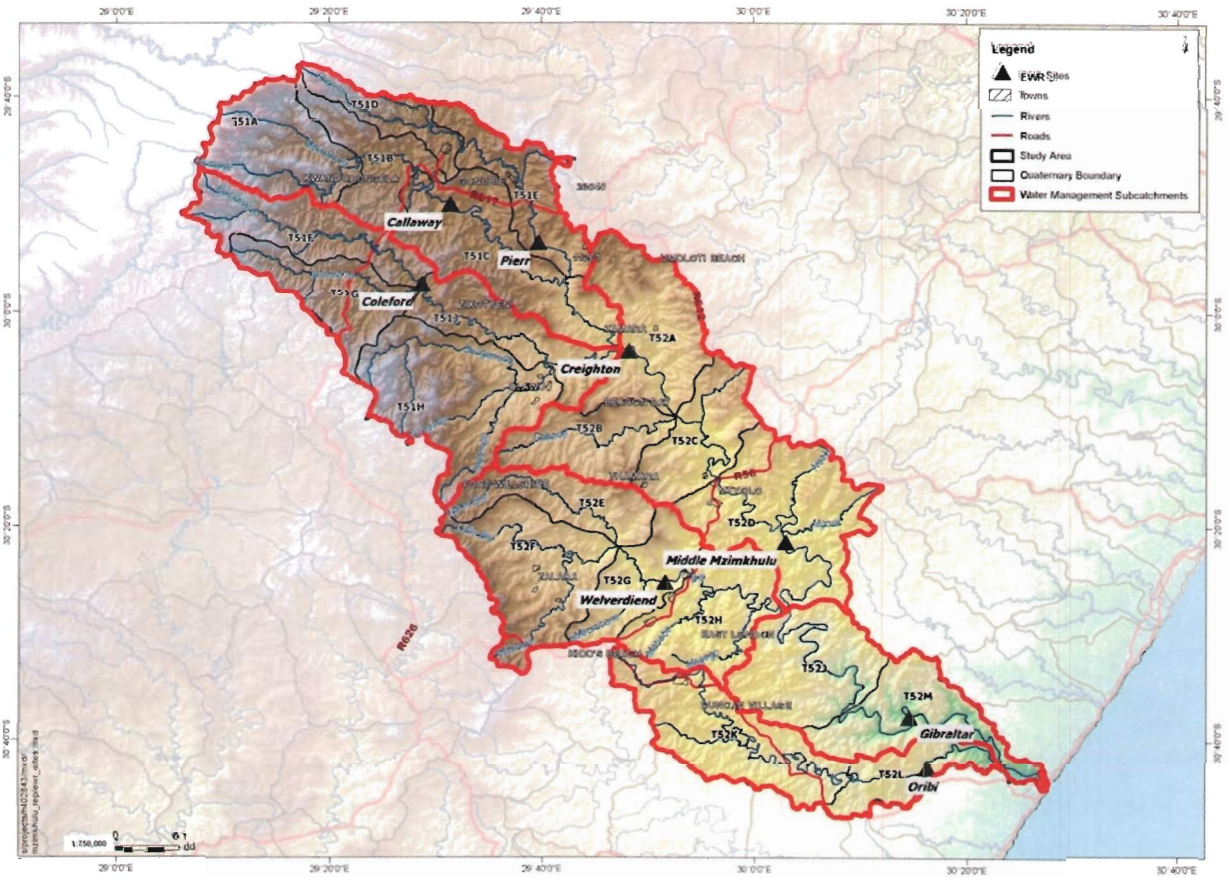

Figure 3.1: Location of EWR Sites

Basic information relating to each of the sites is summarised in **Table 3.1,** below.

More detail is provided in the Riverine Ecological Water Requirements Report *(WMA 11/T50/00/3009, Volume 5*). The EWRs were extrapolated to each quaternary sub-catchment and the total water requirements were incorporated into the Water Resources Yield Model Integrated Management System (WRYM-IMS).

Table 3.1: EWR sites in the Mzimkhulu Catchment

Quaternary catchment	River	EWR site number	EWR site name	Level	PES	REC	Natural MAR (million m^3)	% MAR for Maintenance High Flow	% MAR for Maintenance Low Flow	EWR as % of MAR	% MAR for Drought Low Flow
T51C	Mzimkhulu	EWR2i	Callaway	Intermediate	B	B	261	12,1	12,5	24,6	4,6
T51E	Pholela	EWR9r	Pierr	Rapid 3	B/C	B/C	110	9,7	18,7	28,4	7,0
T51F	Ngwangwane	EWR8r	Coleford	Rapid 3	C	C	117	9,8	11,7	21,4	5,6
T52A	Mzimkhulu	EWR3i	Creighton	Intermediate	B	B	870	3,1	19,9	23,0	4,4
T52D	Mzimkhulu	EWR5i	Middle Mzimkhulu	Intermediate	B	B	1 085	5,5	15,8	21,3	5,3
T52G	Bisi	EWR13r	Welverdiend	Rapid 3	A/B	A/B	195	11,6	31,2	42,8	11,9
T52L	Mzimkhulwana	EWR17i	Oribi	Intermediate	B	B	43	12,4	17,6	30,0	5,9
T52M	Mzimkhulu	EWR6i	Gibraltar	Intermediate	A/B	A/B	1 384	4,7	25,5	30,2	5,7

Notes:

PES = Present Ecological State
RES = Recommended Ecological State
MAR = Mean Annual Run off

3.2. MODELLING RESULTS

The results of the modelling indicated that the current flows, especially the low flows, are, in most cases, insufficient to meet the flows recommended by the ecological scientists to ensure that the Present Ecological State (PES) of the river is maintained. This means that in the periods when there is a "shortage", the river is stressed. However, it appears that the river revives when the next elevated flows occur. The long term effect of these periods of stress is uncertain and the condition of the river may deteriorate if no action is taken. Significant additional development in the basin is likely to cause some deterioration in the riverine environment that this may not be significant.

3.3. ESTUARY

The current state of the estuary and the impact of the additional forestry development were studied separately from the riverine environment and are contained in the Estuarine Ecological Water Requirements Report *(WMA 11/T50/00/3009, Volume 6)* of the series. It was found that with time, the estuary was getting shallower, the depth having reduced from some 3 m in the 1950s to the current 1,5 m, 3 to 4 km from the mouth.

Over the same period, the occurrence of low flows of less than 5 m^3/s has increased from 11% of the time to 29% of the time. Observations have also indicated that the incidence of mouth closure has increased from 2% of the time to 20% of the time. Closure of the mouth leads to salinity building up in the estuary, as far upstream as St Helen's Rocks. The Illovo Sugar Mill has measured salinity levels of 8 000 to 25 000 part per million (ppm) during low flow periods, in recent years. Considering that sea water contains 35 000 ppm, it is clear that there is a problem.

From the rapid level reserve study, it was concluded that the estuary is still in a good condition, namely a B (PES). The Recommended Ecological Category (REC) for an estuary of the importance, (as indicated by importance scoring), is a B. The flow scenarios which were assessed indicated that three of the future scenarios could be acceptable, since the requirements to maintain the REC, B category will be met.

4. CURRENT WATER RESOURCES, WATER USE AND WATER BALANCES

4.1. CURRENT SURFACE WATER USE

The volumes of water consumed by the various water use sectors in the catchment are discussed in the Land Use and Water Requirements Report *(WMA 11/T50/00/3009, Volume 9)*. The present day land use is shown in **Figure 4.1**.

Agriculture and plantations are the predominant land use in the catchment, covering 67% of the land currently developed for commercial production. Activities include irrigation, dry land cropping, plantation forestry and livestock farming. This is followed by indigenous forests and protected grasslands, covering 16% of the catchment. A further 14% is allocated to human settlement (urban and rural) and transportation infrastructure. The remaining area is attributed to rural industry and water bodies.

Irrigated agriculture covers approximately 20 000 ha and uses just under 90 million m^3 of water per annum. Plantation forestry uses about 113 million m^3/a.

Urban consumption (excluding Port Shepstone), amounts to 3,7 million m^3/a, based on the population living in these towns. In contrast, rural settlements which are found throughout the catchment and obtain their water from diffuse sources, including groundwater, account for 6,5 million m^3/a. Together, human settlement in the catchment currently accounts for 11,4 million m^3/a. The total current water use for Port Shepstone, which is outside the catchment, but supplied from the lower Mzimkhulu River, is 16,7 million m^3/a.

Table 4.1 and **Figure 4.1** summarise the total volume of use in the Mzimkhulu catchment, by sector. The total estimated current water use is 278 million m^3/a, with plantation forestry and irrigation as the highest water users in the catchment. Irrigation represents a significant water user, based on abstraction from rivers and dams in the catchment.

Table 4.1: Summarised Land Use and Water Requirements

Land Use	Total Water Requirement (Million m^3/a)	Demand as percentage of total
Plantation forestry	112,7	41%
Irrigation	86,6	31%
Alien Vegetation	39,7	14%
Rural, Urban, Industrial & Commercial	28,1	10%
Sugarcane	6,8	3%
Livestock watering	3,8	1%
Total water use	277,7	100%

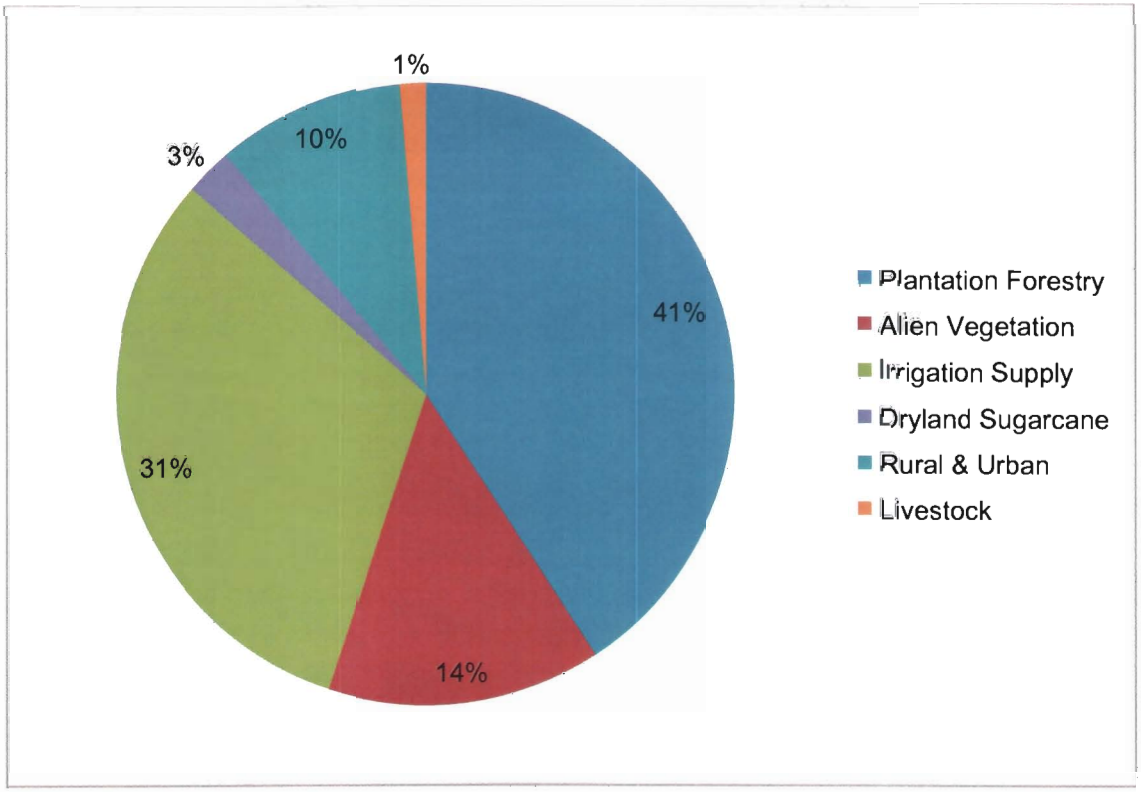

Figure 4.1: Breakdown of Water Use in the Mzimkhulu Catchment by Sector

4.2. WATER RESOURCES

The surface water resources of the Mzimkhulu River, which has a present day MAR of 1 206 million m^3, are fed by the Mzimkhulwana River, the Pholela River, the Bisi River, the Ngwangwane River and a second Mzimkhulwana River. Total water use in the catchment amounts to 278 million m^3. There are no major storage structures in the Mzimkhulu catchment, but combined storage capacity of smaller dams in the catchment, totals some 54 million m^3.

The upper part of the catchment is characterised by irrigated agriculture, fed by numerous farm dams. This area is serviced by the farming towns of Underberg, Himeville, Creighton and Harding, which have reasonably developed water supply infrastructure. Tourism also plays a large role in the upper catchment. Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested.

The town of Umzimkulu in the middle of the catchment is partially situated in the flood plain of the river and is subject to periodic flooding. This middle part of the catchment is predominantly rural tribal trust land.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water from local streams, boreholes and springs.

Lower down, the Oribi Flats form a plateau between the gorges of the Mzimkhulu and the Mzimkhulwana Rivers, the latter, flowing through the Oribi Gorge Nature Reserve, a World Heritage Site, with spectacular scenery.

The estuary drains into the Indian Ocean at Port Shepstone, which is supplied with water from the river.

The Surface Water Resources Report *(WMA 11/T50/00/3009, Volume 3)*, has indicated that the Present day MAR has reduced somewhat from the Natural MAR. This is illustrated in **Table 4.2**, where the MAR's are compared at the eight EWR Sites and the estuary.

Table 4.2: Mean annual runoff at EWR sites for current supply system

EWR Site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)
Callaway	261	186
Pierr	110	86
Coleford	117	100
Creighton	870	755
Middle Mzimkhulu	1 085	883
Welverdiend	195	158
Oribi	43	28
Gibraltar	1 384	1 152
Estuary	1 453	1 206

The hydrological modelling study has indicated the following reductions in the three low flow months (July, August and September) from their natural state to their present state:

Upper Mzimkhulu WMSC

T51B - 57% Reduction (Underberg – Main stream)
T51D - 48% Reduction (Himeville – Pholela)
T51E - 43% Reduction (Pevensey – Pholela)
T51C - 42% Reduction (Main stream)

Middle Mzimkhulu WMSC

T52A - 56% Reduction (Creighton – Nkonzo)
T52D - 42% Reduction (Main stream)
T52C - 44% Reduction (Main stream)

Mzimkhulwana WMSC

T52L - 33% Reduction (Oribi Gorge)

4.3. CURRENT SURFACE WATER BALANCE

4.3.1. Water Balance

Irrigators have experienced water shortages in the Pholela, Nkonzo, Ngwangwane, Mzimkhulwana (Harding) catchments, where many have responded by constructing small dams. The Ugu District Municipality has also experienced deficits in the main stream of the Lower Mzimkhulu River, at St Helen's Rocks, where they abstract water for Port Shepstone. The current water demand at Port Shepstone is 16,7 million m^3/a. The deficits have led to Ugu constructing a small 900 000 m^3 balancing dam and a study by DWA at

feasibility level, into a larger scale off-channel storage dam, the Cwabeni Dam, upstream of Ugu's abstraction works.

However the shortages that are experienced are seasonal and on average, there is more than enough water to meet present and future water requirements.
Present day land and water use requirements, derived from the catchment hydrology, were imposed on the system and EWRs were included for each quaternary sub-catchment. Two scenarios were modelled for the present supply system:

- Present day scenario, which excluded the Cwabeni off-channel storage, currently being investigated, to supplement the current Port Shepstone demand, and
- Present day scenario, which included the Cwabeni off-channel storage dam.

When the EWRs are provided there is no surplus historical firm yield at quaternary sub-catchment level because of the EWR low flow requirements.

4.3.2. Causes of Shortages

The reductions in flow, have given rise to water shortages occurring during certain times of the year. This has resulted in applications from irrigators and the municipality to construct dams to tide them over the periods of deficit. These shortages are the result of many factors, the first being the resource itself, with naturally occurring low seasonal runoff during the winter months. Other causes are human-related and comprise:

- possible over abstraction / over utilisation (by irrigators with insufficient storage);
- possible excess (or unlawful) irrigation and afforestation; and
- inadequate abstraction infrastructure.

The seasonal shortages can be overcome if additional storage is provided.

4.4. GROUNDWATER SITUATION

The Groundwater Resources Report *(WMA 11/T50/00/3009, Volume 4)*, deals with the Groundwater situation in the Mzimkhulu River Catchment.

The following conclusions were drawn and are described more fully in Volume 4:

- Elevated groundwater yields occur to the north of Rietvlei, directly east of Creighton and from west-southwest to northwest of Underberg.
- Rainfall recharges the shallow groundwater, which is intercepted by the boreholes in the catchment.
- Populations (both rural and urban) are situated within these areas, such that groundwater supply to these communities appears viable.
- The high-yielding geological formations are the Drakensberg basalts, the Karoo dolerites and the closely-bedded argillaceous Karoo Supergroup rocks.

- Dolerite dyke and sill contacts and observed lineaments act as the main pathways for groundwater movement and storage (to a certain extent).
- Areas underlain by shallower soil profiles and soils with increased clay content typically exhibit higher yields.
- Magnesium (Mg), nitrate (NO_3) and fluoride (F) are the only potentially problematic determinants in the groundwater, with these three 'peaking' in the southern areas of the Mzimkhulu River Catchment.

The following recommendations are made:

- Groundwater exploration should continue to the north of Rietvlei, near the Centecow Mission, directly east of Creighton and from west-southwest to northwest of Underberg.
- Basaltic, doleritic and argillaceous sedimentary rock areas throughout the area should also be investigated for localised water supply.
- Shallower soil profiles with increased clay contents could be investigated for localised water supply.
- The extreme southern areas of the catchment should not be prioritised for groundwater investigation.
- The extreme northern parts of the catchment should only be investigated further, if no other viable sources are available.

5. FUTURE WATER DEMAND

5.1. EXPECTED FUTURE DOMESTIC / URBAN LIGHT INDUSTRIAL GROWTH IN INLAND AND COASTAL TOWNS (HIGH AND LOW GROWTH SCENARIOS)

Projected growth in future water demand, is discussed in the Land Use and Water Requirements Report (*WMA 11/T50/00/3009, Volume 9)* and further refined in the Surface Water Resources Report *(WMA 11/T50/00/3009, Volume 3)*. **Table 5.1** below, shows the projected water use to 2030 for urban and rural domestic, industry and commercial water users. In many cases, illustrative growth factors have been applied to human settlement and industrial and commercial land uses. The factors have been derived from a review of municipal Integrated Development Plans (IDPs).

Table 5.1: Projected Rural and Urban Water Demand

Quaternary sub-catchment	Rural-Present (million m^3/a)	Urban-Present (million m^3/a)	Present Total (million m^3/a)	Projected 2030 Rural (million m^3/a)	Projected 2030 urban (million m^3/a)	Projected 2030 Total (million m^3/a)	% Increase
UPPER MZIMKHULU							
T51A	0,0	0,0	0,0	0,0	0,0	0,0	0
T51B	0,0	0,1	0,1	0,0	0,2	0,2	100
T51C	0,4	0,5	0,9	0,6	0,8	1,4	56
T51D	0,0	0,0	0,0	0,0	0,0	0,0	0
T51E	0,1	0,0	0,1	0,1	0,0	0,1	0
NGWANGWANE							
T51F	0,0	0,0	0,0	0,0	0,0	0,0	0
T51G	0,1	0,0	0,1	0,2	0,0	0,2	100
T51H	0,6	0,0	0,6	0,9	0,0	0,9	50
T51J	0,4	0,4	0,7	0,6	0,6	1,2	71
MIDDLE MZIMKHULU							
T52A	0,6	0,3	0,9	0,9	0,5	1,4	56
T52B	0,3	0,0	0,3	0,5	0,0	0,5	67
T52C	0,3	0,0	0,3	0,4	0,0	0,4	33
T52D	0,7	1,0	1,7	1,1	1,6	2,8	65
BISI							
T52E	0,2	0,0	0,2	0,3	0,0	0,3	50
T52F	0,2	0,0	0,2	0,3	0,0	0,3	50
T52G	0,2	0,0	0,2	0,2	0,0	0,2	0
T52H	0,8	0,3	1,1	1,3	0,4	1,7	55
MZIMKHULWANA							
T52K	0,4	1,2	1,6	0,7	1,9	2,5	56
T52L	0,0	0.0	0,0	0,0	0,0	0,0	0
LOWER MZIMKHULU							
T52J	1,9	0,0	1,9	3,1	0,0	3,1	63
T52M	0,6	16,7	17,2	0,9	26,5	27,4	59
TOTAL	**7,7**	**20,4**	**28,1**	**12,2**	**32,5**	**44,7**	**59**

5.2. POTENTIAL FOR PLANTATION FORESTRY DEVELOPMENT

5.2.1. Negative Mapping Process

The Land Use and Water Requirements Report *(WMA 11/T50/00/3009, Volume 9)* of this study determined the Commercial Forestry Potential (CFP), using a negative mapping process.

The study examined various types of land cover and excluded:

- Environmentally sensitive areas as per the Ezemvelo KZN Wildlife Conservation Plan (C-Plan);
- Cultivated land (irrigated lands, dry land areas, sugar cane and orchards);
- Indigenous forests and existing plantations;
- Roads, mines and quarries;
- Power lines;
- Rivers, dams and wetlands;
- Rural and urban settlements; and
- Game and nature reserves.

Based on criteria agreed with the Forestry Industry topographic and climatic criteria were used to exclude:

- Areas with a slope greater than 30%;
- Areas with a MAP of less than 700 mm; and
- Areas with an altitude of greater than 1 450 mean average sea level (masl).

From discussions with the commercial forestry industry, it emerged that it would be prudent to adopt slightly more conservative criteria for small growers, resulting in the criteria, set out in **Table 5.2** below:

Table 5.2: Small Grower Exclusion Criteria

Criteria	Commercial Growers	Small Growers
Slope	> 30%	> 20%
MAP	< 700 mm	< 800 mm
Altitude	> 1 450 masl	> 1 200 masl

In addition, the potential of the soils to grow timber was determined, using the soil type, depth, clay content and Bioresource unit slope, giving rise to four classes of bio resource units, Poor, Low, Medium and High. The areas with soils in the Poor class were excluded. The percentage of suitable soils in each of the other classes and the total area with potential is shown in **Table 5.3**.

Table 5.3: Summary of Plantation Forestry Potential

Suitability	Commercial potential (ha)	Small Grower Potential (ha)	% of suitable land
Low	56 170	41 701	20 – 40%
Medium	24 673	15 507	40 – 60%
High	16 608	12 405	>60%
Total	**97 451**	**69 613**	

Applying these criteria throughout the catchment, resulted in a potential area of 97 451 ha for possible commercial plantation forestry development. Given the percentages of soils that are suitable in each category and to allow for the fact that the full potential will not be able to be developed, owing to in-field factors which cannot be determined in a broad-based study of this nature, a weighting process was adopted. For large growers, 40 % of the low, 60 % of the medium and 80 % of the high potential areas were assumed to be utilisable. This resulted in an area of 50 350 ha with potential for forestry. See **Appendix A, Table 2**.

In order to obtain a potential area for possible small grower development, the slightly more conservative criteria of 30 % of the low, 50 % of the medium and 75% of the high potential were used. An area of 29 400 ha, was obtained. See **Appendix A, Table 1**.

The greatest need for development of small growers is in the former Transkei area, which was, until recently, part of the Eastern Cape Province, see **Table 5.1**. In order to assess the impact of concentrating development in this area, the Bisi and Middle Mzimkhulu WMSCs were assessed on their own. Using the small grower criteria, an area of 21 050 ha has potential. See **Appendix A, Table 1**.

5.2.2. Catchments with the greatest Plantation Forestry potential

The areas in the catchment, at a macro scale with the level of forestry potential for All growers and Small growers, are shown in **Figure 5.2** and **Figure 5.3** respectively.

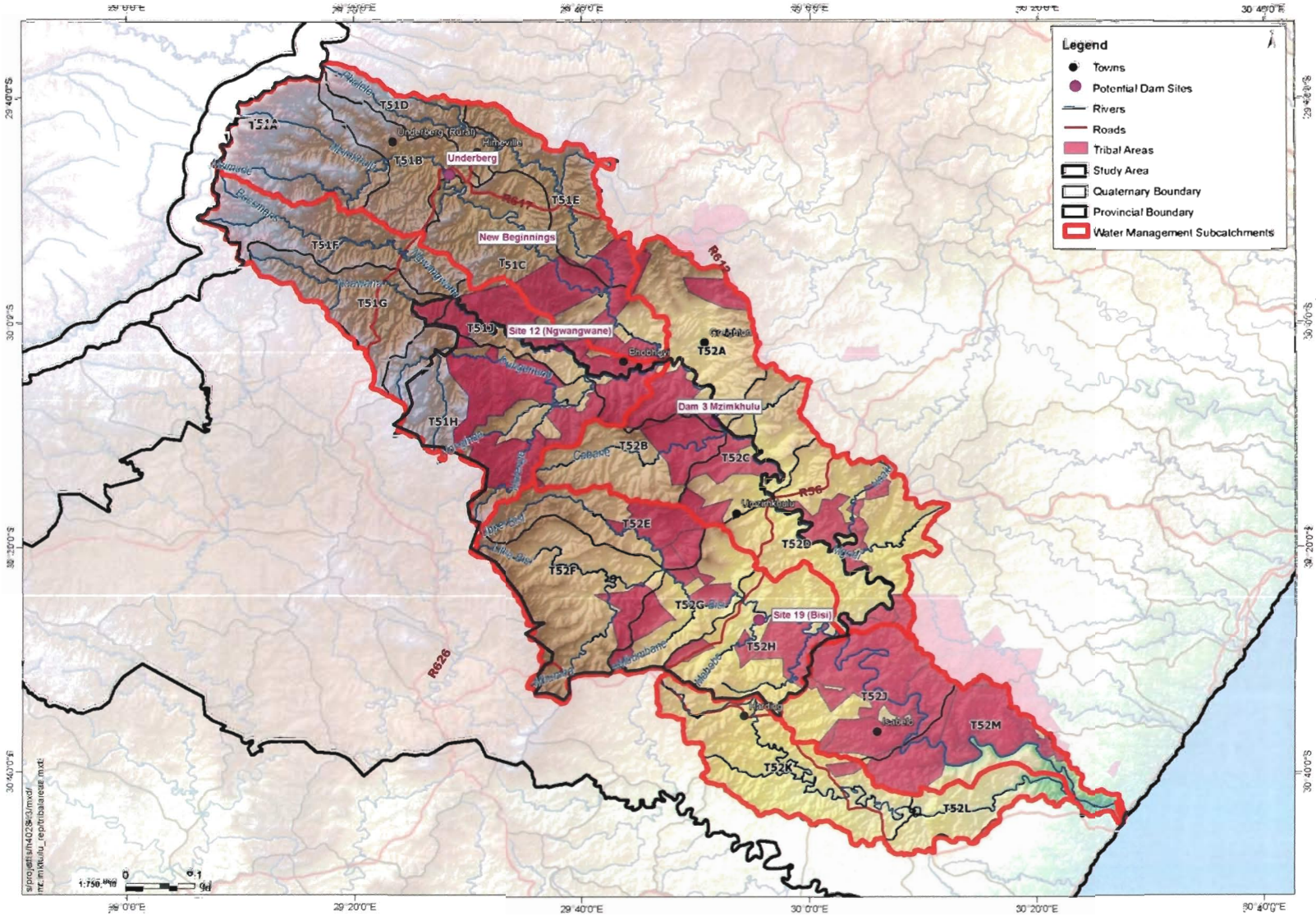

Figure 5.1: Old Transkei Provincial boundaries

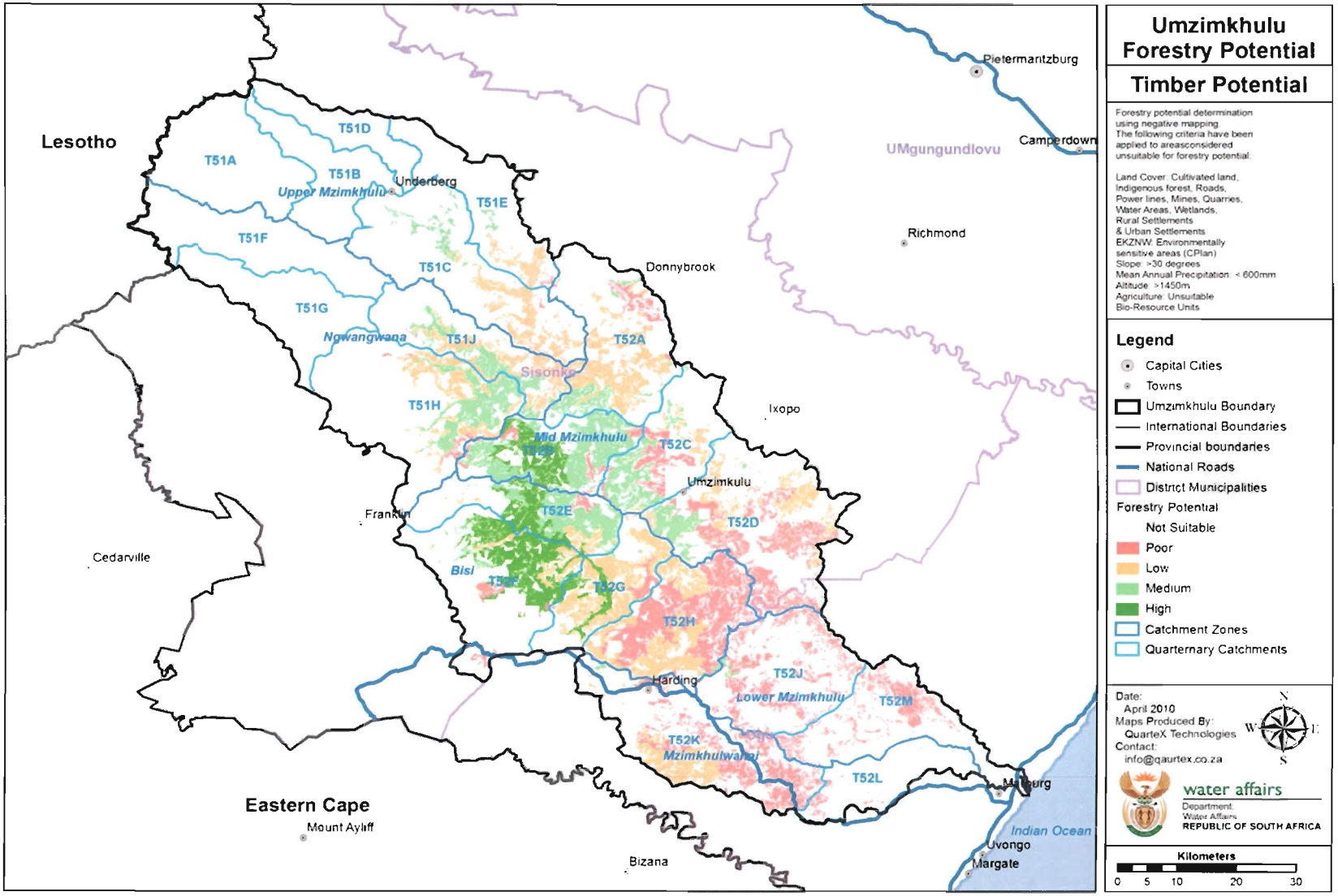

Figure 5.2: All Grower Forestry Potential

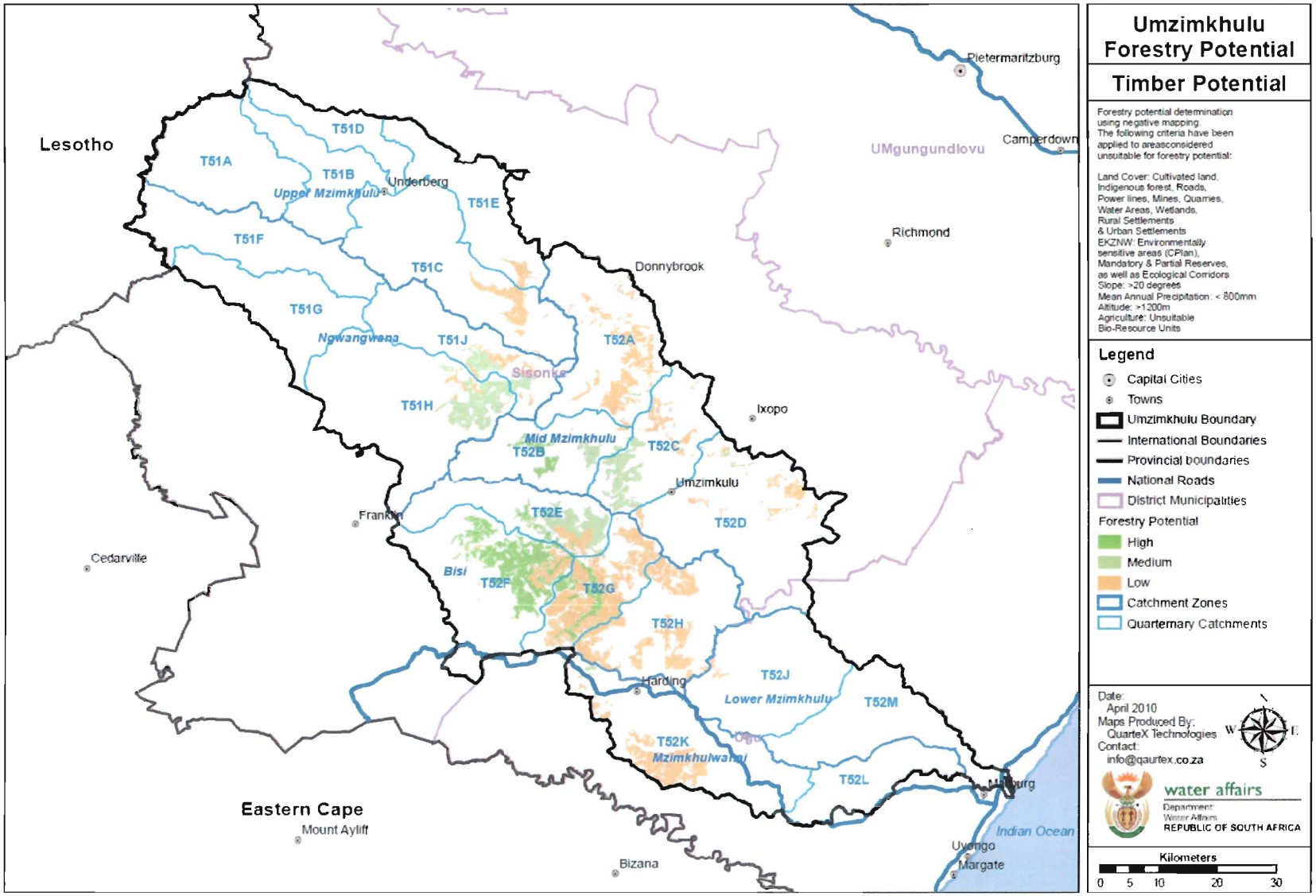

Figure 5.3: Small Grower Forestry Potential

The quaternary sub-catchments with the greatest forestry potential for all growers are shown in **Table 5.4**.

Table 5.4: Quaternary Sub-catchments with greatest Plantation Forestry Potential

WMSC	RIVER	QUAT	AREA (Ha)
Ngwangwane	Gungununu	T51H	5 200
9 000 ha	Lower Ngwangwane	T51J	3 800
Middle Mzimkhulu	Mzimkhulu	T52A	3 000
	Cabane	T52B	3 700
	Mzimkhulu	T52C	3 550
11 500 ha	Mzimkhulu	T52D	1 250
Bisi	Upper Bisi	T52E	5 300
	Little Bisi	T52F	8 800
	Bisi	T52G	6 100
23 400 ha	Bisi	T52H	3 200
Balance (Smaller areas distributed in the remaining quaternary sub-catchments)			6 450
		Total	**50 350**

5.2.3. Pending Plantation Forestry Licence applications

Since the relevant sections of the National Water Act, 1998, came into force in October 1999, licences for an area of 505 ha of plantation forestry have been issued by the Department of Water Affairs. Details as at 5 May 2010 are contained in Appendix B. The areas for which Licences have been issued, bear no resemblance to the area of existing forestry in the catchment, as prior to 1972, no permission was needed to establish plantations. The Afforestation Permit System, in terms of the Forest Act, came into force in 1972 and after 1998, was replaced with Stream Flow Reduction Activity Licences, under the National Water Act. Registered plantation forestry on the DWA Water Use Authorisation Registration Management System (WARMS) database, is 71 931 ha. The total area of plantation forestry in the catchment, obtained by remote sensing, was 83 290 ha. This area was used for modelling purposes, as it was more conservative than the WARMS figure. This is discussed fully in the Land Use and Water Requirements Report *(WMA 11/T50/00/3009, Volume 9)*.

Owing to reported shortages in the lower catchment, DWA put a hold on issuing licences in recent years. This study was commissioned in order to assess the current situation and the impact of further afforestation. A list of applications received by the Department, but awaiting the outcome of this study, is also contained in Appendix B, and totals 1 218 ha. It should be borne in mind that there are many potential growers, who would have applied, but did not, as they were advised by DWA, that there was little or no chance of a Licence being granted, until this study was completed.

The current pending applications are distributed as shown in **Table 5.5**.

Table 5.5: Plantation Forestry Applications per Quaternary sub-catchment

WMSC	Quaternary sub-catchment	Area (ha)
Middle Mzimkhulu	T52B	193
Middle Mzimkhulu	T52C	297
Middle Mzimkhulu	T52D	25
Bisi	T52F	40
Bisi	T52G	31
Bisi	T52H	614
Mzimkhulwana	T52L	18
	TOTAL	1 218

It will be noted from the above **Table 5.5**, that all but 18 ha of areas applied for, fall within the Bisi and Middle Mzimkhulu WMSCs.

5.3. APPLICATIONS FOR TAKING AND STORING WATER

Licences for a total abstraction of 11,6 million m^3 of water and the storage of 12,0 million m^3, have been issued by the Department of Water Affairs, in terms of the National Water Act, 1998. Details as in April, 2010, are contained in **Appendix B**. The volumes for abstraction and storage, for which Licences have been issued, once again, bear no resemblance to the existing situation in the catchment, as the amendment to the 1956 Water Act, requiring permits for storage, was only promulgated in 1975. Prior to that, no permission was needed to store water.

A list of applications for storage, received by the Department, but still under consideration, is also contained in Appendix B, and totals 10,0 million m^3. These 'pending' applications are included in the future scenarios, which have been modelled. It will be noted that there are no applications for abstraction, only storage. Owing to the perceived low flow deficits, DWA was loath to issue licences for abstraction, without storage. It should, therefore be borne in mind that there are applicants who would have applied, particularly to abstract water from run of river, but did not, as they were discouraged by DWA, as there was little chance of a Licence being granted.

5.4. IRRIGATION EXPANSION

Any significant increase in water use by commercial agriculture will probably be as a result of expansion of irrigated areas, which will require abstraction and/or storage Licences from DWA.

Irrigation expansion in this catchment is a function of water availability and land suitable for this type of cultivation.

There is widespread agricultural potential within the catchment and it is unknown exactly where expansion is likely to take place. For the purpose of modelling the future scenarios, it was deemed prudent to assume that all existing irrigation would expand

and increase its water use by 20%. **Table 5.6** below shows current irrigation use, the assumed increased volumes, as well as the existing and expected return flows, for each quaternary sub-catchment.

If either of the two storage options, modelled and discussed later, were to go ahead, there would be adequate surplus yield to support additional irrigation development, if the necessary infrastructure is established.

Table 5.6: Current and Increased Irrigation Volumes and Return Flows

Quaternary sub-catchment	Current irrigation supply (million m^3/a)	Current Irrigation return flows (million m^3/a)	20% increase in Irrigation supply (million m^3/a)	20% increase in Irrigation return flows (million m^3/a)
T51A	1,7	0,2	2,1	0,2
T51B	10,3	1,0	12,4	1,2
T51C	13,2	1,3	15,8	1,6
T51D	3,6	0,4	4,3	0,4
T51E	9,0	0,9	10,8	1,1
T51F	8,7	0,9	10,4	1,0
T51G	2,8	0,3	3,3	0,3
T51H	0,5	0,0	0,5	0,1
T51J	13,2	1,3	15,8	1,6
T52A	15,5	1,5	18,5	1,9
T52B	0,0	0,0	0,0	0,0
T52C	3,3	0,3	3,9	0,4
T52D	3,1	0,3	3,7	0,4
T52E	0,1	0,0	0,1	0,0
T52F	0,2	0,0	0,2	0,0
T52G	0,0	0,0	0,0	0,0
T52H	0,0	0,0	0,0	0,0
T52J	0,0	0,0	0,0	0,0
T52K	0,9	0,1	1,1	0,1
T52L	0,8	0,1	0,9	0,1
T52M	0,0	0,0	0,0	0,0
T51 total	**62,9**	**6,3**	**75,4**	**7,5**
T52 total	**23,8**	**2,4**	**28,5**	**2,9**
Total	**86,6**	**8,7**	**103,9**	**10,4**

6. WATER RESOURCE MANAGEMENT INTERVENTIONS

6.1. UNDERLYING OBJECTIVES

The Mzimkhulu River, as a water resource, needs to be managed in a sustainable manner. After meeting the legal commitment to both the Basic Human Needs as well as the Ecological Reserve, allocations need to be made responsibly to ensure that the EWRs are not compromised. In this study, development opportunities, particularly for forestry development, have been identified and the impacts of the potential developments on the water resource and the environment are assessed to ascertain whether the water requirements of the developments remain within the bounds of sustainability. In the cases where potential use exceeds the level of sustainability, physical steps are proposed to mitigate the impact on the resource.

Underlying objectives are:

- Ensuring that water is available to maintain a balance between the need for future economic development and sustainability.
- Ensuring awareness of impacts of further development on the EWR.
- Phased implementation of River Management measures to restore the EWR.
- Where large scale, high impact development is proposed, to implement mitigation measures to restore the EWR.

6.2. SHORT TO MEDIUM TERM MANAGEMENT INTERVENTIONS

One management intervention which is already underway is the Wetland Rehabilitation Project, taking place in the Upper Bisi River in quaternary catchments T52E and T52F. The project falls under the Working for Wetlands programme, a government initiative, which started in 2001, and is managed by the South African National Biodiversity Institute (SANBI), on behalf of the national government Departments of Environmental Affairs, Water Affairs and Agriculture, Forestry and Fisheries. It forms part of the Expanded Public Works Programme.

Three wetlands in the Mzimkhulu catchment are currently being rehabilitated under this programme.

Quaternary Sub-catchment T52E (two wetlands):
Regarding the so-called Sneezewood wetlands, with areas of 48 and 89 ha respectively, the land owners should support a detailed initial survey of the wetlands (if it has not already been done) in order to obtain an inventory of what is present. This should be followed by a management plan for the wetlands. Populations of threatened fauna should then be actively monitored, if present. The wetlands could provide habitat for threatened fauna.

Quaternary Sub-catchment T52F:
Good progress has been made in rehabilitating this 135 ha wetland, known as the Mpur Wetland. The following generic management guidelines are relevant to the site and should be incorporated into management plans for the wetland area:

- Control of alien invasive plants;
- Livestock management;

- Fire management; and
- Careful design of road crossings to ensure that they have minimal impact on flow patterns through the wetland and maintenance of road culverts.

The following activities should be undertaken to limit unnecessary or inappropriate water use and to improve the efficiency of water use.

- Remove alien vegetation. It is estimated that there could be up to 250 km^2 of alien vegetation in the catchment, consuming up to 40 million m^3 per annum. Removal of one quarter of this, particularly in riparian zones, could boost the available water by 10 million m^3 per annum. This could be a combined effort between the Forestry Sector and the Working for Water Teams in the DWA and the KZN Department of Agriculture and Environmental Affairs.

- Implement Water Conservation and Demand Management (WCDM) Measures to improve to efficiency of water use available. The DWA has developed WCDM strategies and guideline documents for three main water use sectors: water services, agriculture and industry, mines and power generation.

    - Municipal: The DWA All Town Study, (DWA 2011), has revealed that urban and domestic unaccounted for water (pipe bursts, leaks, unlawful connections etc.), ranges from 25 to 40 % of bulk from abstraction. Reducing Ugu District Municipality's losses by half, (i.e. reducing say 30 % to 15 %), could reduce bulk water demand by 2,5 million m^3/a on current use and 4 million m^3/a by 2030. If this was to be applied to all domestic use in the catchment, the savings could be up to 7 million m^3/a. The practical steps that can be applied at water supplier level are:

        - Identifying and applying Best Management Practice (BMP);
        - Applying appropriate user charges to minimise wastage;
        - Addressing the issue of non-revenue water ("illegal" water use and losses);
        - Implementing water audits;
        - Establishment of discrete supply zones with metering, pressure reduction and leakage management; and
        - Implementation of structured tariffs to encourage water saving.

    - Agriculture: In terms of the National Water Act, 1998, Water User Associations (WUAs) and Irrigation Boards (IBs) are required to submit annual Business Plans, of which Water Management Plans can form a part. It is suggested that the IBs or WUAs, when formed, be tasked to describe their current water use and conservation measures and set out how they plans to implement Best Management Practices (BMP's) using accepted benchmarks to improve their water supply to water users and to achieve quantifiable water savings. Best Management Practices include:

        - Optimising irrigation water requirements for crops in their climatic zone;
        - Selecting the most appropriate irrigation system for specific crops on specific soils;
        - Practising irrigation scheduling to meet the crop water requirements;

- Measuring irrigation application;
- Maintaining on-farm canals, pipelines and dams to minimise wastage;
- Maintaining irrigation equipment to ensure efficient water application;
- Installing and maintaining irrigation drainage facilities, where needed.

WCDM initiatives will not be effective unless there is a tangible incentive to the supplier (WUA) and the user (irrigator). Some of these benefits are listed below for both water suppliers and irrigators:

- Cost savings (e.g. reduction in pumping costs and user charges);
- Larger areas irrigated with same water allocation;
- Long-term assurance of adequate water; and
- Improved yield and quality of crop (improved income).

A 10% saving on the irrigation use of 90 million m^3/a, could free up an additional 9 million m^3/a.

- It is possible that there are water users who have not registered their use, or who may be exceeding their lawful use. If 5 % of the irrigation use of 90 million m^3/a, is unlawful, addressing this, could free up about 4,5 million m^3/a. Similarly, dealing with unlawful plantation forestry, could free up between 5 and 6 million m^3/a. It therefore necessary that the DWA undertake a Validation and Verification exercise on all registered water use in the catchment. This will also expose unlawful use, which needs to be terminated, thereby freeing up more water and increasing the level of assurance of supply for lawful users, as well as potential new users.

- Develop Groundwater Resources. There are remote rural and urban settlements, which it is not feasible to serve with surface water. These communities would be best served with groundwater. Where yields are sufficient, groundwater resources could also be developed for small scale irrigation to provide food security.

6.3. WATER RESOURCE DEVELOPMENT OPTIONS

The options discussed below, would form part of developments on a much larger scale, which would not be able to be mitigated by means of the management interventions, discussed in the previous paragraph. Such development would involve more drastic mitigation measures, such as the construction of one or more dams.

Reports from previous studies conducted by DWA, Umgeni Water and Municipalities, were studied. Details of these reports may be found in the list of References at the end of the main part of the report. Some 20 possible sites had been previously identified on the Main stream and tributaries of the Mzimkhulu River. These are tabulated in **Appendix C**.

There are two recent Department of Water Affairs and Forestry (DWAF) reports, namely the Southern KwaZulu-Natal Water Resources Pre-Feasibility Study, Phase 2 Report (DWA 2005) and the Mzimkhulu River Off-Channel Storage, Pre-Feasibility Study Reconnaissance Report (DWA 2007), which gave rise to the current Feasibility Study into the Cwabeni Dam.

Umgeni Water undertook the KwaZulu-Natal Regional Bulk Water Supply Reconnaissance Study: Southern Regional Schemes (UW 2006) and the Sisonke District Municipality (SDM) commissioned the Umzimkhulu Flood Town Protection Pre-Feasibility Study (SDM 2009).

Possible sites identified are shown in **Figure 6.1** below. Names and reference numbers as used in the original reports have been retained. A table containing the available details of each of the sites may be found in **Appendix C**.

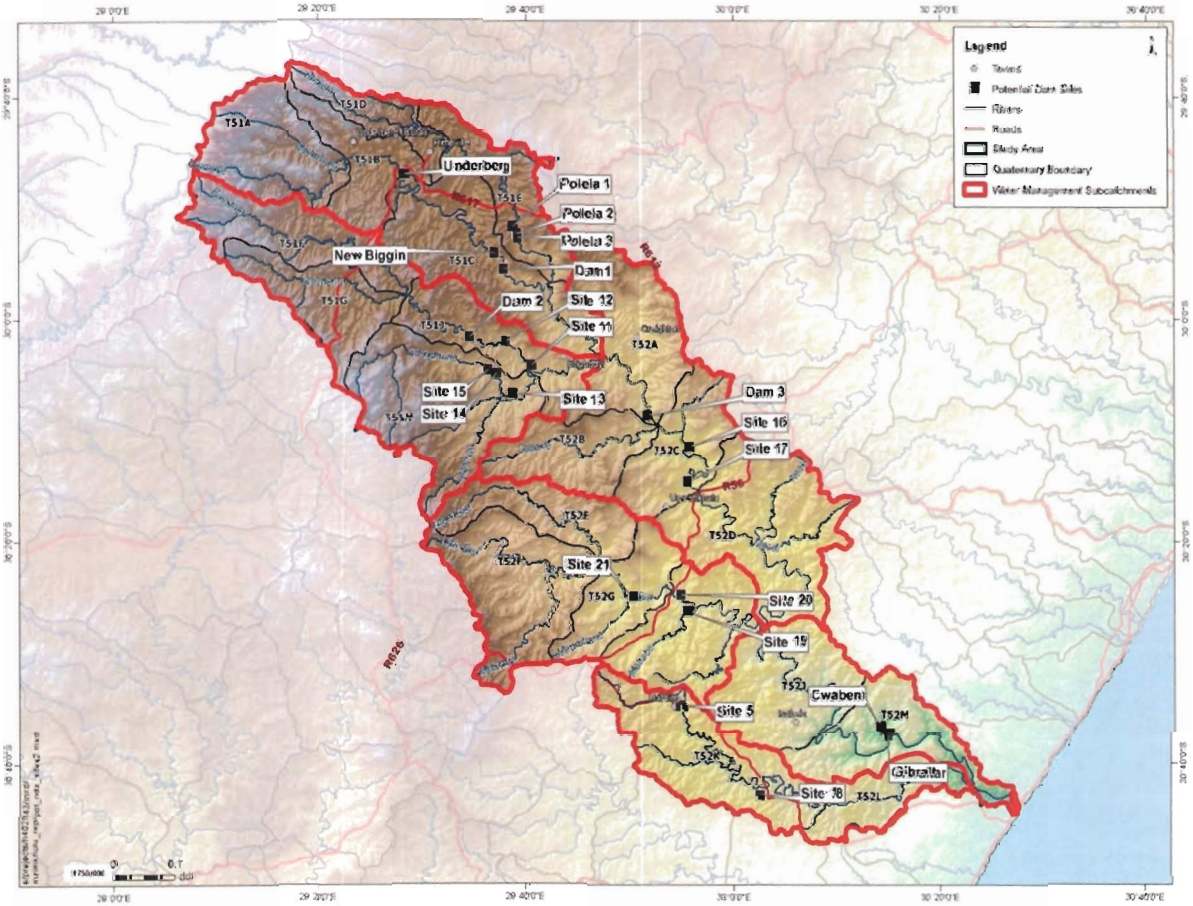

Figure 6.1: Previously identified Dam Sites

6.4. STORAGE POTENTIAL IN THE MAIN STREAM OF THE MZIMKHULU RIVER

Sites identified on the main stream of the Mzimkhulu River in previous studies are:

- Underberg sites: A number of possible sites exist in the Mzimkhulu gorge, some 2 km North West and west of Underberg (DWAF 2005). A relatively large dam could be built, but there would be severe infrastructure inundation. The R617 between Underberg and Swartberg, as well as the road to Drakensberg Gardens would have to be rerouted.

- New Biggin Site: This site is on the property New Biggin 13390 and is 16,5 km upstream of the confluence with the Pholela River (DWAF 1984). Being at an elevation of 1 360 m, it is suitable for a link to the Pholela River and for water

transfer to the Mkomazi catchment, upstream of the Smithfield site, which has been identified as a possible site from which to supply Durban.

- Dam 1: This site, situated some 83 km upstream of Umzimkulu town, was identified (SDM 2009) as a possible flood control dam, to protect the town. The report mentions a capacity of 121 million m^3.

- Mornington / Dam 3: A number of possible sites are located between 27 and 30 km upstream of Umzimkulu town (SDM 2003). The potential was originally identified in a 1984 DWAF report (DWAF 1984) and was also identified as a site for a possible flood control dam, to protect Umzimkulu town (SDM 2003).

- Sites 16 & 17: These sites were identified in a study for Umgeni Water and are situated close to each other, some 3 km upstream of the town of Umzimkulu. Possible storage ranges from 230 to 335 million m^3, with assumed wall heights of 30 m. The dams were considered too large for the purpose of the previous study.

- Gibraltar: This site was mentioned (although not as an option), in the flood study by Sisonke District Municipality (SDM 2003) and is situated 39 km upstream of the mouth of the Mzimkhulu River on the property Gibraltar 8258, named after a distinctive rock of the same name. Although the site lends itself to a large dam, it is too low down in the catchment to be of any real benefit, apart from Port Shepstone and the estuary.

- St Helen's Rocks: This site, identified in the DWAF study, (DWAF 2005), is situated 9 km upstream of the mouth of the Mzimkhulu River. This is where the Ugu District Municipality has their main abstraction works. This site, although suited to a large dam, is also too low down in the catchment to benefit any users, other than the Municipality and the estuary. A weir at the site, to facilitate abstraction, has been proposed. The design would have to cater for silt, possibly with the provision of fish belly flaps.

6.5. STORAGE POTENTIAL ON TRIBUTARIES OF THE MZIMKHULU RIVER

The following dam sites, on tributaries were identified in previous studies:

- Ngwangwane River: Site named Dam 2: This site is situated about 38 km upstream of the confluence of the Ngwangwane River with the Mzimkhulu River. It was identified (SDM 2009), as a potential site for a flood control dam for the town of Umzimkulu. A dam wall, 100 m high, would be 1 192 m long, and store some 565 million m^3.

- Ngwangwane River: Site 12: This site is about 9,5 km downstream of Dam 2, described in the previous bullet. This site is situated 28 km upstream of the confluence with the Mzimkhulu River, about 8 km north North West of Edgeton. The UW 2006 study indicated that a dam with a wall, 45 m high, would have a length of 325 m and would store 50 million m^3, while a 30 m high wall would have a length of 325 m.

- Ngwangwane River: Site 11: This site is situated 4 km north of Enyanisweni. A volume of 128 million m^3 could be stored with a wall height of 30 m. The site was not selected in the previous study (UW 2006), on account of the high cost of the 770 m long wall and considerable relocation of infrastructure.

- Gungununu River: Site 13: The site is located 2 km west of Enyanisweni and could store 145 million m^3 at a wall height of 30 m. It was not considered to be favourable in the previous study (UW 2006), owing to its high cost and a large flooded area.

- Gungununu River: Site 14: The site is located 3 km west of Edgeton. The site was not considered (UW 2006), owing to high cost and the fact that there are better sites in the area.

- Gungununu River: Site 15: The site is located 6 km north west of Edgeton. Storage of 51 million m^3 could be achieved with a wall height of 30 m and a relatively short wall of 470 m (UW 2006). The site is considered to be well situated, as it is fairly high up in the catchment.

- Bisi River: Site 19: The site is located 7 km east of Kok's Hill. About 35 million m^3 could be stored with a wall height of 30 m and a length of 480 m. It is considered to be a reasonably good site. The previous study by Umgeni Water (UW 2006), mentioned that there are better sites elsewhere, but for the purpose of this study, the locality is ideally suited for mitigation, considering the forestry potential in the sub-catchment.

- Bisi River: Site 20: The site is located 5 km north east of Kok's Hill. A volume of 67 million m^3 could be stored with a wall height of 30 m. The site was not considered to be favourable, in the previous study (UW 2006), owing to high environmental costs.

- Bisi River: Site 21: The site is located 18,25 km north north west of Harding and 26 million m^3 could be stored with a wall height of 30 m. The site was considered to be a good site (UW 2006), but relocation of people and infrastructure will be required.

- Mzimkhulwana River: Site 5: The site is located 3 km south east of Harding. It could possibly be developed as a resource for Harding and the south coast. About 50 million m^3 could be stored with a wall height of 30 m (UW 2006). It would be costly to develop, as the wall would be long. The N2 would have to be re-routed.

- Mzimkhulwana River: Site 18: The site is located 20 km south east of Harding. A 30 m wall height would create storage of 59 million m^3. This site was not considered to be suitable (UW 2006), as it is fairly low in the catchment and there are better sites elsewhere.

- Pholela River: Near Cascades 10833: There are a number of sites in the river reach, situated about 14 km upstream of the confluence with the Mzimkhulu River. (DWAF 2007) The elevation, at 1 300 m, is such that is suitable to receive

water via a tunnel, from the New Biggin site on the main Mzimkhulu River for transfer to the Mkomazi catchment, upstream of the Smithfield site, which has been identified as a possible site from which to supply the Mgeni Catchment.

6.6. SCREENING OF SITES

6.6.1. Basis of Screening

One of the main objectives of creating storage, would be to mitigate the effects of possible additional development in the catchment and at the same time, where possible, to provide the full recommended EWR flow regime in the river, to its desired ecological state.

The selection of potential dam sites for inclusion in the scenarios was based on the following primary considerations.

- The undammed nature of the river has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) programme and the river is ranked as one of the most important for conservation in the region.
- The potential of all the identified dam sites be considered in relation to the objective, while being cost effective.
- As the Mzimkhulu is a large river, with a wide channel, development on the main stem would require a large structure, with a large spillway capacity, both of which would be expensive.
- Developing storage sites on the main stem of the river, would not address shortages on tributaries.
- The main stem carries a huge silt load, which would have to be catered for.
- Floods in the main stem of the river are important for the ecology and a dam would trap them.
- A number of good sites on the main stem are low down in catchment, which means that they have a reduced area of influence.
- A large dam on the main stem would have a have a larger potential impact on the ecosystem, whilst smaller dams planned for tributaries, would have much less impact on the system.

It was thus decided to focus on smaller scale storage on tributaries (Where cost-effective storage can be created). As discussed later, the first three sets of scenarios simulate development on the tributaries. The fourth set of scenarios does, however, test the impact of a large dam on the main stem, together with smaller dams on the tributaries, operated to meet the EWR, with all the surplus water being exported out of the catchment.

6.6.2. Preferred sites on Tributaries of the Mzimkhulu River

As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, are best positioned to mitigate the forestry impacts on the low flows. Using criteria from the previous reports, and considering the location of forestry potential, two sites, were selected for the scenarios:

- Site 12 on the Ngwangwane River, and
- Site 19 on the Bisi River.

The storage- yield curves for the potential dam sites were developed on the present day hydrology for a range of dam sizes. The curves for Site 12 and Site 19 are shown in **Figure 6.2** and **Figure 6.3** respectively, while the locality of the sites is shown in **Figure 6.4**.

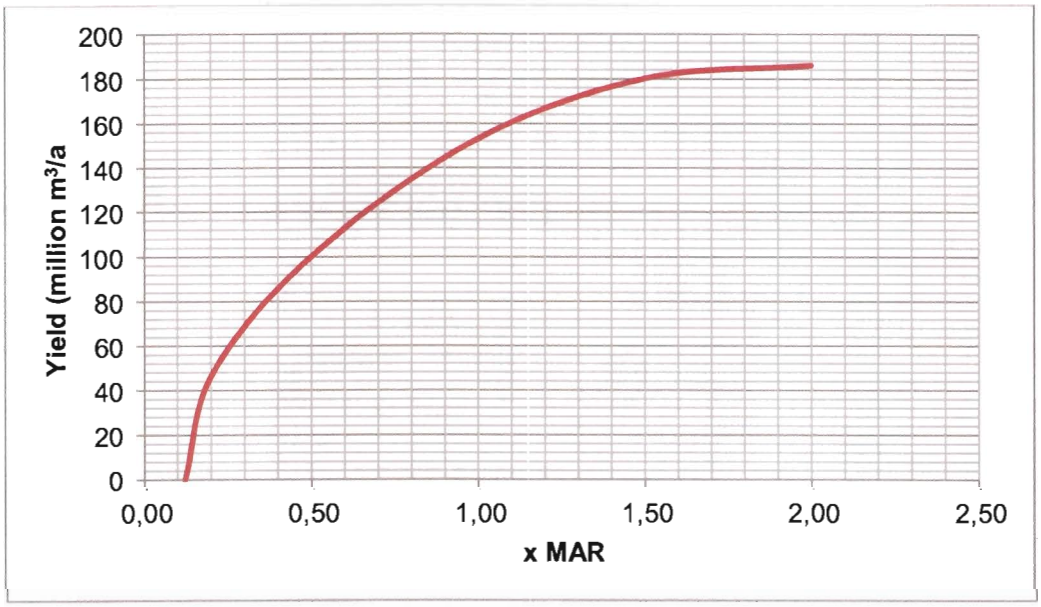

Figure 6.2: Storage-yield curve for Site 12 - Ngwangwane

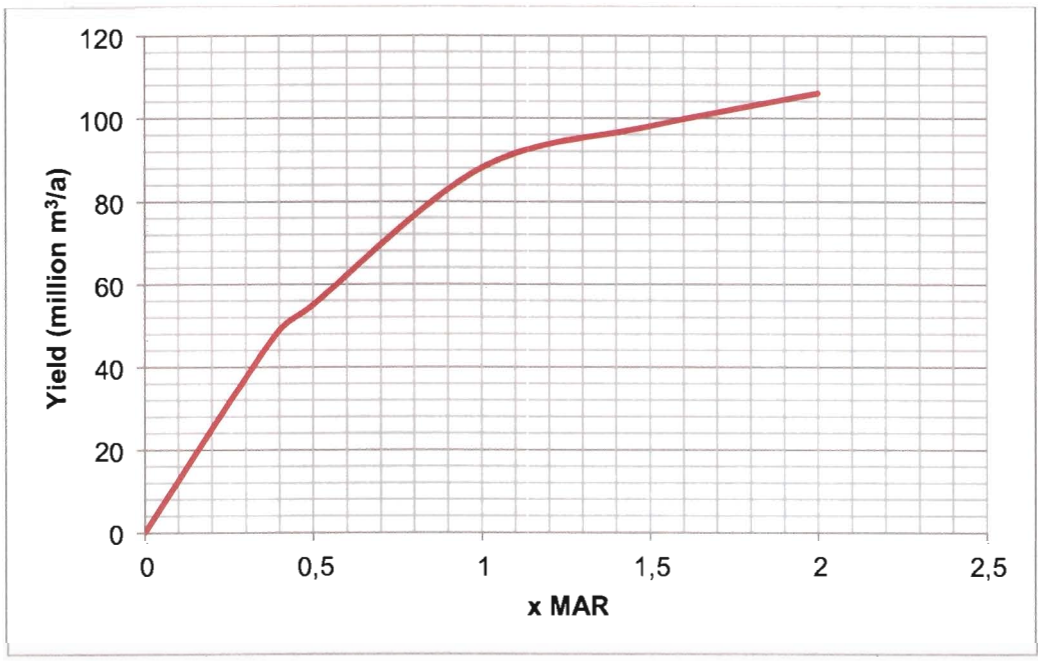

Figure 6.3: Storage-yield curve for Site 19 - Bisi

6.6.3. Sites on the main stem to be considered in Scenarios

Two sites on the main stem were selected for inclusion in Scenarios, to test the impact on the EWRs, of a possible large dam on the main stem of the river, with the entire surplus yield being exported.

These sites are:

- Underberg, and
- New Biggin.

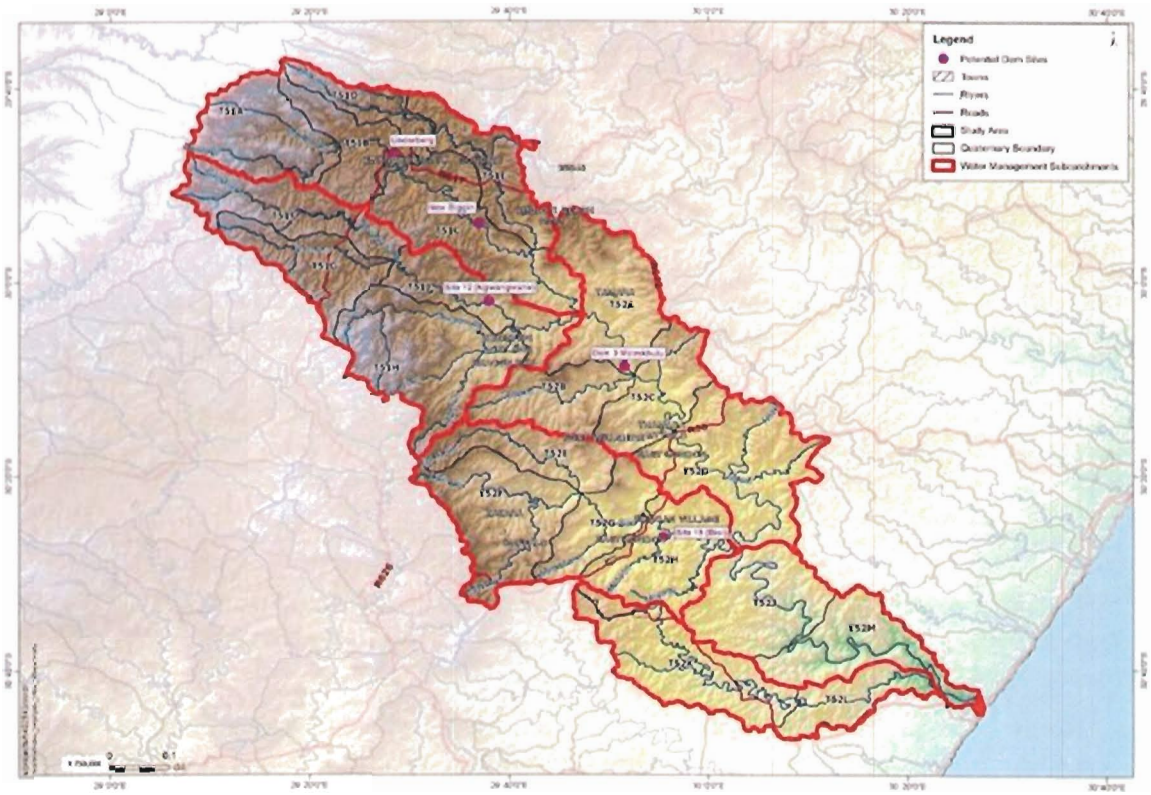

Figure 6.4: Dam Sites selected for Scenarios

6.7. SECONDARY CONSIDERATIONS

In addition to the primary considerations, the possibility of any dam being a multi-purpose dam or providing other secondary benefits was also considered. They are as follows:

- Flood protection for Umzimkulu Town by an upstream dam;
- Hydro power development potential;
- Pumped storage development potential;
- Inter-basin transfers to neighbouring catchments, e.g. Proposed Mhlabatshane Regional Water Supply Scheme; and
- Multi-purpose combinations of the above.

6.8. CURRENT DEVELOPMENT INITIATIVES

6.8.1. Investigation of Off-Channel Storage Development on the Cwabeni by DWA

The DWA has commenced a feasibility study of the proposed off-channel storage site, about 20 km upstream of Ugu's abstraction point at St Helen's Rocks on the Cwabeni River. (DWA 2010 a)

Four possible sites had been identified in a previous study. The site on the Cwabeni River is the preferred site and if needed, a second site on the Gugamela River, may be studied.

This off-channel storage dam will address periodic shortages of supply, especially during summer, to Port Shepstone. It will have a limited impact on main stream, as water will be abstracted by pumping, only during relatively high flows. Releases will be made during times of low flow, to augment the main stream at Ugu's abstraction point at St Helen's Rocks. It should be noted that the dam and pumping installation will not be designed to provide additional water for the estuary, as all water released from the dam will have been pumped into the dam at considerable cost. Storage is limited and the operating rules will be designed in such a way that the dam will have minimal impact on the estuary, the requirements of which are being assessed by this study.

6.8.2. Mhlabatshane Regional Water Supply Scheme

The Mhlabatshane Regional Water Supply Scheme comprises a dam, currently under construction, on the Mhlabatshane River, a tributary of the Mzumbe River, to the North of the Mzimkhulu. As the yield of the river is limited, the supply from the dam will be augmented from the Mzimkhulu River in Quaternary Sub-catchment T52D, as from 2015.

Abstraction will take place between December and July, essentially when flows in the Mzimkhulu River are higher and volumes will rise from 0,2 million m^3/a in 2015 to 1,7 million m^3/a in 2021, after which the abstraction is expected to remain constant.

6.9. POTENTIAL FOR WATER EXPORT TO NEIGHBOURING CATCHMENTS

6.9.1. Future Augmentation of the Mgeni River System

Once the construction of the Spring Grove Dam on the Mooi River, is complete and the dam operational, the current thinking is that the next augmentation of the Mgeni System, to meet the growing demands of the Ethekwini Metropolitan Municipality, will come from the proposed Smithfield and Impendle Dams on the Mkomazi River. In future years, this resource could be augmented from the Mzimkhulu River.

Possible sites upstream of the confluence of the Pholela and the Mkomazi Rivers (DWAF 1984) would allow water to be gravitated to the Mkomazi River.

The sites New Biggin on the main stem and a number of sites on the Pholela near the property Cascades 1083 are located some 16,5 km upstream of the confluence on the Mzimkhulu and 14 km upstream of the confluence on the Pholela River. (See **Figure 6.5**). The two dams could be linked by means of a 5 km tunnel and could discharge into the Luhane River via a 14,5 km tunnel. The Luhane River joins the Mkomazi about 8 km upstream of the Smithfield Dam site.

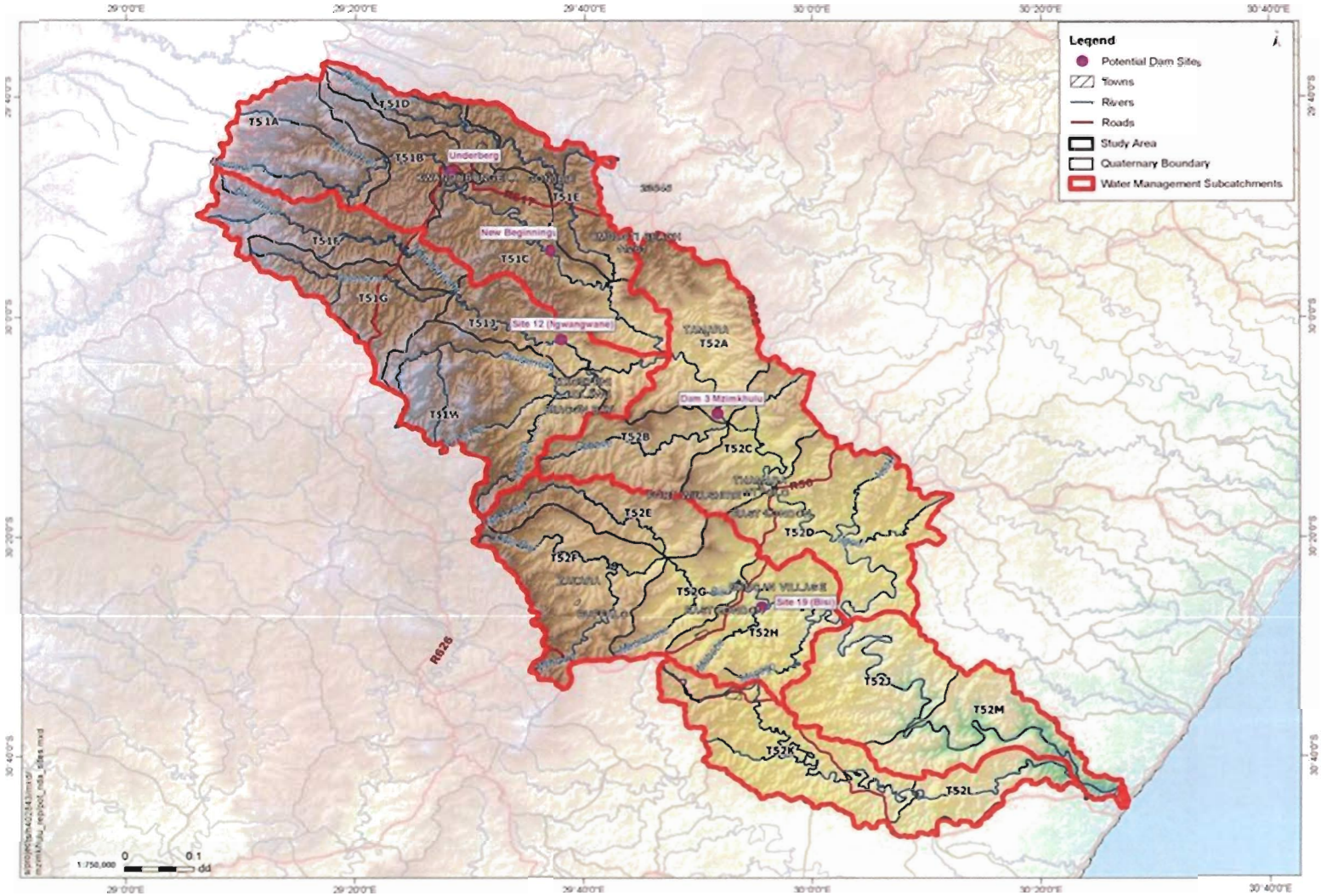

Figure 6.5: **Potential Dam Sites**

A dam 4 or 5 km downstream of the confluence of the Pholela and the Mzimkhulu, would also have sufficient head to gravitate to the Smithfield site, but would require a considerably longer tunnel.

The DWA has published the Terms of Reference for the Mkomazi Water Project Phase 1: Technical Feasibility Study: Raw Water and has received proposals.

6.9.2. Water export to supply coastal resorts

Once a stabilised, sustainable flow has been achieved at St Helen's Rocks, additional water could be abstracted and exported via the potable water supply infrastructure, to supply the towns and resorts to the north and south of Port Shepstone. Currently, the Ugu District Municipality's Boboyi Treatment Works (in quaternary sub-catchment T52M), supplies water 26 km north, as far as Hibberdene, inland as far as Murchison and 16 km south, to Ramsgate. This expansion has been allowed for in the projected future water requirements.

7. FUTURE DEVELOPMENT AND WATER RESOURCE SCENARIOS

7.1. INTRODUCTION

The Mzimkhulu River system was modelled for the period 1920 to 2007 in the WRYM-IMS, using updated hydrology, all known water demands, as well as riverine EWRs to maintain the PES, extrapolated to each quaternary sub-catchment for the present day system.

The surplus yields for each quaternary sub-catchment were calculated initially, to determine which catchments might have available yield which could be taken up by the future development of plantation forestry.

Inputs to Scenarios:

- **Environmental Water Requirements**
  - Reserve Requirements at EWR Sites.
- **Urban / Industrial Requirements to 2030**
  - Domestic / Urban / Industrial Requirements, including Ugu / Port Shepstone;
  - Non-urban industrial growth; and
  - Rural communities.
- **Future Land Use**
  - Possible Afforestation Expansion; and
  - Possible Irrigation Expansion.
- **Future Water Exports**
  - Currently planned Water exports; and
  - Possible Exports of surplus water (after development of a dam).

The future scenarios were developed in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. In all the scenarios, Port Shepstone's projected future (2030) water demand of 27 million m^3/a, from the Mzimkhulu River abstraction works at St Helen's Rock, was taken into account. Known future land and water use requirements discussed above and in more detail in the Land Use and Water Requirements Report (*Report no. WMA 11/T50/00/3009 Volume 9*), were modelled and EWRs were included for each quaternary catchment for the present ecological state (PES). The following four basic scenarios were evaluated. Each has a number of sub-scenarios, giving a total of 15 future development scenarios, as summarised below and in **Appendix D**, in bullet and tabular form (**Table D1**). The scenarios assessed the impacts of increased land and water use, with and without mitigation, provided by one of two dam options in a given scenario.

The resultant mean annual runoff at the each of the EWR sites for the various future development scenarios is presented in the sections below as well as the surplus yield available from the dam options.

The scenarios detailed below, have been given Reference codes, for identification.

The codes are as follows:

U – Unmitigated – no dams
M – Mitigated by one or more dams
SG – Forestry potential for Small Plantation Growers
LG – Forestry potential for Large Plantation Growers
A – All forestry areas
Irr 20 – Additional 20% irrigation water use
Bisi – Bisi in the Middle Mzimkhulu WMCS
OCS – Off-channel Storage (Cwabeni Dam)

7.2. FUTURE SCENARIO 1 (FS 1): ALL SMALL GROWERS

Scenario 1 assumes current known use projected to 2030, with small grower plantation forestry expansion of 29 400 ha, with no increase in irrigated agriculture. A number of sub-scenarios were run:

- Two unmitigated (U), scenarios: with and without the off-channel storage (OCS) at Cwabeni (FS 1U OCS (SG A)) and (FS 1U (SG A)).
- A migrated (M) scenario, with a 0,5 MAR dam at Site 12 on the Ngwangwane, operated to meet all EWRs at Gibraltar and the surplus yield assumed to be fully utilised or exported. (FS 1M 1 (SG A))
- Mitigated scenarios, to size a dam at Site 12 on the Ngwangwane, to meet all EWR flows at Gibraltar (FS 1M 2 (SG A)).
- Mitigated scenarios, to size a dam at Site 12 on the Ngwangwane, to meet all present day flows at Gibraltar (FS 1M 3 (SG A)).

The dam sizes and surplus yield from the dam at Site 12 are summarised in **Table 7.1** below and more detail may be found in **Table D1** in **Appendix D**.

Table 7.1: Site 12 dam characteristics for Scenario 1 Mitigated

Dam at Site 12 (Ngwangwane)	FS1M1	FS1M2	FS1M3
Capacity (million m^3/a)	122	45	10
Capacity as proportion of MAR	0,5	0,18	0,04
Surplus yield (million m^3/a)	80	1	0

From the results of the modelling runs, it became apparent that even relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site. These flows could be restored by a dam of about 10 million m^3 dam (4% MAR) at Site 12 on the Ngwangwane River. A larger dam of about 45 million m^3 (about 20% MAR), would restore the river to meet all recommended EWR flows at Gibraltar, while the 50% MAR dam produced a surplus of about 80 million m^3.

7.3. FUTURE SCENARIO 2 (FS 2): SMALL GROWERS, BISI

Scenario 2 concentrates on the Bisi River catchment, where an additional area of 21 050 ha of plantation forestry for small growers has been modelled, with no increase in irrigated agriculture. A dam at Site 19 on the Bisi River, was included to mitigate the impacts of increased plantation forestry in these quaternary sub-catchments and on the EWR at Gibraltar.

Three scenarios were run:

- A mitigated (M), scenario, with a 0,5 MAR dam at Site 19 on the Bisi, operated to meet the EWR at Gibraltar and the surplus yield assumed to be fully utilised or exported. (FS 2M 1 (SG Bisi)).

- Mitigated, scenarios, to size a dam at Site 19 on the Bisi, to meet all the EWR flows at Gibraltar (FS 2M 2 (SG Bisi)).

- Mitigated, scenarios, with a dam at Site 19 on the Bisi, to size a dam to meet all present day flows at Gibraltar (FS 2M 3 (SG Bisi)).

The surplus yield from the modelled dams at Site 19, are summarised in **Table 7.2.**

Table 7.2: Site 19 dam characteristics for Scenario 2 mitigated

Dam at Site 19 (Bisi)	FS2M1	FS2M2	FS2M3
Capacity (million m^3)	113	45	15
Capacity as proportion of MAR	0,5	0,2	0,07
Surplus yield (million m^3)	30	3	0

From the results of the modelling runs, as mentioned above, even relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site, but did impact on the low flows at the Bisi EWR site. In this scenario, the present day flows at Gibraltar could be restored by a small, less than 15 million m^3 dam (7% MAR) at Site 19 on the Bisi River. A larger dam of about 45 million m^3 (about 20% MAR), on the same site, would restore the river to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of about 30 million m^3/a.

7.4. FUTURE SCENARIO (FS 3): ALL GROWERS, SMALL AND LARGE

Scenario 3 has an increased forestry area for small and large growers, throughout the Mzimkhulu catchment, totalling 50 350 ha, as well as a 20% increase in irrigated agriculture. Four scenarios were run:

- Two unmitigated scenarios, (U): with and without the off-channel storage (OCS) at Cwabeni: (FS 3U OCS (LGA + Irr 20)), and (FS 3U (LGA + Irr 20)). The latter scenario was not used in the EWR assessment;

- A mitigated (M) scenario, with a 0,5 MAR dam at Site 12 on the Ngwangwane, operated to meet all the EWR flows at Gibraltar and the surplus yield assumed to be fully utilised or exported. (FS 3M 1 (LG A + Irr 20))

- Mitigated scenarios, to size a dam at Site 12 on the Ngwangwane, just large enough to meet the EWR in all months at Gibraltar (FS 3M 2 (LG A+ Irr 20)).

- Mitigated (M), scenarios were run to size a dam at Site 12 on the Ngwangwane just large enough to meet all present day flows at Gibraltar (FS 3M 3 (LG A+ Irr 20)). There was no surplus yield.

The dam sizes and surplus yield from the dam at Site 12 are summarised in **Table 7.3** below and more detail may be found in **Table D1** in **Appendix D**.

Table 7.3: Site 12 dam characteristics for Scenario 3 mitigated

Dam at Site 12 (Ngwangwane)	FS3M1-1	FS3M2	FS3M3
Capacity (million m^3)	122	48	16.5
Capacity as proportion of MAR	0,5	0,20	0,07
Surplus yield (million m^3)	76	2	0

From the results of the modelling runs, as in the previous cases, an even larger area of additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site. In this case, these flows could be restored by a small 16,5 million m^3 dam (7% MAR) at Site 12 on the Ngwangwane River. A larger dam of 48 million m^3 (20% MAR) would restore the river to meet all EWR flows at Gibraltar and produce a surplus of just under 80 million m^3/a.

7.5. FUTURE SCENARIO 4: LARGE DAM SCENARIO

Scenario 4 was developed, in order to explore the impacts of large scale water resource development, either for export of water or to meet significant new demands, on the river and estuarine flows.

The results are presented in the Riverine Ecological Water Requirements Report (*Report No. WMA 11/T50/00/3009, Volume 5)* and the Estuarine Ecological Water Requirements Report (*Report No. WMA 11/T50/00/3009, Volume* 6). The additional scenario has the same land and water use as for Scenario 3, i.e. all small and large growers (LG A) forestry (50 350 ha) and 20% increased irrigation. In addition, there are three cases:

- The first (FS 4a (M: LG A + Irr 20) has the following dams:

    - a 0,18 MAR dam at Site 19 on the Bisi, operated to meet all EWR flows at Gibraltar, with any surplus utilised or exported;

    - a 0,17 MAR dam at Site 12 on the Ngwangwane, operated to support the above dam at Site 19, to meet all EWRs at Gibraltar, if required, with the surplus utilised. The model indicated that this dam was not needed.

    - a 1,0 MAR dam on the main stem of the river, 2 km west of Underberg, operated, not to supply the EWR requirements at Gibraltar, but with all the surplus historical firm yield, exported out of the catchment.

    - No Off-channel storage at Cwabeni.

- The second (FS 4c Full (M: LG A + Irr 20) has:
    - a 0,5 MAR dam at Site 19 on the Bisi to meet the full EWRs at Gibraltar. All surplus yield assumed to be fully utilised or exported;
    - a 1,5 MAR dam on the farm, New Biggin, exporting its historical firm yield;
    - No Off-channel storage at Cwabeni.
- The third (FS 4c Low (M: LG A + Irr 20) is identical to the previous scenario, except that:
    - the 0,5 MAR dam at Site 19 on the Bisi meets only the low flow EWRs at Creighton and Gibraltar (**See Appendix D, Table D 1**. All surplus yield assumed to be fully utilised or exported;

The dam sizes and surplus yields from the dams at Underberg and New Biggin are summarised in **Table 7.4:** and **Table 7.5** below and more detail may be found in **Table D 1** in **Appendix D**.

Table 7.4: Dam characteristics for Scenario 4a

Scenario 4a Dams		FS4a
Capacity (million m^3)	Dam at Underberg	248
Capacity as proportion of MAR		1,0
Surplus yield (million m^3)		180

Table 7.5: Dam characteristics for Scenario 4c Full and Low

Scenario 4c Dams		FS4c
Capacity (million m^3)	Dam at New Biggin	473
Capacity as proportion of MAR		1,5
Surplus yield (million m^3)		228

As mentioned above, Scenario 4 was added to ascertain what the impacts of exporting a large volume of water would be and to see if EWR flows could still be met. It can be seen in the above tables, that volumes of 180 and 228 million m^3 respectively, could be made available for export while meeting all EWR flows. The effect of the three Scenarios 4 on the MAR at the EWR sites is shown in **Table 7.6**.

Table 7.6: Mean annual runoff at EWR sites for Future Scenario 4

EWR Site	Natural MAR (million m^3)	Present day MAR (million m^3)	FS4a (million m^3)	FS4c_full (million m^3)	Fs4c_low (million m^3)
Callaway	261	186	71	198	198
Pierr	110	86	87	87	87
Coleford	117	100	100	100	100
Creighton	870	755	580	528	523
Middle Mzimkhulu	1 085	883	698	649	642
Welverdiend	195	158	131	130	131
Oribi	43	28	29	29	29
Gibraltar	1 384	1 152	925	852	836
Estuary	1 453	1 206	951	878	862

8. DISCUSSION AND CONCLUSIONS

8.1. DISCUSSION

The Mzimkhulu River system was modelled for the period 1920 to 2007 in the WRYM-IMS, using updated hydrology estimates and including EWRs for the PES, extrapolated to each quaternary sub-catchment for the present day system. This resulted in small surpluses in 11 of the 20 quaternary sub-catchments. However, when the system model was run with the objective of meeting all the EWRs, there was no surplus yield in any of the catchments.

Future development scenarios were configured to assess the impact of increased land and water use requirements on catchment runoff. Potential dam sites on the Ngwangwane and the Bisi Rivers were modelled in order to mitigate the impacts of increased water use. Full details are given in the Riverine Ecological Water Requirements Report *(Report No. WMA 11/T50/00/3009, Volume 5)* and the Estuarine Ecological Water Requirements Report *(Report No. WMA 11/T50/00/3009, Volume* 6), whilst the salient points are discussed in this report.

The overall conclusion of the EWR investigation is that the state of the ecosystem in this catchment is generally good, ranging from an A/B to a B (Volumes 5 and 6). For a river system, as large as the Mzimkhulu, it is unusual for South Africa, to have a river in such good condition. The river also proves to be fairly resilient, being relatively unresponsive to the proposed development of additional forestry and irrigation in the catchment. This resilience is based on a combination of the mountainous upper catchment, the presently good condition of the river, the good water quality, which is not expected to deteriorate much, and the lack of special or unique aspects to the components of the ecosystem.

It emerged that there is not much risk attached to allowing a fair degree of forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows (0,04 to 0,07 MAR) and a slightly larger dam (0,18 to 0,2 MAR) to restore the full EWR, at the Gibraltar EWR site.

It is important to note that the scope of the project only made provision for a limited number of EWR sites. These sites are on the main Mzimkhulu River and on the larger tributaries. Whilst the impact at these sites was relatively small, there may be considerably more severe impacts locally, on some of the smaller tributaries. These possible impacts need to be assessed when considering licence applications. The sites on the tributaries are also generally above the sites where dams were modelled, meaning that the ecological impacts did not consider the impacts of the dams on the tributaries themselves, but only on the main stem river, after the confluence. There is thus a zone of unknown ecological impact, below the prospective dams and above the confluence with the main river.

There are a number of limitations to this assessment, which have been described in the Riverine Ecological Water Requirements Report (*Report No. WMA 11/T50/00/3009, Volume 5)*. While none of these constitutes a "fatal flaw" in the investigation, there are some areas of uncertainty that should be resolved before approval is given for major developments. During the study the greatest uncertainty revolved around the accuracy of

the predicted reductions in flow, with increasing forestry, especially in the Bisi catchment, which also happens to be the catchment, most likely to be developed for forestry.

8.2. CONCLUSIONS

The developments modelled, assuming a large dam on the main stream of the river, would have the largest potential impact on the ecosystem, with those smaller dams modelled on the tributaries, having considerably less impact. This aligns with conservation proposals, where the undammed nature of the river has been recognised by the NFEPA programme and the Mzimkhulu is ranked as one of the most important rivers for conservation in the region.

By providing storage, the impacts of increased plantation forestry and irrigation can be successfully mitigated, meeting all EWRs at Gibraltar.

If the dams are sized to be larger than required for mitigation, they would provide some surplus yield, which could be exported or used for supply additional development within the catchment.

The cost estimates of the proposed dams at site 12 on the Ngwangwane River and site 19 on the Bisi River, were based on the smallest possible dams to meet all the EWR requirements at the Gibraltar site. On each site, a dam with storage volume of 42 million m^3 was assumed for costing purposes and costs are estimated to be R366,46 million and R264,75 million respectively.

Details of the cost breakdowns are given in Appendix E.

Annual costs of redemption on loans construct the above dams, repaid over a period of 40 years, at different interest rates, are set out in **Table 8.1**.

Table 8.1: Annual Capital Repayments of possible dams over 40 years

	Site 12 (Ngwangwane) R 366 460 000 (million Rand)	Site 19 (Bisi) R 264 750 000 (million Rand)
8%	28,5	20,6
10%	34,0	24,6
12%	39,7	28,7

The gross marginal cost of timber production in the catchment is estimated to be in the order of R2 500/ha/a (SAPPI 2010). See Appendix F.

The annual costs of capital to create additional storage, in order to mitigate the impact of developing additional areas of plantation forestry in the Mzimkhulu catchment, for a range of interest rates, are set out in **Table 8.2** below:

Table 8.2: Cost of capital per hectare to create additional storage to mitigate impact of additional plantation forestry

Scenario (ha)	Ngwangwane (Rand)			Bisi (Rand)		
	8%	10%	12%	8%	10%	12%
21 050	1 350	1 620	1 890	976	1 170	1 360
29 400	970	1 160	1 350	700	840	970
50 350	560	680	790	410	490	570

If one was to add the additional 20% irrigation expansion, this would add about 3000 ha and reduce the above figures by about 15% for the 21 050 ha scenario and 6% for the 50 350 ha scenario.

It can be seen from **Table 8.2** that, provided reasonably large areas of plantation forestry are planted, the costs of constructing a mitigating dam to provide the EWR flows, are within reach.

It should also be noted that the scope of this study did not make provision for the identification of new dam sites. Previously identified sites were used, in order to model the impacts. As the sizes of dams required to mitigate the development of additional irrigation and plantation forestry are relatively small, it is quite probable that, once the approximate size of dam required on the specific tributary, has been determined, a more economical site could be found further upstream on the tributary, with a more favourable storage to MAR ratio, than the low figures which emerged from the modelling.

9. RECOMMENDATIONS

9.1. SHORT TO MEDIUM TERM MANAGEMENT (1-5 YEARS)

The following steps can be taken in the short term (within the next 5 years) to support socio-economic development in the catchment, maintain or improve the level of assurance of supply to water users in the catchment while maintaining the EWR flows:

Environmental

- Implement on-going ecological monitoring at the EWR sites, especially the RAPID III sites, and upgrading them to Intermediate category, and determine if the ecological state of the river is deteriorating or not.

- As soon as possible determine and implement Resource Classification Objectives following the newly published procedure, so that there can be clear objectives for the management of the river.

- Establish Intermediate EWR sites and gauge flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu WMSC. Monitor flows at these points and at the Gibraltar EWR site continuously. Maintain regular river health monitoring at these EWR sites.

- Carry out on-going monitoring of the estuary, as discussed in the Estuarine Ecological Water Requirements Report *(WMA 11/T50/00/3009, Volume 6*). This on-going monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored.

- Evaluate the findings of this EWR investigation in the light of the new data which is gathered, including that from the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from that study will provide information on the Reserve situation in the smaller tributaries.

- Extend the current Wetland Rehabilitation Project to drained and degraded wetlands, wetlands, currently not receiving attention.

Hydrological Monitoring

- Review the calibration of key flow gauges, as discussed in the Hydrology Report (*WMA 11/T50/00/3009, Volume 8*).

- Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).

Water Resource Management

- Implement Water Conservation and Demand Management measures. If estimated losses in urban and domestic use in the catchment could be halved, the savings could be up to 7 million m^3/a.

- Validate and verify all registered water use in the catchment and eliminate unlawful use. If 5% of the current irrigation use of 90 million m^3/a, is unlawful, this could free up about 4,5 million m^3/a. Similarly, removal of illegal plantation forestry, could free up between 5 and 6 million m^3/a.

- Monitor to ensure compliance with licence conditions, to ensure amongst others, that abstraction volumes are not being exceeded and plantation areas are not being exceeded.

- Identify and remove alien vegetation. Removing a quarter of the estimated area, could boost the available water by 10 million m^3/a.

- Maintain water quality monitoring in the catchment and recommence water quality monitoring in the Lower Mzimkhulu.

- Educate people in rural areas to prevent over-grazing.

- Institute catchment conservation measures, including wetland rehabilitation and removal of alien vegetation, which will assist in meeting the Reserve.

Water Use Licensing

- Invite and process licence applications for an initial area of up to 5 000 ha of plantation forestry in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu WMSCs with priority being given to small growers. Applications in other sub-catchments could also be considered. Local impacts of all applications need to be evaluated.

- There is a large amount of alien vegetation in the catchment. Removal of these can be replaced with equivalent afforestation.

- Ensure that any new licence application for development includes information of potential impacts as provided by an EIA process and potentially a Reserve study, conducted at a local level. The Reserve information provided in this report cannot be construed to cater for all local level situations. Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively may have a high impact, need to be considered in a larger context. This is especially the case for small scale forestry developments. Co-ordination of the management of these larger impacts should be the responsibility of DWA with support from the Provincial Environmental management authority.

Water Resource Development

- Investigation of Cwabeni off channel storage must continue in order to have mechanism ready to address dry season water shortages in the short term.

- Carry out an initial comparison, including realistic time lines and lifetime economics between the Cwabeni off-channel storage dam and a storage dam on the Ngwangwane and Bisi Rivers, sized to supply Ugu District Municipality's requirements and mitigate the impacts of additional plantation forestry.

- Develop Groundwater Resources for remote rural and urban settlements and where yields are sufficient, also for small scale irrigation to provide food security.

9.2. LONGER TERM MANAGEMENT AND DEVELOPMENT OPTIONS

In the longer term, it is recommended that the Department of Water Affairs should:

- On the basis of the results of the additional monitoring recommended in section 9.1, review the EWR results for the rivers (including smaller tributaries) and estuary.

- Having implemented the recommended monitoring, assess the impact on stream flow of the water use in the catchment, including that of the first areas of additional forestry, when at least 5 years monitoring is available and the additional forestry has been in place for at least 5 years.

- The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.

- Re-assess the impacts of increased forestry and other activities in the catchment.

- The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.

- Having monitored the impact of the first 5 000 ha of additional forestry over a period of 5 to 10 years, if the impact does not appear significant, as indicated by the flow regimes and ecological monitoring, invite and process licence applications in batches of 5 000 ha, for the balance of the potential area of 30 000 ha of plantation forestry, in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu WMSCs.

- Small growers should receive priority and the impact should be continuously monitored. Applications in other sub-catchments could also be considered.

- Local impacts on the water resource and the environment should continue to be monitored

- The impacts need to be evaluated for each application and cumulative effects considered.

- If impact have been observed or predicted, proceed with the next recommendation.

- If unacceptable impacts are observed then undertake a pre-feasibility study to investigate the possibility of a dam on the Ngwangwane or the Bisi River. The purpose of this would be:

    - to mitigate as far as possible, the impact of realising the full potential plantation area of 50 000 ha;
    - to restore the EWR flows;
    - to investigate whether there are sites upstream of those modelled on the Ngwangwane and the Bisi Rivers with a more favourable capacity to MAR ratios;
    - to meet the shortfalls at the Ugu's St Helen's Rocks abstraction works on the main river, this could do away with the need for the Cwabeni off-channel dam currently being investigated. This could avoid duplication and save the off-channel pumping costs

- *Identify the* technical, *economic and environmental feasibility of developing a dam.*

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APPENDIX A
PLANTATION FORESTRY POTENTIAL

Table A1	Commercial plantation potential Small Growers														
	Quaternary Catchment			Existing Commercial Forestry		Plantation Forestry Potential		Weighted Forestry Potential				Total (future and existing)			
Sub Catchment	No	Area (ha)	% of Cment	Area (ha)	% of Quat	Potential	Area (ha)	30%	50%	75%	Potential Area (ha)	Total Cmen: Area (ha)	% of Quat	Model SG	Model Bisi Selected
Upper Mzimkhulu	T51A	32 659	5%	654,26	2,0%	High	-			0,00	0,00	654,26	2,0%	0,00	0,00
						Medium	-		0,00						
						Low	-	0,00							
	T51B	20 750	3%	1 854,22	8,9%	High	-			0,00	0,00	1 854,22	8,9%	0,00	0,00
						Medium	-		0,00						
						Low	-	0,00							
	T51C	46 366	7%	8 873,97	14,8%	High	-			0,00	749,85	7 623,83	16,4%	750,00	0,00
						Medium	-		0,00						
						Low	2 499,51	749,85							
	T51D	13 882	2%	1 006,53	7,3%	High	0,87			0,66	0,92	1 007,46	7,3%	0,00	0,00
						Medium	0,20		0,10						
						Low	0,56	0,17							
	T51E	25 983	4%	3 784,29	14,6%	High	-			0,00	231,26	4 015,55	15,5%	250,00	0,00
						Medium	0,02		0,01						
						Low	770,84	231,25							
Ngwangwana	T51F	30 234	5%	1 673,64	5,5%	High	-			0,00	0,00	1 673,64	5,5%	0,00	0,00
						Medium	-		0,00						
						Low	-	0,00							
	T51G	26 331	4%	1 564,55	5,9%	High	-			0,00	1,37	1 565,92	5,9%	0,00	0,00
						Medium	-		0,00						
						Low	4,57	1,37							
	T51H	51 997	8%	2 949,34	5,7%	High	-			0,00	2 361,53	5 310,87	10,2%	2 350,00	0,00
						Medium	4 307,24		2 153,62						
						Low	693,03	207,91							
	T51J	26 327	4%	1 781,59	6,8%	High	-			0,00	1 416,18	3 197,78	12,1%	1 400,00	0,00
						Medium	1 966,71		983,35						
						Low	1 442,77	432,83							
Middle Mzimkhulu	T52A	38 698	6%	8 718,17	22,5%	High	-			0,00	1 888,66	10 606,83	27,4%	1 900,00	0,00
						Medium	286,00		143,00						
						Low	5 818,87	1 745,66							
	T52B	25 608	4%	1 681,57	6,6%	High	1 102,31			826,73	1 374,19	3 055,76	11,9%	1 350,00	1 350,00
						Medium	1 030,26		515,13						
						Low	107,76	32,33							
	T52C	25 368	4%	7 250,24	28,6%	High	-			0,00	2 196,06	9 446,30	37,2%	2 200,00	2 200,00
						Medium	3 560,76		1 780,38						
						Low	1 385,59	415,68							
	T52D	52 702	8%	7 875,31	14,9%	High	-			0,00	885,52	8 760,84	16,6%	900,00	900,00
						Medium	378,83		189,42						
						Low	2 320,36	696,11							
Bisi	T52E	23 595	4%	6 060,38	25,7%	High	633,98			475,49	2 622,88	8 683,26	36,8%	2 600,00	2 600,00
						Medium	3 562,92		1 781,46						
						Low	1 219,78	365,93							
	T52F	41 745	6%	12 886,69	30,9%	High	8 460,45			6 345,34	6 842,69	19 729,38	47,3%	6 850,00	6 850,00
						Medium	-		0,00						
						Low	1 657,85	497,36							
	T52G	21 646	3%	2 396,92	11,1%	High	2 207,73			1 655,80	4 756,46	7 153,38	33,0%	4 750,00	4 750,00
						Medium	147,62		73,81						
						Low	10 089,50	3 026,85							
	T52H	34 977	5%	927,34	2,7%	High	-			0,00	2 398,76	3 326,10	9,5%	2 400,00	2 400,00
						Medium	51,41		25,70						
						Low	7 910,20	2 373,06							
Lower Mzinkhulu	T52J	36 617	5%	1 278,56	3,5%	High	-			0,00	111,47	1 390,03	3,8%	0,00	0,00
						Medium	-		0,00						
						Low	371,57	111,47							
Mzimkulwana	T52K	46 848	7%	11 271,93	24,1%	High	-			0,00	1 714,04	12 985,97	27,7%	1 700,00	0,00
						Medium	183,42		91,71						
						Low	5 407,78	1 622,33							
	T52L	13 291	2%	761,77	5,7%	High	-			0,00	0,00	761,77	5,7%	0,00	0,00
						Medium	-		0,00						
						Low	-	0,00							
Lower Mzinkhulu	T52M	31 231	5%	38,74	0,1%	High	-			0,00	16,00	54,75	0,2%	0,00	0,00
						Medium	32,00		16,00						
						Low	-	-							
	Total					High	12 405,35			9 304,01	29 567,86				
						Medium	15 507,39		7 753,69						
						Low	41 700,52	12 510,16							
	Total	666 855	100%	83 290	12,49%		69 613,26				29 567,86	112 857,88	16,9%	29 400	21 050

Table A2	Commercial plantation potential													
	Quaternary Catchment			Existing Commercial Forestry		Plantation Forestry Potential		Weighted Forestry Potential				Total (future & existing)		Rounded
Sub Catchment	No	Area (ha)	% of Cment	Area (ha)	% of Quat	Potential	Area (ha)	40%	60%	80%	Potential Area (ha)	Total Cment Area (ha)	% of Quat	Total Cment Area (ha)
Upper Mzimkhulu	T51A	32 659	5%	654,26	2,0%	High	-			0,00	0,00	654,26	2,0%	0
						Medium	-		0,00					
						Low	-	0,00						
	T51B	20 750	3%	1 854,22	8,9%	High	-			0,00	0,00	1 854,22	8,9%	0
						Medium	0,00		0,00					
						Low	-	0,00						
	T51C	46 366	7%	6 873,97	14,8%	High	-			0,00	2 931,25	9 805,23	21,1%	2 950
						Medium	1 367,81		820,68					
						Low	5 276,42	2110,57						
	T51D	13 882	2%	1 006,53	7,3%	High	1,09			0,87	1,22	1 007,75	7,3%	0
						Medium	0,20		0,12					
						Low	0,56	0,22						
	T51E	25 983	4%	3 784,29	14,6%	High	-			0,00	1 279,26	5 063,55	19,5%	1 300
						Medium	294,02		176,41					
						Low	2 757,11	1102,84						
Ngwangwana	T51F	30 234	5%	1 673,64	5,5%	High	-			0,00	0,00	1 673,64	5,5%	0
						Medium	-		0,00					
						Low	-	0,00						
	T51G	26 331	4%	1 564,55	5,9%	High	-			0,00	1,83	1 566,38	5,9%	0
						Medium	0,00		0,00					
						Low	4,57	1,83						
	T51H	51 997	8%	2 949,34	5,7%	High	1,95			1,56	5 201,06	8 150,40	15,7%	5 200
						Medium	4 716,06		2829,63					
						Low	5 924,65	2369,86						
	T51J	26 327	4%	1 781,59	6,8%	High	-			0,00	3 822,59	5 604,18	21,3%	3 800
						Medium	3 796,80		2278,08					
						Low	3 861,27	1544,51						
Middle Mzimkhulu	T52A	38 698	6%	8 718,17	22,5%	High	-			0,00	2 980,21	11 698,38	30,2%	3 000
						Medium	673,22		403,93					
						Low	6 440,69	2576,28						
	T52B	25 608	4%	1 681,57	6,6%	High	2 651,74			2121,39	3 710,98	5 392,55	21,1%	3 700
						Medium	2 568,90		1541,34					
						Low	120,63	48,25						
	T52C	25 368	4%	7 250,24	28,6%	High	-			0,00	3 542,76	10 793,00	42,5%	3 550
						Medium	4 842,22		2905,33					
						Low	1 593,57	637,43						
	T52D	52 702	8%	7 875,31	14,9%	High	-			0,00	1 248,11	9 123,42	17,3%	1 250
						Medium	397,39		238,43					
						Low	2 524,18	1009,67						
Bisi	T52E	23 595	4%	6 060,38	25,7%	High	1 775,22			1420,18	5 314,79	11 375,17	48,2%	5 300
						Medium	5 369,41		3221,65					
						Low	1 682,43	672,97						
	T52F	41 745	6%	12 886,69	30,9%	High	9 864,54			7891,63	8 770,17	21 656,86	51,9%	8 750
						Medium	109,32		65,59					
						Low	2 032,37	812,95						
	T52G	21 646	3%	2 396,92	11,1%	High	2 313,34			1850,67	6 118,05	8 514,97	39,3%	6 100
						Medium	270,97		162,58					
						Low	10 261,97	4104,79						
	T52H	34 977	5%	927,34	2,7%	High	-			0,00	3 195,10	4 122,43	11,8%	3 200
						Medium	51,70		31,02					
						Low	7 910,20	3164,08						
Lower Mzinkhulu	T52J	36 617	5%	1 278,56	3,5%	High	-			0,00	148,63	1 427,19	3,9%	0
						Medium	-		0,00					
						Low	371,57	148,63						
Mzimkuiwana	T52K	46 848	7%	11 271,93	24,1%	High	-			0,00	2 273,25	13 545,18	28,9%	2 250
						Medium	183,56		110,14					
						Low	5 407,78	2163,11						
	T52L	13 291	2%	761,77	5,7%	High	-			0,00	0,00	761,77	5,7%	0
						Medium	-		0,00					
						Low	-	0,00						
Lower Mzinkhulu	T52M	31 231	5%	38,74	0,1%	High	-			0,00	19,20	57,95	0,2%	0
						Medium	32,00		19,20					
						Low	-	0,00						
	Total					High	16 607,89			13286,31	50 558,45			0
						Medium	24 673,59		14804,15					
						Low	56 169,97	22467,99						
	Total	666 855	100%	83 290	12,49%		97 451,45				50 558,45	133 848,47	20,07%	50 350

APPENDIX B
WATER USE AND STORAGE LICENCE APPLICATIONS

SFRA (FORESTRY) LICENCES ISSUED IN T51 & T52 CATCHMENTS MAY 2010				
DATE ISSUED	LICENCE NUMBER	APPLICANT	CATCHMENT	HECTARES
27/2/2002	1850000264	Cele Tribal Authority	T52D	3,74
27/2/2002	1850000264	Cele Tribal Authority	T52J	6,52
27/2/2002	1850000264	Cele Tribal Authority	T52H	0,86
27/2/2002	1850000262	Isibonda TA	T52K	0,60
27/2/2002	1850000261	Kwabotho TA	T52J	2,90
27/2/2002	1850000260	Nkunbini TA	T52K	2,00
27/2/2002	1850000263	Sizwe Hlanganani TA	T52D	3,20
28/10/2002	1850000265	C Kidger	T52A	35,00
28/10/2002	1850000266	C Kidger	T52A	15,00
23/09/2004	1850000279	Sappi Manufacturing	T52K	0,60
11/05/2005	1852000000	NG Magabisa (Mrs)	T52D	21,00
29/09/2005	1852000005	RC Nzimande	T52G	8,50
29/09/2005	1852000004	MN Mayeza	T52G	9,90
3/11/2005	1852000003	AV Mazelem	T52F	19,90
3/11/2005	1852000002	XE Sibhayi	T52G	19,90
23/2/2006	1852000012	MB Cele	T52D	2,50
23/2/2006	1852000011	ME Kunene	T52D	8,00
07/04/2006	1851000001	The Derek Nicholson Family	T51B	35,00
11/5/2006	1852000010	Matyeni Community	T52H	11,40
11/5/2006	1852000007	Matyeni Community	T52H	14,30
11/5/2006	1852000008	Lucingweni Community	T52H	13,50
11/5/2006	1852000009	Machumeni Community	T52G	27,50
4/7/2006	1852000014	MC Hloba	T52G	8,50
4/7/2006		Nomdaphu Com.Woodlot	T52H	7,00
7/7/2006	1852000015	Sappi Manufacturing	T52C	2,70
7/7/2006	1852000016	Sappi Manufacturing	T52C	7,50
7/7/2006	1852000017	Sappi Manufacturing	T52C	1,90
7/7/2006	1852000018	Sappi Manufacturing	T52C	4,80
7/7/2006	1852000019	Sappi Manufacturing	T52A	2,40
7/7/2006	1852000020	Sappi Manufacturing	T52C	0,40
7/7/2006	1852000021	Sappi Manufacturing	T52K	2,20
1/11/2006	1852000025	TDR Oliver Family Trust	T52D	13,50
1/11/2006	1852000026	TDR Oliver Family Trust	T52D	49,70
1/11/2006	1852000027	TDR Oliver Family Trust	T52D	17,00
1/11/2006	1852000022	Dumanomhuhu Com.Wood.	T52E	11,90
3/11/2006	1852000001	R Dlamini	T52G	19,90
3/11/2006	1852000028	GV Mzizi	T52D	5,00
15/6/62007	1852000029	DM Strachan	T52C	40,00
5/9/2007	1852000030	Sappi Manufacturing	T52D	11,30
5/9/2007	1852000024	Sappi Manufacturing	T52C	12,10
1/2/2008	1852000032	MA Ndlangisa	T52J	9,00
20/5/2009	1852000033	NL Madiba	T52K	7,66
28/10/2009	1852000035	SE Ngubo	T52D	9,00
			Total	**505,28**

SFRA (FORESTRY) LICENCE APPLICATIONS ON HOLD IN THE MZIMKHULU CATCHMENT MAY 2010			
13/7/2006	Bobore LF	T52L	3
13/7/2006	Cele C	T52L	10
19/8/2005	Dzanibe MC	T52C	197
8/8/2008	Hadebe SS	T52C	100
15/2/2007	Mabandla Community Trust	T52H	27,9
2/2/2006	Mahlawe WP	T52F	40
25/1/2007	Mbanjwa BJ	T52H	586
8/8/2008	Memela MW	T52D	25
15/11/2006	Mnyembane W	T52G	25
20/6/2006	Mvuna Project	T52L	0,3
19/6/2008	Ngevu Developments	T52B	193
13/7/2006	Shelembe CN	T52L	5
1/11/2005	Singisi Forest Products	T52G	6,15
		Total	**1 218,35**

ISSUED ABSTRACTION AND STORAGE LICENCES APRIL 2010

Quat	Applicant	Total Abstraction (1 000m^3)	Total Storage (1 000m^3)	Co-ordinates									
T51C	Glenlea Farms CC	530	360	29	°	48'	30"	S	29	°	35'	00"	E
T51C	Scotston Trust		288	29	°	48'	35"	S	29	°	27'	51"	E
T51C	Turner VP		392	29	°	47'	15"	S	29	°	33'	28"	E
T51C	Lang KD	917	850	29	°	49'	58"	S	29	°	30'	05"	E
T51D	Forde D		350	29	°	43'	05"	S	29	°	32'	30"	E
T51D	Pholela Water Users Association (Forde D)	2 500	2 500	29	°	43'	19"	S	29	°	29'	41"	E
T51D	Pholela Water Users Association (Forde D)	7 400	4 500	29	°	45'	11"	S	29	°	32'	22"	E
T51F	Couzens FS		80	29	°	53'	40"	S	29	°	19'	47"	E
T51F	Couzens FS		70	29	°	54'	25"	S	29	°	18'	30"	E
T51G	Clifton Trust	270	550	29	°	59'	10"	S	29	°	23'	45"	E
T51G	Wilton MG		156	30	°	00'	05"	S	29	°	22'	20"	E
T51G	Fettercairn Farm Land Trust (ACH Gilson)		1 400	29	°	58'	22"	S	29	°	21'	31"	E
T51G	Fettercairn Farm Land Trust (ACH Gilson)		150	29	°	58'	55"	S	29	°	20'	01"	E
T52A	Mingay BW		185	30	°	00'	30"	S	29	°	48'	30"	E
T52A	NA Smith Family Trust		154 (2)	30	°	00'	13"	S	29	°	52'	48"	E
				30	°	00'	12"	S	29	°	53'	16"	E
	TOTAL	**11 617**	**11 985**										

Quat	Applicant	Total Storage (1 000m^3)	Co-ordinates									
T40E	Ugu District Municipality (Not in Mzimkhulu catchment)	200	30	°	53'	40"	S	30	°	08'	20"	E
T51C	Burnlea Trust	151	29	°	54'	15"	S	29	°	33'	50"	E
T51C	Burnlea Trust	98	29	°	54'	34"	S	29	°	33'	29"	E
T51C	Glenlea Farms CC (James Little)	245	29	°	47'	54"	S	29	°	35'	10"	E
T51D	Scafell Trust	206	29	°	42'	40"	S	29	°	25'	01"	E
T51E	Mingay RE	270	29	°	50'	40"	S	29	°	30'	41"	E
T51F	Dommet PM	5	29	°	51'	45"	S	29	°	18'	09"	E
T51F	Dommet PM	92 (4)	Not available									
T51F	Dommet PM	65 (4)	29	°	52'	20"	S	29	°	18'	10"	E
			29	°	52'	12"	S	29	°	18'	38"	E
			29	°	52'	06"	S	29	°	18'	50"	E
			29	°	52'	18"	S	29	°	18'	54"	E
T51F	Dommet PM	273 (3)	29	°	50'	45"	S	29	°	15'	37"	E
			29	°	0.5'	0.4"	S	29	°	15'	34"	E
			29	°	15'	55"	S	29	°	51'	0.3"	E
T51F	Struan Farm CC	63 (2)	29	°	53'	45"	S	29	°	20'	58"	E
			29	°	53'	37"	S	29	°	21'	12"	E
T51F	WJP Trust	50	29	°	54'		S	29	°	21'		E
T52A	Bhaletsheni Trust-Trustees	308	30	°	02'	59"	S	29	°	49'	46"	E
T52A	Nkonza Irrigation Board	8 000 (2)	29	°	59'	49"	S	29	°	50'	33"	E
			29	°	58'	58"	S	29	°	50'	48"	E
	TOTAL	**10 026**										

APPENDIX C
DAM SITE DETAILS

	SITE REF ID	LOCALITY DESCRIPTION	STORAGE CAPACITY (Million m^3)	WALL HEIGHT (m)	WALL LENGTH (m)	SURFACE AREA (ha)	COMMENTS	ADDITIONAL INFO	SOURCE
MAIN RIVER	UNDERBERG	2 km NW OF UNDERBERG	247,7	132,00		1 100	HUGE INFRASTRUCTURE INUNDATION. COSTLY DIVERSIONS AND RELOCATION REQUIRED		JOHANN GERINGER (EX DWA) PRAGIN MAHARAJ/ DUNCAN SHAW JOINT STUDY: AURECON & MNA CONSULTANTS: UPDATE OF SISONKE REGIONAL BULK WATER PLAN
MAIN RIVER									
	ST HELEN'S ROCKS	9 km UPSTREAM FROM ESTUARY MOUTH - CURRENT UGU DM ABSTRACTION POINT					WEIR TO FACILITATE ABSTRACTION SOLID ROCK 10M BELOW RIVER BED TOO LOW DOWN FOR A LARGE DAM TO BE OF VALUE	FIRST IDENTIFIED BY GMKS, THEN ENDORSED BY UWP	DWAF-GOBA MOAHLOLI KEEVE STEYN SOUTHERN KZN WR PRE-FEASIBILITY STUDY. PHASE 2 MAIN REPORT: FEBRUARY 2005 P WMA 11/000/00/0505 DWAF-UWP MZIMKHULU RIVER OFF-CHANNEL STORAGE DRAFT 2: 15 JAN 2007 PROJECT 2005-190
MAIN RIVER	GIBRALTAR	39 km U/S OF ESTUARY							REF: ARCUS GIBB
MAIN RIVER	DAM 1	83 km UPSTREAM OF MZIMKULU TOWN	121,00	100,00	947	200	FLOOD ATTENUATION		SISONKE DISTRICT MUNICIPALITY -ARCUS GIBB UMZIMKHULU FLOOD TOWN PROTECTION STUDY PRE FEASIBILITY STUDY: SDM 194/DLGTA/2007 SEPTEMBER 2009
MAIN RIVER	DAM 3	30 km U/S OF UMZIMKULU TOWN	411,00	100,00	812	671	FLOOD ATTENUATION & WATER SUPPLY SOLID BEDROCK		SISONKE DISTRICT MUNICIPALITY -ARCUS GIBB UMZIMKHULU FLOOD TOWN PROTECTION STUDY PRE FEASIBILITY STUDY: SDM 194/DLGTA/2007 SEPTEMBER 2009
MAIN RIVER	SITE 16	3 km NORTH OF UMZIMKULU TOWN	509,03	45,00	300 AT 30 m HEIGHT	2 374	NOT CONSIDEDED. (TOO LARGE FOR ILISO STUDY). MAJOR DAM ON LARGE RIVER. MAY BE SUITABLE FOR IB TRANSFER. HIGH YIELD.		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
MAIN RIVER	SITE 17	3 km NORTH OF UMZIMKULU TOWN	734,76	45,00	300 AT 30 m HEIGHT	3 156	NOT CONSIDEDED. (TOO LARGE FOR ILISO STUDY). MAJOR DAM ON LARGE RIVER. MAY BE SUITABLE FOR IB TRANSFER. HIGH YIELD.		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
MAIN RIVER	MORNINGTON 7978	27 km UPSTREAM OF UMZIMKULU TOWN					WAS PREVIOUSLY TO BE USED TO GRAVITATE TO LOWER MKOMAZI.	NO LONGER AN OPTION AS NGWADINI SITE ON LOWER MKOMAZI NOT PART OF PLAN	1984 DWA REPORT
MAIN RIVER	ON OR NEAR NEW BIGGIN 13390	16,5 km UPSTREAM OF CONFLUENCE WITH POLELA	472,50	94,00		2173	ELEVATION OF RIVER 1360 M. SUITABLE FOR TRANSFER TO MKOMAZI CATCHMENT UPSTREAM OF SMITHFIELD	CAN BE LINKED TO SITE ON POLELA WITH 4.8 KM TUNNEL FOR TRANSFER TO MKOMAZI CATCHMENT	1984 DWA REPORT
TRIBUTARY									
PHOLELA	ON OR NEAR CASCADES 10833	14,2 km UPSTREAM OF CONFLUENCE WITH MZIMKHULU RIVER					ELEVATION OF RIVER 1300 M. SUITABLE FOR TRANSFER TO MKOMAZI CATCHMENT UPSTREAM OF SMITHFIELD SITE	CAN BE LINKED TO SITE ON MZIMKHULU WITH 4.8 KM TUNNEL FOR TRANSFER TO MKOMAZI. A 15.6 KM TUNNEL TO DELIVER INTO LUHANE RIVER, TRIBUTARY OF MKOMAZI	1984 DWA REPORT
NGWANGWANE	DAM 2	38 km U/S OF CONFLUENCE WITH MZIMKHULU	565,00	100,00	1 192	792	SAME SITE AS SITE 12 BELOW FLOOD ATTENUATION		SISONKE DISTRICT MUNICIPALITY -ARCUS GIBB UMZIMKHULU FLOOD TOWN PROTECTION STUDY PRE FEASIBILITY STUDY: SDM 194/DLGTA/2007 SEPTEMBER 2009
NGWANGWANE	SITE 12	8 km NORTH NORTH WEST OF EDGETON 28 km UPSTREAM OF THE CONFLUENCE WITH THE MZIMKHULU	9.0 42.0 50.33 122.0	25 41 45 71	325	332	CONSIDERED. GOOD SITE. MAY BE ALTERNATIVE TO SITE 15.		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
MZIMKHULWANA	SITE 5	3 km EAST OF HARDING	105,10	45,00	680 AT 30 m HEIGHT	492	CONSIDERED. POSSIBLE SUPPLY FOR HARDING & S COAST. HIGH COST. LONG WALL. RELOCATION OF N2.		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
NGWANGWANE	SITE 11	4 km NORTH OF ENYANISWENI	128,00	30,00	770		NOT CONSIDERED. HIGH COST OF WALL & RELOCATION. BETTER SITES NEARBY		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
GUNGUNUNU	SITE 13	2 km WEST OF ENYANISWENI	145,00	30,00	1 000		NOT CONSIDERED. HIGH COST & LARGE FLOODED AREA		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
GUNGUNUNU	SITE 14	3 km WEST OF EDGETON	66,00	30,00	880		NOT CONSIDERED. HIGH COST & BETTER SITE IN SAME AREA		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
GUNGUNUNU	SITE 15	6 km NORTH-WEST OF EDGETON	51,00	30,00	470		CONSIDERED. GOOD SITE HIGH IN THE REGIONAL CATCHMENT AREA		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
MZIMKHULWANA	SITE 18	20 km SOUTH-EAST OF HARDING	59,00	30,00	720		NOT CONSIDERED. FAIRLY LOW IN THE CATCHMENT & BETTER SITES ELSEWHERE		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
BISI	SITE 19	7 km EAST OF KOK'S HILL	11 35 42 113	17 30 32 56	480		CONSIDERED. GOOD SITE, BUT BETTER SITES ELSEWHERE		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
BISI	SITE 20	5 km NORTH-EAST OF KOK'S HILL	67,00	30,00	510		NOT CONSIDERED. HIGH ENVIRONMENTAL COSTS.		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006
BISI	SITE 21	NORTH OF HARDING	26,00	30,00	340		CONSIDERED. GOOD SITE, BUT SOME RELOCATION OF PEOPLE & SERVICES REQUIRED		UMGENI WATER-ILISO KZN REGIONAL BULK WATER SUPPLY RECONNAISSANCE STUDY SOUTHERN REGIONAL SCHEMES MARCH 2006

APPENDIX D
FULL DESCRIPTION OF SCENARIOS

DESCRIPTION OF SCENARIOS

PRESENT DAY SCENARIO
Current situation and "normal" growth in water demand

Present day (2007) water use and infrastructure plus "Normal" Economic growth and water use up to 2030, including the coastal strip supplied via Port Shepstone (with seasonal peak)

FUTURE SCENARIOS
The scenarios detailed below, have been given Reference codes, for identification.
The codes are as follows:

U – Unmitigated – no dams
M – Mitigated by one or more dams
SG – Forestry potential for Small Plantation Growers
LG – Forestry potential for Large Plantation Growers
A – All forestry areas
Irr 20 – with 20% additional irrigation water use
Bisi – Bisi in the Middle Mzimkhulu WMCS
OCS – Off-channel Storage (Cwabeni Dam)

EWR	Estuary	Description
1	3	**FS 1U OCS (SG A): Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry areas from Table of Agreed percentages of land suitable for small grower **(SG)** commercial forestry expansion. (Table 1) = 29 400 ha • Unmitigated **(U)**. • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security) • The Cwabeni off-channel storage (OCS) Dam was included. • This scenario was also modelled with the OCS excluded, but this was not considered in the assessment of EWRs
2	4	**FS 1M 1 (SG A): Present Day Scenarios, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry areas from agreed percentages of land suitable for small grower **(SG)** commercial forestry expansion. (Table 1) = 29 400 ha • Mitigation **(M)** through 0,5 MAR Dam (FSL = 1 226 masl, Storage = 122 million m^3) at site 12 (Ngwangwane), operated to meet all EWRs at Gibraltar. • The surplus yield of the dam was assumed to be fully utilised or exported • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security)

EWR	Estuary	Description
x	x	**FS 1M 2: (SG A)** • The same as Future Scenario 1M-1 except: o Size of dam at site 12 (Ngwangwane), reduced to be just big enough to meet all EWR at Gibraltar (0,17 MAR) (FSL = 1 196 masl, Storage = 42 million m^3) o Dam operated to meet all EWRs at Gibraltar o There was no surplus yield
x	x	**FS 1M 3: (SG A) as for Present Day Scenarios, plus:** • The same as Future Scenario 1M-1 except: o Size of the dam at site 12 (Ngwangwane), reduced to be just big enough to meet all present day flows at Gibraltar (0,04 MAR) (FSL = 1 180 masl Storage = 9 million m^3) o Dam operated to meet all present day flows at Gibraltar o There was no surplus yield
3	5	**FS 2M 1: (SG Bisi): Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • Additional areas for Forestry small grower **(SG Bisi)** areas only in the Bisi (in Quats T52E to H plus T52B and C) from agreed percentages of land suitable for small grower commercial forestry expansion. (Table 1) = 21 050 ha • Mitigation **(M)** through 0,5 MAR (FSL = 611 masl, Storage = 113 million m^3) dam at site 19 (Bisi) operated to meet all EWRs in all months, at Gibraltar • Surplus yield from dam assumed to be fully utilised or exported • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security)
x	x	**FS 2M 2: (SG Bisi) as for Present Day Scenario, plus:** • The same as Future Scenario 2M-1 except: o Dam at site 19 (Bisi) reduced in size to be just big enough to meet EWR in all months at Gibraltar (0,18 MAR) (FSL = 587 masl, Storage = 42 million m^3) o Dam operated to meet all EWR flows at Gibraltar o There was no surplus yield
x	x	**FS 2M 3: (SG Bisi) as for Present Day Scenarios, plus:** • The same as Future Scenario 2M-1 except: • Dam at site 19 (Bisi) reduced in size to be just big enough meet all present day flows in all months at Gibraltar (0,05 MAR) (FSL = 572 masl Storage = 11 million m^3) • Dam operated to meet present day flows at Gibraltar • There was no surplus yield
4	6	**FS 3U OCS: (LG A + Irr 20) as for Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry **(LG A)** areas from agreed percentages of land

EWR	Estuary	Description
		suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • Cwabeni off-channel storage (OCS) Dam was included • The scenario was also modelled without the OCS but that option was not used for EWR assessment
*	7	**FS 3M 1: (LG A + Irr 20) as for Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry **(LG A)** areas from agreed percentages of land suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • Mitigation **(M)** through 0,5 MAR (FSL = 1 226 masl, Storage = 122 million m^3) dam at site 12 (Ngwangwane) operated to meet EWRs at Gibraltar in all months • Surplus yield from dam at site 12 assumed to be fully utilised or exported • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security).
x	x	**FS 3M 2: (LG A + Irr 20) as for Present Day Scenario, plus:** • The same as Future Scenario 3M_1 except: • Dam at site 12 (Ngwangwane) reduced in size to be just big enough to meet EWR in all months at Gibraltar (0,20 MAR) (FSL = 1 199 masl, Storage = 48 million m^3) • Dam at site 12 (Ngwangwane) operated to meet EWRs in all months • There was no surplus yield
x	x	**FS 3M 3: (LG A + Irr 20) as for Present Day Scenario, plus:** • The same as Future Scenario 3M_1 except: • Dam at site 12 reduced in size to be just big enough to meet all present day flows at Gibraltar (0,06 MAR) (FSL = 1 182 masl, Storage = 13 million m^3) • Dam at site 12 operated to meet all present day flows at Gibraltar • There was no surplus yield
5	2	**FS 4a (M: LG A + Irr 20) as for Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry **(LGA)** areas from agreed percentages of land suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • Mitigation (M) through 0,18 MAR (FSL = 587 masl Storage =

EWR	Estuary	Description
		42 million m^3) dam at site 19 (Bisi) operated to meet all EWR flows at Gibraltar • Surplus yield assumed to be fully utilised or exported • 0,17 MAR (FSL = 1 196, Storage = 42 million m^3) dam at site 12 (Ngwangwane) operated to support the dam at Site 19 (Bisi) to meet all EWRs at Gibraltar if required. But was not needed. • Surplus yield assumed to be fully utilised or exported • 1,0 MAR (1 492 FSL, Storage = 248 million m^3) dam at Underberg to export all surplus yields out of the basin. (export = 180 million m^3/a) • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security)
		FS 4b: (M: LG A + Irr 20) as for Present Day Scenario plus: THIS SCENARIO WAS NOT MODELLED • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry **(LGA)** areas from agreed percentages of land suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • 0,5 MAR (FSL = 611 masl Storage = 113 million m^3) dam at site 19 (Bisi) operated to meet EWRs at Gibraltar • All surplus yield assumed to be fully utilised or exported • 0,5 MAR (FSL = 1 226 masl, Storage = 122 million m^3) dam at site 12 (Ngwangwane) operated to support dam 19 to meet EWRs at Gibraltar if required • All surplus yield assumed to be fully utilised or exported • 1 MAR dam at Underberg (FSL = 1492 masl Storage = 248 million m^3) • 1,5 MAR dam (Mzimkhulu Dam 3) (Storage = 1 425 million m^3) • All surplus yield exported • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security).
6	1	**FS 4c_Full (LG A + Irr 20) as for Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural Economic growth and associated increase in water use up to 2030 • All additional forestry **(LGA)** areas from agreed percentages of land suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • 0,5 MAR (FSL = 611 masl Storage = 113 million m^3) dam at site 19 (Bisi) operated to meet **full** EWRs at Creighton and Gibraltar • Surplus yield from the dam assumed to be fully utilised or exported

EWR	Estuary	Description
		• 1,5 MAR (FSL = 1 454 masl Storage = 473 million m^3) dam on the farm New Biggin. All surplus yields exported out of the basin (export = 227 million m^3/a) • Develop Groundwater resources (small urban & rural communities and small scale irrigation for food security).
7		**FS 4c_Low: (M LG A + Irr 20) as for Present Day Scenario, plus:** • Present day (2007) water use and infrastructure plus "Normal" urban and rural economic growth and associated increase in water use up to 2030 • All additional forestry **(LGA)** areas from agreed percentages of land suitable for large commercial forestry expansion. (Table 2) = 50 350 ha • Additional 20% demand from irrigated agriculture **(+ Irr 20)** in all Quats with irrigated agriculture, throughout the catchment • 0,5 MAR (FSL = 611 masl Storage = 113 million m^3) dam at site 19 (Bisi) operated to meet only **low** flow EWRs at Creighton and Gibraltar • Surplus yield assumed to be fully utilised or exported • 1,5 MAR (FSL = 1 454 masl Storage = 473 million m^3) dam on the farm New Biggin to export all surplus yields out of the basin (export = 227 million m^3/a) • No OCS at Cwabeni • Develop groundwater resources (small urban & rural communities and small scale irrigation for food security).

Table D 1: Summary of Future Development Scenarios

Scenario		FS 1U_OCS (SG A)	FS 1M 1 (SG A)	FS 1M 2 (SG A)	FS 1M 3 (SG A)	FS 2M 1 (SG Bisi)	FS 2M 2 (SG Bisi)	FS 2M_3 (SG Bisi)	FS 3U OCS (LG A + Irr 20)	FS 3M 1 (LG A + Irr 20)	FS 3M 2 (LG A + Irr 20)	FS 3M 3 (LG A + Irr 20)	FS 4a (M: LG A)	FS 4c (M: LG A Full)	FS 4c (M: LG A Low)
River EWR Scenario Number		1	2				3		4				5	6	7
Estuary		3	4				5		6				2	1	
Characteristics															
Increased forestry		29 400 ha	29 400 ha	29 400 ha	29 400 ha	21 050 ha	21 050 ha	21 050 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha
Increased demand from irrigated agriculture		NIL	NIL	NIL	NIL	NIL	NIL	NIL	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)
Cwabeni OCS		Yes (and No)	No	No	No	No	No	No	Yes (and No)	No	No	No	No	No	No
Dam at site 12 (Ngwangwane)	Size	No	0,5 MAR	0,17 MAR	0,04 MAR	No	No	No	No	0,5 MAR	0,20 MAR	0,06 MAR	0,17 MAR	No	No
	Operation		Operated to meet all EWRs at Gibraltar in all months	Operated to meet all EWRs at Gibraltar. Surplus yield exported or used.	Operated to meet present day flows at Gibraltar. Surplus yield exported or used.					Operated to meet EWRs at Gibraltar and surplus yield exported	Operated to meet EWRs in all months	Operated to meet all present day flows at Gibraltar	Operated to support the dam at Site 19 to meet all EWRs at Gibraltar – surplus yield exported		
Dam at site 19 (Bisi)	Size	No	No	No	No	0,5 MAR	0,18 MAR	0,05 MAR	No	No	No	No	0,18 MAR	0,5 MAR	0,5 MAR
	Operation					Operated to meet all EWRs in all months at Gibraltar – surplus yield exported or used	Operated to meet all EWR flows in all months at Gibraltar	Operated to meet all present day flows in all months at Gibraltar					Operated to meet all EWR in all months at Gibraltar – surplus yield exported	Operated to meet all EWRs in all months at Creighton and Gibraltar. Surplus yield exported or used.	Operated to meet EWRs in low flow months at Creighton and Gibraltar. Surplus yield exported or used.
Underberg	Size												1,0 MAR		No
	Operation												All yield exported out of the basin 180 million m^3/a		
New Biggin	Size												No	1,5 MAR	1,5 MAR
	Operation													All yields exported out of basin. Export 227 million m^3/a	All yields exported out of basin. Export 227 million m^3/a

Expected impact on EWR sites

- Callaway
- Pierr
- Coleford
- Creighton
- Middle Mzimkhulu
- Welverdiend
- Gibraltar
- Oribi

NOTES:

1. In all scenarios the base is present day infrastructure, forestry and irrigation agriculture.
2. In all scenarios the growth in urban and rural domestic water use is a 30% increase up to 2030 and includes the coastal strip, supplied by Port Shepstone, with seasonal demands.
3. Scenario 4b was defined but not modelled.

APPENDIX E
ESTIMATED COSTS OF NGWANGWANE AND BISI DAMS

Dam capacity: 42 million m^3 Wall height: 40 m Cost Item	Site 12 (Ngwangwane)			
	Unit	Rate (R)	Quantity	Amount (R)
Clearing				
(a) Sparse	ha	5 600	150	840 000
(b) Brush	ha	16 800	300	5 040 000
(c) Trees	ha	28 000	230	6 440 000
River Diversion	Sum	2 000 000	1	2 000 000
Excavation				
(a) Bulk				
(i) All materials	m^3	40	40 000	1 600 000
(ii) Extra over for rock	m^3	72	19 550	1 407 600
(b) Confined				
(i) All materials	m^3	60	2 300	138 000
(ii) Extra over for rock	m^3	100	1 150	115 000
(c) Final foundation preparation	m^2	0	0	
Preparation of solum				
(i) All materials	m^2	20	19 550	391 000
(ii) Extra over for rock	m^2	20	19 550	391 000
Drilling and Grouting				
(a) Curtain grouting	m drill	448	3 450	1 545 600
(b) Consolidation grouting	m drill	448	13 800	6 182 400
Embankment				
(a) Earthfill	m^3	48	0	
(b1) Rockfill	m^3	100	708 553	70 855 300
(b) Filters	m^3	176	42 513	7 482 320
(c) Rip-rap	m^3	96	0	
(d) Core	m^3	27	174 100	4 700 700
(e) Overhaul beyond 5 km	m^3-km	4	830 875	3 323 500
Concrete (% of Embankment)	%	50	86 361 820	43 180 910
Mechanical items				
(a) Valves & gates	Sum	1	0	10 000 000
(b) Cranes & hoists	Sum	1	0	5 000 000
Landscaping & Fencing (% of all above)	%	5	170 633 330	8 531 666
Miscellaneous (% of all above)	%	15	179 164 996	26 874 749

Dam capacity: 42 million m^3 Wall height: 40 m Cost Item	Site 12 (Ngwangwane)			
	Unit	Rate (R)	Quantity	Amount (R)
SUB TOTAL A				206 039 745
Preliminary & general	%	15,0%		30 905 962
Preliminary works				
(a) Access road	km	240 000	10	2 400 000
(b) Electricity to site	Sum	1	2 000 000	2 000 000
(c) Construction water to site	Sum	1	1 000 000	1 000 000
Accommodation	Sum	1	725 000	725 000
SUB TOTAL B				243 070 707
Contingencies	%	15%		36 460 606
SUB TOTAL C				279 531 313
Planning design & supervision	%	15%		41 929 697
SUB TOTAL D				321 461 010
VAT	%			45 004 541
Cost of land acquisition	ha	30000	50	1 500 000
TOTAL PROJECT COST			**R**	**366 465 552**

Note: Base Date 2010

Dam capacity: 42 million m^3 Wall height: 32 m Cost Item	Site 19 (Bisi)			
	Unit	Rate (R)	Quantity	Amount (R)
Clearing				
(a) Sparse	ha	5 600	150	840 000
(b) Brush	ha	16 800	300	5 040 000
(c) Trees	ha	28 000	230	6 440 000
River Diversion	Sum	2 000 000	1	2 000 000
Excavation				
(a) Bulk				
(i) All materials	m^3	40	40 000	1 600 000
(ii) Extra over for rock	m^3	72	19 550	1 407 600
(b) Confined				
(i) All materials	m^3	60	2300	138 000
(ii) Extra over for rock	m^3	100	1150	115 000
(c) Final foundation preparation	m^2	0	0	
Preparation of solum				
(i) All materials	m^2	20	19550	391 000
(ii) Extra over for rock	m^2	20	19550	391 000
Drilling and Grouting				
(a) Curtain grouting	m drill	448	3450	1 545 600
(b) Consolidation grouting	m drill	448	13 800	6 182 400
Embankment				
(a) Earthfill	m^3	48	0	
(b1) Rockfill	m^3	95	454 699	43 196 405
(b) Filters	m^3	176	15 334	2 698 784
(c) Rip-rap	m^3	96	0	
(d) Core	m^3	27	176 000	4 752 000
(e) Overhaul beyond 5 km	m^3-km	4	830 875	3 323 500
Concrete (% of Embankment)	%	50	53 970 689	26 985 345
Mechanical items				
(a) Valves & gates	Sum	1	0	10 000 000
(b) Cranes & hoists	Sum	1	0	5 000 000
Landscaping & Fencing (% of all above)	%	5	122 046 634	6 102 332
Miscellaneous (% of all above)	%	15	128 148 965	19 222 345

Dam capacity: 42 million m^3 Wall height: 32 m Cost Item	Site 19 (Bisi)			
	Unit	Rate (R)	Quantity	Amount (R)
SUB TOTAL A				147 371 310
Preliminary & general	%	15,0%		22 105 696
Preliminary works				
(a) Access road	km	240 000	10	2 400 000
(b) Electricity to site	Sum	1	2 000 000	2 000 000
(c) Construction water to site	Sum	1	1 000 000	1 000 000
Accommodation	Sum	1	725 000	725 000
SUB TOTAL B				175 602 006
Contingencies	%	15%		26 340 301
SUB TOTAL C				201 942 307
Planning design & supervision	%	15%		30 291 346
SUB TOTAL D				232 233 654
VAT	%			32 512 711
Cost of land acquisition	ha	30000	50	1 500 000
TOTAL PROJECT COST			**R**	**264 746 365**

Note: Base Date 2010

APPENDIX F
ESTIMATED MARGINS FOR TIMBER PRODUCTION

(SAPPI 2010)

ESTIMATED AVERAGE GROSS MARGINS AT MILL GATE - UMZIMKULU CASE STUDY

NOTE - No interest included - for a site quality 2 / 3 area - i.e. medium / high production

NB, This is an estimate based on actuals for a southern KZN region

		GUM	PINE	WATTLE
		wwt*	wbt*	wwt
Volumes per hectare per annum	Pulp	17	8	10
	Sawlogs - 50%		8	
	Bark (if market)			2
	TOTAL	17	16	12
		R	R	R
Selling price at mill gate / R/wwt - includes FSC where applicable	Pulp	474	340	600
	Sawlogs if available		480	
	Bark per wwt of timber (if marketable)			50
	TOTAL (avg)	474	420	650
Sales per annum / hectare		R 8 058	R 6 560	R 6 100
Harvesting R/wwt		85	65	120
Short haul		35.58	35.58	35.58
Load		12.5	12.5	12.5
Longhaul (weighted average) - road		95	100	100
Total costs extraction / delivery		R 228.08	R 213.08	R 268.08

	GUM	PINE	WATTLE
	wwt*	wbt*	wwt
Standing value (i.e. income less extraction costs)	R 245.92	R 206.92	R 381.92
Gross income per hectare per annum	4181	3311	4583
Less stumpage R/wwt	75	90	135
Stumpage per ha per annum (includes insurance, silviculture and fire protection)	1275	1440	1620
GROSS MARGIN per annum, delivered at mill gate, excluding cost of capital (interest) and management# (Staff, offices, transport etc.)	R 2 906	R 1 871	R 2 963

* wwt: Wet white ton – usually associated with gum & wattle.
wbt: Weighbridge ton – usually associated with pine.

\# Management costs vary greatly, hence their exclusion. SAPPI usually waives these costs for small growers on their Project Grow scheme. Charges by companies vary between R 500 and R660 per ha/a. The size of the plantation also plays a huge role in the cost of management.

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Surface Water Resource Report

Original

FINAL REPORT

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Surface Water Resource Report

Report no.: WMA 11/T50/00/3009 Volume 3

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PROJECT NAME	:	**MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY (WP990)**
REPORT TITLE	:	Surface Water Resources Report
AUTHORS	:	Ms L. Dobinson & Dr V. Jonker
REPORT STATUS	:	Final Report
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DATE	:	March 2011

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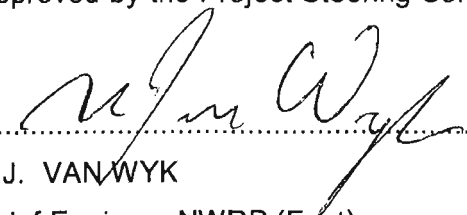

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LIST OF REPORTS	
Title	**Report Number**
Main Report	WMA 11/T50/00/3009 Volume 1
Management and Development Options	WMA 11/T50/00/3009 Volume 2
Surface Water Resources	**WMA 11/T50/00/3009 Volume 3**
Groundwater Resources	WMA 11/T50/00/3009 Volume 4
Riverine Ecological Water Requirements	WMA 11/T50/00/3009 Volume 5
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High Level Water Quality Assessment	WMA 11/T50/00/3009 Volume 7
Hydrology	WMA 11/T50/00/3009 Volume 8
Land Use and Water Requirements	WMA 11/T50/00/3009 Volume 9

Executive Summary

The objective of the surface water resources task for the Mzimkhulu River Catchment Water Resources Study is to present the updated system yield analysis for the current supply system as well as for future scheme development options in the catchment.

The Water Resources Yield Model – Information Management System (WRYM-IMS) has been used to update the Mzimkhulu River system configuration to include present day land and water use, for the period 1920 to 2007 as well as the Ecological Water Requirements (EWRs) for each quaternary catchment. The model was then configured to include future scheme developments which included five potential dam options and scenarios of increased plantation forestry, irrigation and urban and rural water use. Areas for potential forestry development were determined through a negative mapping approach which assessed the catchment according to timber growing potential characteristics. Three scenarios of increased plantation forestry areas were considered:

- *An additional 29 400 ha on land suitable for small growers throughout the catchment,*
- *An additional 21 050 ha on land suitable for small growers only in the Bisi and Middle Mzimkhulu catchments, and*
- *An additional 50 350 ha of forestry throughout the catchment, with 29 400 ha of the land being suitable for small growers.*

The potential irrigation expansion was assumed to increase in volume by 20% and it was assumed that the future water use by 2030 for rural and urban domestic, industrial and commercial purposes would increase by 60% from current use. The potential dam sites were included in the scenarios for two different purposes. To provide mitigation for the impacts of increased water demands as a result of additional plantation forestry and irrigation in the catchment by releasing the EWRs for the Gibraltar site in the Lower Mzimkhulu catchment. Alternatively to provide storage from which the yield would be exported from the catchment.

The detailed assessment of the impacts of the different scenarios on the EWR sites in the catchment is presented in the Riverine Ecological Water Requirements Report (Report No. WMA 11/T50/00/3009, Volume 5). The results of the scenario modelling indicate that the impacts of increased plantation forestry and irrigation in the catchment can be mitigated by providing relatively small storage volumes, operated to maintain present day flows at Gibraltar or to meet the EWR flows determined by the specialist study for the Present Ecological State (PES) at Gibraltar. Moreover, the dams would provide some surplus yield which could be exported or utilised within the catchment.

Abbreviations

ACRU	-	Agricultural Catchment Research Unit
CBD	-	Central Business District
DWAF	-	Department of Water Affairs and Forestry
DWA	-	Department of Water Affairs
EIA	-	Environmental Impact Assessment
EWR	-	Ecological Water Requirements
FRA	-	Flow Reducing Activity
GIS	-	Geographical Information System
MAR		Mean Annual Runoff
NWRP	-	National Water Resources Planning
OCS	-	Off-Channel Storage
PES	-	Present Ecological State
SAPWAT	-	South African Procedure for Estimating Irrigation Water requirements
SFR	-	Stream Flow Reduction
TOR	-	Terms of Reference
WAA	-	Water Availability Assessment
WMSC	-	Water Management Sub-catchments
WRYM-IMS	-	Water Resources Yield Model – Information Management System
WRYM		Water Resources Yield Model
WRSM2000	-	Water Resources Simulation Model 2000
WQT	-	Water Quality Model

Scenario Abbreviations

A	-	All
Bisi	-	Selected sub catchments
FS	-	Future Scenario
Irr 20	-	plus 20% additional Irrigation
M	-	Mitigated
LG	-	Large Growers
SG	-	Small Growers
U	-	Unmitigated

Units

km	-	kilometre
ℓ/km^2/day	-	litre per square kilometre per day
ℓ/s	-	litre per second
m	-	metre
Ma	-	million years
mm/a	-	millimetres per annum
mm/m	-	millimetres per metre
mm/s	-	millimetres per second
mS/m	-	millisiemens per metre

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1. INTRODUCTION

This report documents the updated system configuration for the Water Resources Yield Model (WRYM) and the system analysis for the current system and for future development scenarios in the Mzimkhulu River catchment. The WRYM configuration for the Mzimkhulu River Off-Channel Storage (OCS) Pre-feasibility Study was obtained from the Department of Water Affairs (DWA) and was used as a basis for the development of the final configuration of the system in the current study. The purpose of this report is to present the updated system configuration as well as the results of the system yield analysis for current and future water use scenarios in the catchment.

1.1 OBJECTIVES OF STUDY

The main objectives of the study as defined in the inception phase are as follows:

- To determine the existing and potential future water use in and from the catchment of the Mzimkhulu River.
- To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry, while also considering other envisaged future requirements.
- To reassess the hydrology and the water supplies available from existing sources, which are mainly run of river, taking the ecological flow requirements into account, in order to determine, to what extent the existing sources can meet the existing and potential future usage requirements.
- To recommend possible schemes for meeting future requirements, including potential additional afforestation, as well as interventions for moderating existing and potential future usage requirements.

This report is one of the deliverables in support of meeting these objectives.

2. WATER RESOURCES YIELD MODEL – INFORMATION MANAGEMENT SYSTEM

The Water Resources Yield Model (WRYM) that was used is the same as that used in the previous study, namely the Water Resources Yield Model – Information Management System (WRYM-IMS). This model is identical to the standard Water Resource Yield Model (WRYM) except that it has a windows graphical user interface.

The WRYM is a general multi-purpose multi-reservoir monthly simulation programme. The model can represent any water resource system that incorporates the following physical processes:

- Naturalised inflows;
- Precipitation and evaporation associated with reservoirs;
- Diffuse irrigation and afforestation demands;
- Storage and releases of water from reservoirs for irrigation or EWR purposes;
- Specified demands such as irrigation and alien vegetation;
- Water flow in channels;
- Losses in channels; and
- Pump station and/or weir diversions.

The model can simulate a wide range of operating rules, which are defined by a penalty structure. During operation, the model attempts to minimise the system penalties incurred, while at the same time supplying the demands. The interconnections of demand, storage and conveyance routes are described in the model by means of a network of nodes and channels. Nodes are conceptual elements representing points of natural inflow, points of storage or channel confluences. Channels, on the other hand, are conceptual conveyance links that can be natural or man-made, and represent river flow, diversions, canals, return flows, demands, river releases and spills from reservoirs.

To give a visual interpretation of such a system network of nodes and channels, a schematic system diagram is compiled, which shows all the components of the system.

The latest version of the WRYM-IMS allows the network features such as irrigation and streamflow reduction activities to be modelled explicitly as opposed to earlier versions of the WRYM, where they were input as time series water requirements. As part of the update of the Mzimkhulu system configuration, these network features were included so that modelling of future scenarios of land development could be facilitated.

Irrigation water requirements and return flows are modelled in the WRYM-IMS using the Irrigation Block sub-model and the Water Quality Model (WQT) methodology. The irrigation block is represented by a network node and it is linked to the network by means of two channels, the abstraction channel and the return flow channel. In earlier versions of the WRYM-IMS, irrigation water requirements and return flows were generally modelled as time-series and implemented in the system network either as diffuse water requirements, using the *.IRR data file, or using the time-series requirement channel type. These time-series, however, had to be generated externally to the model with specialist pre-processors

and utilities such as the South African Procedure for Estimating Irrigation Water Requirements (SAPWAT).

The impact of streamflow reductions can be modelled in the WRYM-IMS using the Streamflow Reduction (SFR) sub-model recently developed as part of the five Water Availability Assessment (WAA) studies commissioned by the DWA, Directorate: National Water Resource Planning (NWRP). The sub-model is based on the principle that a portion of the incremental sub-catchment associated with a node or reservoir in the system network is covered by an SFR land-use type. The SFR sub-model may be applied to any one of the following:

a) Commercial forestry;
b) Dry-land sugarcane; or
c) In-catchment alien invasive vegetation (located in mountain catchment areas).

For this purpose, a time-series data file of monthly unit runoffs is required for each SFR catchment portion modelled in the system network. The data in this file will be used for the calculation of the monthly runoff volume for the SFR portion in question.

Finally, it should also be noted that in earlier versions of the model, the impact of SFRs was generally modelled as time-series of runoff reduction volumes and implemented in the system network either as diffuse water requirements using the *.AFF data file. These time-series, however, did not allow for the user to adjust SFR areas and therefore to undertake scenario analyses without the use of pre-processors. The *.AFF-file has therefore now been largely superseded by the SFR sub-model described above.

However, following the update of the system with these features, it was found that the estimates of forestry requirements were less than those obtained in the catchment hydrology user-defined estimates with differences of up to 35%. There is no specific output from the model that quantifies the forestry demand therefore one has to check the outflow from each incremental node with runoff to the natural incremental flow to check whether the forestry demands are being correctly modelled.

The estimates of irrigation using the irrigation block sub-model were much higher than those obtained in the catchment hydrology. The reason for this was that in the Water Resources Simulation Model 2000 (WRSM2000), the user has the option of calculating the total return flows or the net return flows and in the WRYM-IMS this option is not enabled and only the total return flows are activated. This results in additional flows to the system generated by the irrigation block area.

Although the WRYM-IMS is capable of estimating water uses such as irrigation, afforestation and alien vegetation using sub-modules described above, these water requirements were represented as time series demands in the final configuration as calculated in the catchment hydrology due to the differences that were obtained between the catchment hydrology and the WRYM sub-modules. Additionally, by having these water uses represented as demand files, more control could be applied to them.

3. DESCRIPTION OF THE MZIMKHULU RIVER SYSTEM

3.1 OVERVIEW

The existing Mzimkhulu River system is comprised of surface water resources in the Mzimkhulu River catchment, and contributions from its tributaries, including the Mzimkhulwana River, the Pholela River, the Bisi River and the Ngwangwane River.

The upper part of the catchment is characterised by agricultural development, mainly under irrigation and fed by numerous farm dams. The area is serviced by the farming towns of Underberg, Himeville, Creighton and Harding, which have reasonably developed water supply infrastructure. Tourism also plays a large role in the upper catchment, where there are numerous resorts and hotels, many with dams offering boating, trout fishing, hiking, mountaineering, horse riding and golf.

Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested. The DWA has put a hold on any further licences for plantation forestry, because there are water shortages in the lower catchment during low flow periods.

The Mzimkhulu River then flows past the Northern and Eastern sides of the town of Umzimkulu. The Central Business District (CBD) is situated in the flood plain of the river and is subject to periodic flooding. This middle part of the catchment is predominantly rural tribal trust land and formed part of the previously independent Transkei. In this area, there are scattered subsistence rural communities drawing water from run-of-river. There is a great need for poverty alleviation and job creation in this area.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water mostly from local streams, but also from boreholes and springs.

The river then enters a deep gorge, where it is joined by the Bisi River and lower down, the (second) Mzimkhulwana River. The Oribi Flats, form a plateau between the gorges of the Mzimkhulu and the Mzimkhulwana Rivers, the latter, emanating from the Oribi Gorge Nature Reserve, a world heritage site and well known tourist attraction, with spectacular scenery.

The Mzimkhulu River drains tertiary sub-catchments T51 and T52, then winds its way to the Indian Ocean at Port Shepstone. The estuary used to be navigable, with difficulty, in days gone by and provided a sea link (hence the prefix "Port") with Durban, prior to the construction of the coastal railway line.

3.2 STORAGE STRUCTURES

There are no major storage structures in the Mzimkhulu catchment. The Gilbert Eyles Dam which is situated on the Mzimkhulwana River in quaternary sub-catchment T52L was decommissioned in the 1990s due to siltation problems. There are a large number of farm dams throughout the catchment used for irrigation purposed and representing a combined storage capacity of some 54 million m^3.

3.3 CONVEYANCE STRUCTURES

There is no bulk conveyance infrastructure in the Mzimkhulu catchment at present.

3.4 ABSTRACTIONS, DIVERSIONS AND TRANSFERS

The proposed Ncakubana Scheme will abstract about 0,15 million m^3 from the main stream of the Mzimkhulu River in quaternary sub-catchment T52C. The scheme is currently in the Environmental Impact Assessment (EIA) phase but has been factored into the future development scenarios and included in the model configuration.

The proposed abstraction from the main stream of the Mzimkhulu River, in quaternary sub-catchment T52D, to supplement the yield of the proposed dam in the adjacent catchment from December to July has been included in the model configuration for the 2015 estimate which is 0,22 million m^3/a.

The abstraction works at St Helen's Rock is currently being upgraded. The maximum possible abstraction rate will be 1,25 m^3/s (39,4 million m^3/a) and it will have a capacity of 900 000 m^3. The future design capacity of the Bhobhoyi water treatment works is 110 Mℓ/d (40 million m^3/a). The WRYM has been configured to model these increased capacities cater for these improvements.

There are no diversion structures or transfers currently contributing to the Mzimkhulu Water Resources System.

3.5 WATER USE AND WATER RESOURCES OF THE MZIMKHULU SYSTEM

Water demands on the Mzimkhulu System are primarily due to agriculture and afforestation which are the biggest water users in the system representing 31% and 41% of total water use respectively. Rural and urban demands represent 10% of the water use, with dryland sugar cane and stock watering representing 3% and 1% respectively. Water use by alien vegetation is estimated to be 14% of the total catchment water use.

There are no major effluent return flows in the catchment. Irrigation return flows have been accounted for in each quaternary sub-catchment and are estimated to be 10% of the irrigation supply, using the WQT methodology in the catchment hydrology model.

3.5.1. Agricultural demand

Agricultural demand in the system is primarily diffuse within the catchment, met by abstractions directly from rivers and streams, as well as demands from farm dams by individuals or groups of farmers. All irrigation demands have been estimated in the WRSM2000 model using the WQT methodology based on inputs of area and crop factors and crop types. The total irrigation supply is estimated to be 87 million m^3/a. Stock water demands account for an additional 4 million m^3/a. Sugarcane is not irrigated in this catchment and is considered to be a dryland crop. Therefore it is modelled as a flow reducing activity in the WRSM2000 model and it accounts for 7 million m^3/a of the total catchment water demand.

3.5.2. Plantation forestry water use

Plantation forestry is distributed throughout the Mzimkhulu catchment but is concentrated in the Bisi, the Mzimkhulwana and the Middle Mzimkhulu Water Management sub-catchments (WMSC). It is the largest consumer of water in the Mzimkhulu System and is estimated to use 113 million m^3/a.

3.5.3. Rural and urban demand

Point source abstractions from the Mzimkhulu River and its tributaries for commercial, industrial and domestic demands in rural and urban areas are supplied from the rivers in the catchment. The urban towns in the catchment are Underberg, Himeville, Creighton, Umzimkulu and Harding. Port Shepstone is located just outside of the catchment, but it draws water from the Mzimkhulu River at St. Helen's Rock in quaternary sub-catchment T52M and supplies the coastal strip to the north and south of the town. Rural settlements are found throughout the catchment and obtain their water from diffuse sources, including groundwater. Rural water requirements are estimated to be in the order of 7 million m^3/a and urban water requirements within the catchment are estimated to be in the order of 4 million m^3/a. Port Shepstone's demand, which is supplied from the catchment is estimated to be some 17 million m^3/a.

3.6 HYDROLOGY

The updated hydrology for the Mzimkhulu River catchment has been documented in Report Volume 8 including details of climatic and hydrological data as well as catchment modelling results. Hydrological sequences for catchment runoff and present day water use have been generated for the period 1920 to 2007. Input into the WRYM consists of a range of data files. These include the four types of monthly long-term hydrological sequences containing runoff (INC), rainfall (RAN), diffuse irrigation (IRR) and afforestation (AFF) within a catchment. These four files for each catchment are then combined to form the so-called PARAM.DAT file which statistically correlates them, without which a stochastic analysis cannot be performed. Note that in the present system, diffuse irrigation has been set to zero as all these uses are modelled as specified demand files. Instead, due to the limitation on the number of demand files that can be included in the model, the diffuse irrigation file was used to represent the alien vegetation requirements which were estimated using the WRSM2000 model. Afforestation requirements were included as determined by the WRSM2000. The electronic hydrology files are included in **Appendix A.**

3.7 ENVIRONMENTAL WATER REQUIREMENTS

The Ecological Water Requirements (EWRs) for eight riverine sites in the Mzimkhulu Catchment were assessed as part of this study by a specialised team. Basic information relating to each of the sites is summarised in **Table 3.1** and more detail is provided in the *Riverine Ecological Water Requirements Report (Report No. WMA 11/T50/00/3009, Volume 5)*. The EWRs were extrapolated by the EWR team, to each quaternary in the catchment and the EWR water requirements were incorporated into the WRYM-IMS using the IFR pre-processor function which enables the user to add multiple EWR sites to the model database. A separate EWR channel was added at the outlet of each quaternary sub-catchment in the model configuration. **Figure 3.1** shows the location of the EWR sites in the catchment.

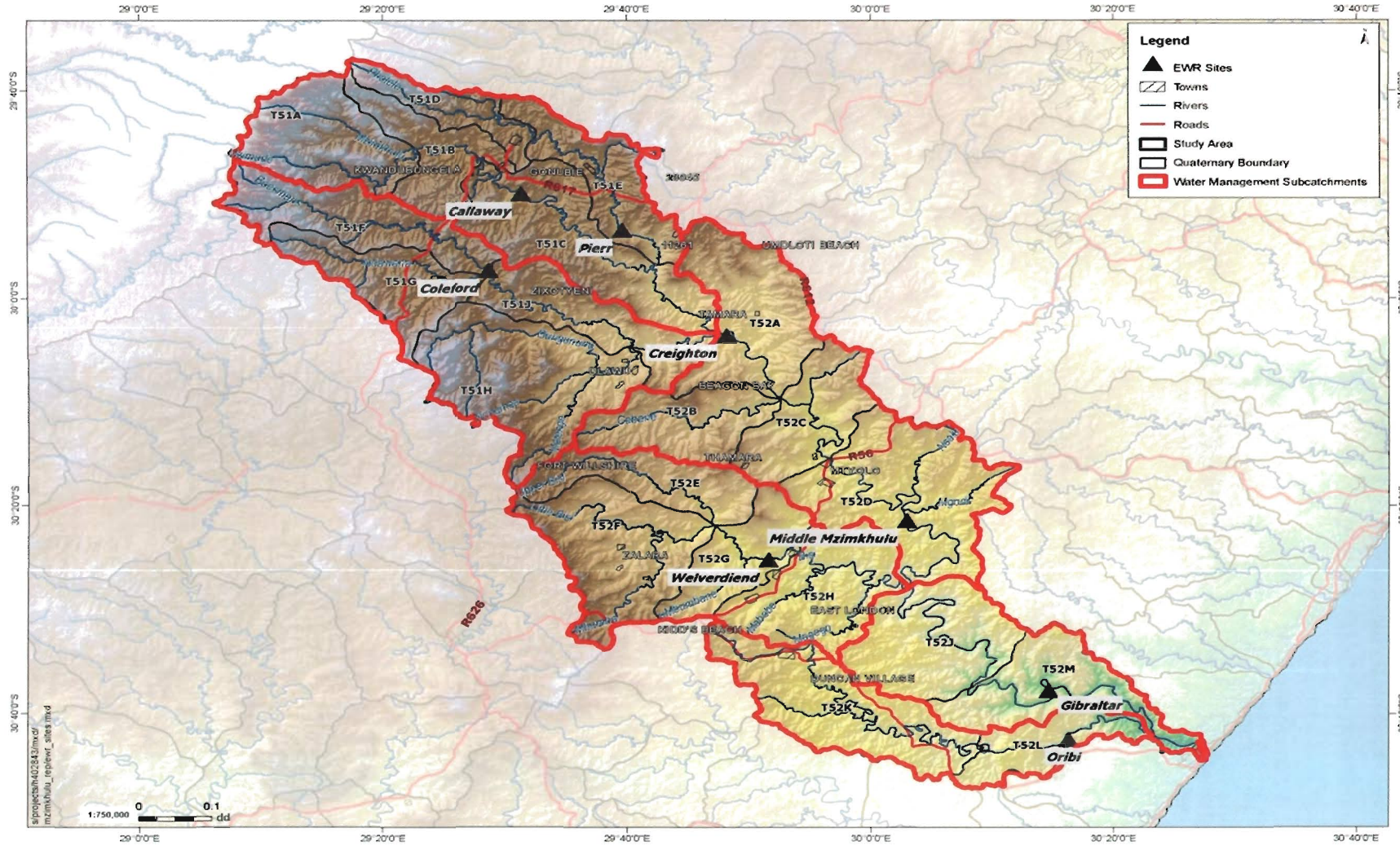

Figure 3.1: Map showing location of EWR sites in the Mzimkhulu catchment

Table 3.1: EWR sites in the Mzimkhulu

Quaternary catchment	River	EWR site number	EWR site name	Level	PES	REC	Natural MAR (million m^3)	%Maintenance Low Flow	%Maintenance High Flow	%EWR	%Drought Low Flow
T51C	Mzimkhulu	EWR2i	Callaway	Intermediate	B	B	261	12,5	12,1	24,6	4,6
T51E	Pholela	EWR9r	Pierr	Rapid 3	B/C	B/C	110	18,7	9,7	28,4	7,0
T51F	Nwangwane	EWR8r	Coleford	Rapid 3	C	C	117	11,7	9,8	21,4	5,6
T52A	Mzimkhulu	EWR3i	Creighton	Intermediate	B	B	870	19,9	3,1	23,0	4,4
T52D	Mzimkhulu	EWR5i	Middle Mzimkhulu	Intermediate	B	B	1 085	15,8	5,5	21,3	5,3
T52G	Bisi	EWR13r	Welverdiend	Rapid 3	A/B	A/B	195	31,2	11,6	42,8	11,9
T52L	Mzimkhulwana	EWR17i	Oribi	Intermediate	B	B	43	17,6	12,4	30,0	5,9
T52M	Mzimkhulu	EWR6i	Gibraltar	Intermediate	A/B	A/B	1 384	25,5	4,7	30,2	5,7

4. MODEL CONFIGURATION

4.1 CURRENT SUPPLY SYSTEM

The current supply system configuration was based on the configuration obtained from the Mzimkhulu River Off-Channel Storage Pre-Feasibility Study (Department of Water Affairs and Forestry (DWAF), 2007) which was modelled for the period 1925 – 1998. The hydrology and water use requirements were extended and updated to the 2007 hydrological year and EWR channels were added for each quaternary sub-catchment.

The future Cwabeni OCS Dam was added to the system configuration to supplement the demand at St Helen's Rock for Port Shepstone and it was included in some, but not all, future scenarios. The upgrades to the abstraction works at St Helen's Rock were included in the current day configuration.

4.2 FUTURE DEVELOPMENT SCENARIOS

Future development scenarios were configured in the WRYM-IMS to include the potential dam sites and estimated future demands of land use and water requirements. The scenarios are described in more detail in the Management and Development Options Report *(Report No. WMA 11/T50/00/3009 Volume 2)* and are summarised in **Table 4.1**. The WRYM was configured to assess the impacts of potential additional plantation forestry and irrigation options with mitigation provided by potential dams. The estimated future demands for plantation forestry, irrigation and rural and urban water requirements are presented in more detail in the following sections. Storage-yield curves were developed for five potential dam sites under consideration for mitigation of the impacts of land use development scenarios and two were selected for the scenario analysis. The area-capacity-elevation relationships for five dam options are included in **Appendix B**.

The system diagram for the Mzimkhulu supply system is included in **Appendix C** showing the locations of potential dam sites in the configuration.

Table 4.1: Mzimkhulu Basin study Future Development Scenarios

Scenario		FS 1U_OCS (SG A)	FS 1M 1 (SG A)	FS 1M 2 (SG A)	FS 1M 3 (SG A)	FS 2M 1 (SG Bisi)	FS 2M 2 (SG Bisi)	FS 2M_3 (SG Bisi)	FS 3U OCS (LG A + Irr 20)	FS 3M 1 (LG A + Irr 20)	FS 3M 2 (LG A + Irr 20)	FS 3M 3 (LG A + Irr 20)	FS 4a (M: LG A)	FS 4c (M: LG A Full)	FS 4c (M: LG A Low)
River EWR Scenario Number		1	2				3		4				5	6	7
Estuary		3	4				5		6				2	1	
Characteristics															
Increased forestry		29 400 ha	29 400 ha	29 400 ha	29 400 ha	21 050 ha	21 050 ha	21 050 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha
Increased demand from irrigated agriculture		NIL	NIL	NIL	NIL	NIL	NIL	NIL	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)
Cwabeni OCS		Yes (and No)	No	No	No	No	No	No	Yes (and No)	No	No	No	No	No	No
Dam at site 12 (Ngwangane)	Size	No	0,5 MAR	0,17 MAR	0,04 MAR	No	No	No	No	0,5 MAR	0,20 MAR	0,07 MAR	0,17 MAR	No	No
	Operation		Operated to meet all EWRs at Gibraltar in all months	Operated to meet all EWRs at Gibraltar. Surplus yield exported or used.	Operated to meet present day flows at Gibraltar. Surplus yield exported or used.					Operated to meet EWRs at Gibraltar and surplus yield exported	Operated to meet EWRs in all months	Operated to meet all present day flows at Gibraltar	Operated to support the dam at Site 19 to meet all EWRs at Gibraltar – surplus yield exported		
Dam at site 19 (Bisi)	Size	No	No	No	No	0,5 MAR	0,18 MAR	0,05 MAR	No	No	No	No	0,18 MAR	0,5 MAR	0,5 MAR
	Operation					Operated to meet all EWRs in all months at Gibraltar – surplus yield exported or used	Operated to meet all EWR flows in all months at Gibraltar	Operated to meet all present day flows in all months at Gibraltar					Operated to meet all EWR in all months at Gibraltar – surplus yield exported	Operated to meet all EWRs in all months at Creighton and Gibraltar. Surplus yield exported or used.	Operated to meet EWRs in low flow months at Creighton and Gibraltar. Surplus yield exported or used.
Underberg	Size												1,5 MAR		No
	Operation												All yield exported out of the basin 180 million m^3/a		
New Biggin	Size												No	1,5 MAR	1,5 MAR
	Operation													All yields exported out of basin. Export 227 million m^3/a	All yields exported out of basin. Export 227 million m^3/a

Expected impact on EWR sites

- Callaway
- Pierr
- Coleford
- Creighton
- Middle Mzimkhulu
- Welverdiend
- Gibraltar
- Oribi

NOTES:

1. In all scenarios the base is present day infrastructure, Forestry and Irrigation Agriculture.
2. In all scenarios the urban and rural domestic growth Callaway to Gibraltar in urban and rural domestic water use is a 30% increase up to 2030 and includes the coastal strip, supplied by Port Shepstone, with seasonal demands. Scenario 4b was defined but not modelled.

4.2.1. Plantation forestry

Potential areas of plantation forestry development in the Mzimkhulu catchment were quantified using a negative mapping process which is described in the Land Use and Water Requirements Report *(Report No. WMA 11/T50/00/3009 Volume 9)* and summarised in the Main Report *(Report No. 11/T50/00/3009, Volume 1)*. It resulted in Geographical Information System (GIS) coverages showing areas suitable for growing timber. Three scenarios for the development of future plantation forestry were analysed. The first two were for the development of small grower forestry areas, either throughout the catchment or restricted to the Bisi and Middle Mzimkhulu WMSC and the third was for the development of all potential forestry areas by small and large growers. The future demands of additional forestry areas were estimated using the unit water use for plantations in each quaternary sub-catchment derived from the catchment hydrology. The potential areas and estimated demands for small and all growers are summarised in **Table 4.2** and **Table 4.3** respectively.

Table 4.2: Small grower forestry estimated future demands

Quaternary sub-catchment	Current plantation area (ha)	Current forestry demand (million m^3/a)	Unit Reduction (mm/ha)	Potential Area for Small growers (ha)	Total area (ha)	Total use by current and small growers (million m^3/a)
T51A	643	1,4	218	0	643	1,4
T51B	1 744	3,9	224	0	1 744	3,9
T51C	6 983	12,3	176	750	7 733	13,6
T51D	998	2,7	275	0	998	2,7
T51E	3 763	5,5	147	200	3 963	5,9
T51F	1 684	4,0	235	0	1 684	4,0
T51G	1 550	3,7	237	0	1 550	3,7
T51H	2 914	5,2	177	2 350	5 264	9,4
T51J	1 755	2,5	142	1 400	3 155	4,5
T52A	8 940	12,1	135	1 900	10 840	14,6
T52B	1 683	2,9	171	1 350	3 033	5,2
T52C	6 895	10,2	147	2 200	9 095	13,4
T52D	7 802	3,2	41	900	8 702	3,6
T52E	6 337	10,1	160	2 600	8 937	14,3
T52F	12 575	20,8	165	6 850	19 425	32,1
T52G	2 350	4,2	180	4 750	7 100	12,8
T52H	934	0,7	70	2 400	3 334	2,3
T52J	1 286	1,0	75	0	1 286	1,1
T52K	11 688	6,4	55	1 700	13 388	7,4
T52L	236	0,1	59	0	236	0,1
T52M	0	0,0	0	0	0	0,0
Total	**82 762**	**112,7**	**136**	**29 350**	**112 112**	**155,8**

Table 4.3: All growers forestry estimated future demands

Quaternary sub-catchment	Current plantation area (ha)	Current forestry demand (million m^3/a)	Unit Reduction (mm/ha)	Potential Area for All growers (ha)	Total area (ha)	Total use by current and all growers (million m^3/a)
T51A	643	1,4	218	0	643	1,4
T51B	1 744	3,9	224	0	1 744	3,9
T51C	6 983	12,3	176	2 950	9 933	17,4
T51D	998	2,7	275	0	998	2,7
T51E	3 763	5,5	147	1 300	5 063	7,4
T51F	1 684	4,0	235	0	1 684	4,0
T51G	1 550	3,7	237	0	1 550	3,7
T51H	2 914	5,2	177	5 200	8 114	14,4
T51J	1 755	2,5	142	3 800	5 555	7,9
T52A	8 940	12,1	135	3 000	11 940	16,1
T52B	1 683	2,9	171	3 700	5 383	9,2
T52C	6 895	10,2	147	3 550	10 445	15,4
T52D	7 802	3,2	41	1 250	9 052	3,7
T52E	6 337	10,1	160	5 300	11 637	18,6
T52F	12 575	20,8	165	8 800	21 375	35,4
T52G	2 350	4,2	180	6 100	8 450	15,2
T52H	934	0,7	70	3 200	4 134	2,9
T52J	1 286	1,0	75	0	1 286	1,0
T52K	11 688	6,4	55	2 300	13 988	7,7
T52L	236	0,1	59	0	236	0,1
T52M	0	0,0	0	0	0	0,0
Total	**82 762**	**112,7**	**136**	**50 450**	**133 212**	**188,0**

4.2.2. Irrigation

The potential for the expansion of irrigated agriculture is dependent on water availability and land suitable for cultivation, and subject to approval by the DWA on application for future abstraction licences. However for the purposes of modelling the future expansion of irrigation in the Mzimkhulu catchment, it was assumed that there would be a 20% increase in irrigation volume throughout the catchment. Irrigation would not be developed in quaternaries where there is no current irrigation. The estimated future demands for the irrigation expansion scenario are presented in **Table 4.4**.

Table 4.4: Irrigation estimated future demands 20% increase from present

Quaternary sub-catchment	Current irrigation supply (million m^3/a)	Current Irrigation return flows (million m^3/a)	Irrigation supply: 20% increase (million m^3/a)	Irrigation return flows: 20% increase (million m^3/a)
T51A	1,7	0,2	2,1	0,2
T51B	10,3	1,0	12,4	1,2
T51C	13,2	1,3	15,8	1,6
T51D	3,6	0,4	4,3	0,4
T51E	9,0	0,9	10,8	1,1
T51F	8,7	0,9	10,4	1,0
T51G	2,8	0,3	3,3	0,3
T51H	0,5	0,0	0,5	0,1
T51J	13,2	1,3	15,8	1,6
T52A	15,5	1,5	18,5	1,9
T52B	0,0	0,0	0,0	0,0
T52C	3,3	0,3	3,9	0,4
T52D	3,1	0,3	3,7	0,4
T52E	0,1	0,0	0,1	0,0
T52F	0,2	0,0	0,2	0,0
T52G	0,0	0,0	0,0	0,0
T52H	0,0	0,0	0,0	0,0
T52J	0,0	0,0	0,0	0,0
T52K	0,9	0,1	1,1	0,1
T52L	0,8	0,1	0,9	0,1
T52M	0,0	0,0	0,0	0,0
T51 total	**62,9**	**6,3**	**75,4**	**7,5**
T52 total	**23,8**	**2,4**	**28,5**	**2,9**
Total	**86,6**	**8,7**	**103,9**	**10,4**

4.2.3. Rural and urban water use

It was assumed that, by 2030 rural and urban water use for domestic, industrial and commercial purposes would increase by 60% from the current demand. The projected increase was derived from the estimated future growth by Ugu Municipality for the areas supplied by Port Shepstone. This percentage increase was applied to all rural and urban demands in the catchment and is shown for each quaternary sub-catchment in **Table 4.5**.

Table 4.5: Future Rural and Urban Water Use

Quaternary sub-catchment	Rural-Present (million m^3/a)	Urban-Present (million m^3/a)	Present Total (million m^3/a)	Projected 2030 Rural (million m^3/a)	Projected 2030 urban (million m^3/a)	Projected 2030 Total (million m^3/a)
T51A	0,0	-	0,0	0,0	-	0,0
T51B	0,0	0,1	0,1	0,0	0,2	0,2
T51C	0,4	0,5	0,9	0,6	0,8	1,4
T51D	0,0	-	0,0	0,0	-	0,0
T51E	0,1	-	0,1	0,1	-	0,1
T51F	0,0	-	0,0	0,0	-	0,0
T51G	0,1	-	0,1	0,2	-	0,2
T51H	0,6	-	0,6	0,9	-	0,9
T51J	0,4	0,4	0,7	0,6	0,6	1,2
T52A	0,6	0,3	0,9	0,9	0,5	1,4
T52B	0,3	-	0,3	0,5	-	0,5
T52C	0,3	-	0,3	0,4	-	0,4
T52D	0,7	1,0	1,7	1,1	1,6	2,8
T52E	0,2	-	0,2	0,3	-	0,3
T52F	0,2	-	0,2	0,3	-	0,3
T52G	0,2	-	0,2	0,2	-	0,2
T52H	0,8	0,3	1,1	1,3	0,4	1,7
T52J	0,7	0,0	0,7	3,1	0,0	3,1
T52K	0,4	1,2	1,6	0,7	1,9	2,5
T52L	0,0	-	0,0	0,0	-	0,0
T52M	0,6	16,7	17,2	0,9	26,5	27,4
TOTAL	**6,5**	**20,4**	**28,1**	**12,2**	**32,5**	**44,7**

4.2.4. Potential dams on tributaries

The locations of all the potential dam sites are shown in **Figure 4.1**. Two dams were selected as options for the future development scenarios, namely Site 12 on the Ngwangwane River and Site 19 on the Bisi River, which are shown in **Figure 4.1**. The dam at Site 12 on the Ngwangwane River has a natural inflow of 244 million m^3/a. The dam at Site 19 on the Bisi River has a natural inflow of 226 million m^3/a. The area-capacity-elevation characteristics for each dam are included in **Appendix B**.

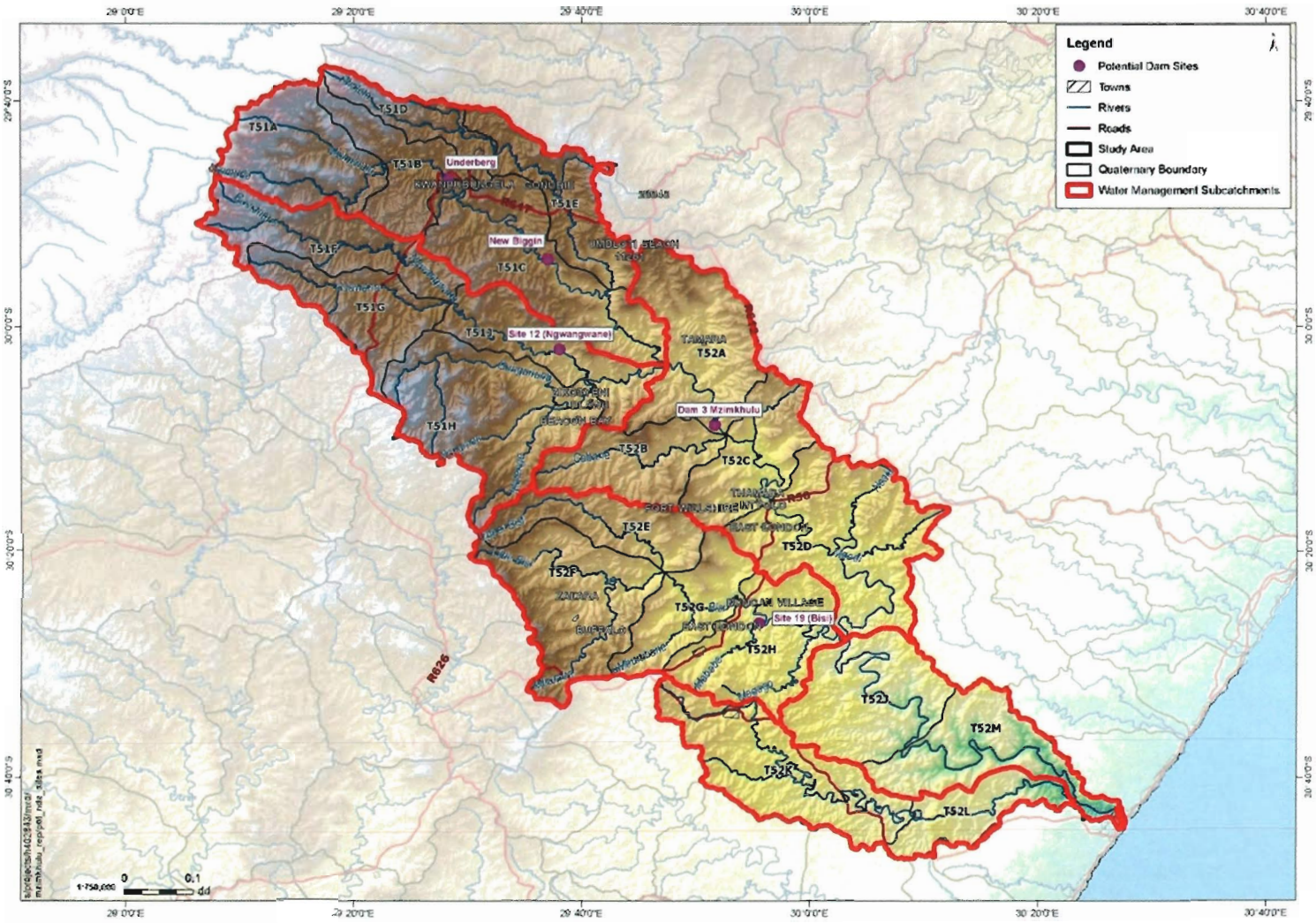

Figure 4.1: Map showing the locations of potential dam sites in the Mzimkhulu catchment

The storage- yield curves for the potential dam sites were developed on the present day hydrology for a range of dam sizes representing 0,5 times to 2 times the natural Mean Annual Runoff (MAR) at the dam site. The curves for Site 12 and Site 19 are shown in **Figure 4.2** and **Figure 4.3** respectively.

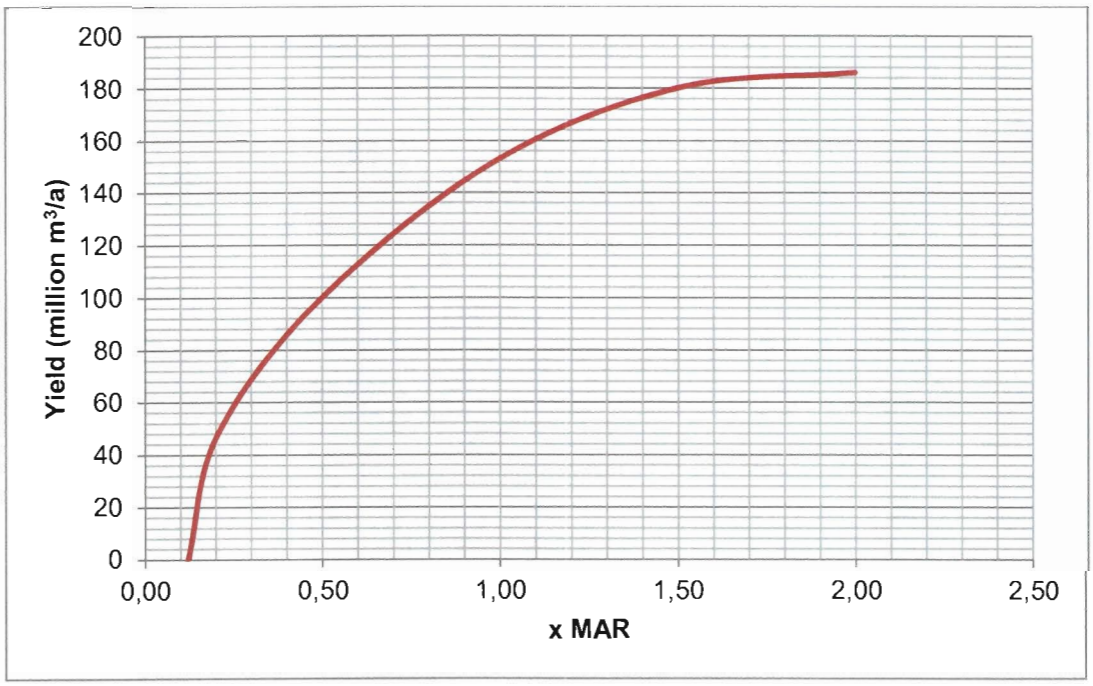

Figure 4.2: Storage-yield curve for Site 12 - Ngwangwane

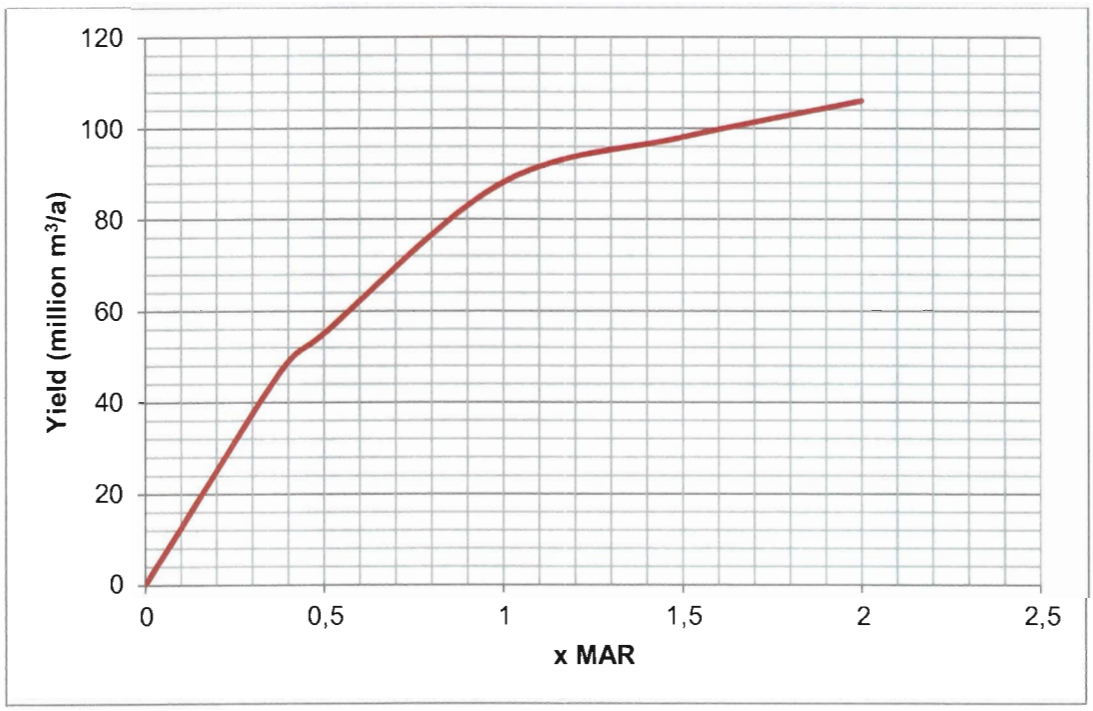

Figure 4.3: Storage yield curve for Site 19 – Bisi

4.2.5. Potential dam sites on the main stem river

The locations of all the potential dam sites are shown in **Figure 4.1**. Two dams were selected as options for the future development scenarios on the main stem of the Mzimkhulu, namely Underberg and New Biggin. The dam at Underberg has a natural inflow of 244 million m^3/a. The dam at New Biggin has a natural inflow of 315 million m^3/a. The storage-yield curves for Underberg and New Biggin are shown in **Figure 4.4** and **Figure 4.5** respectively. The area-capacity-elevation characteristics for each dam are included in **Appendix B**.

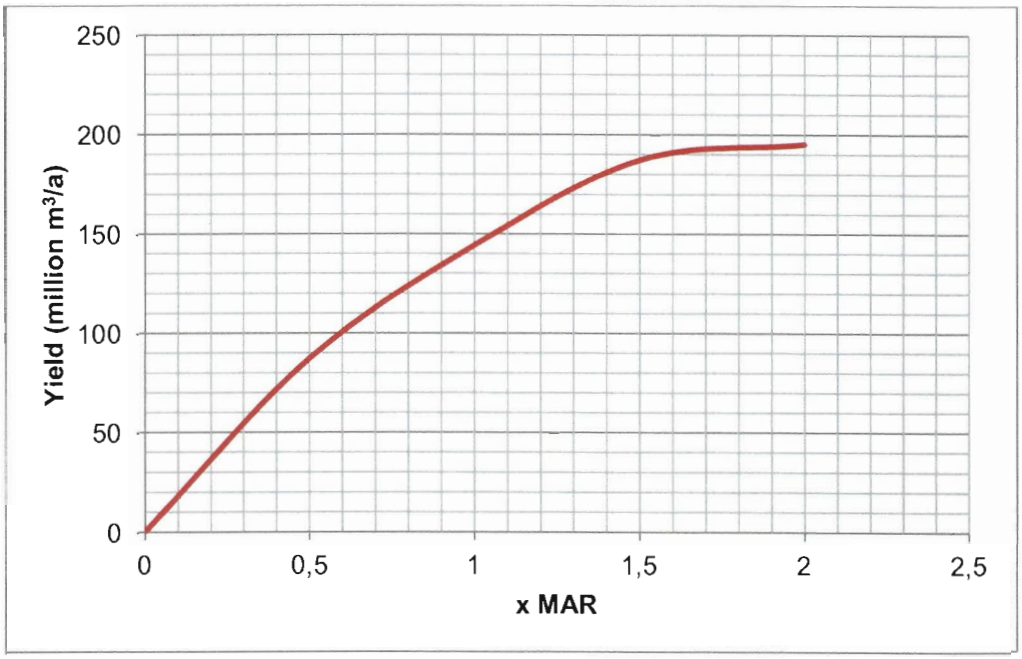

Figure 4.4: Storage-yield curve for Underberg Site

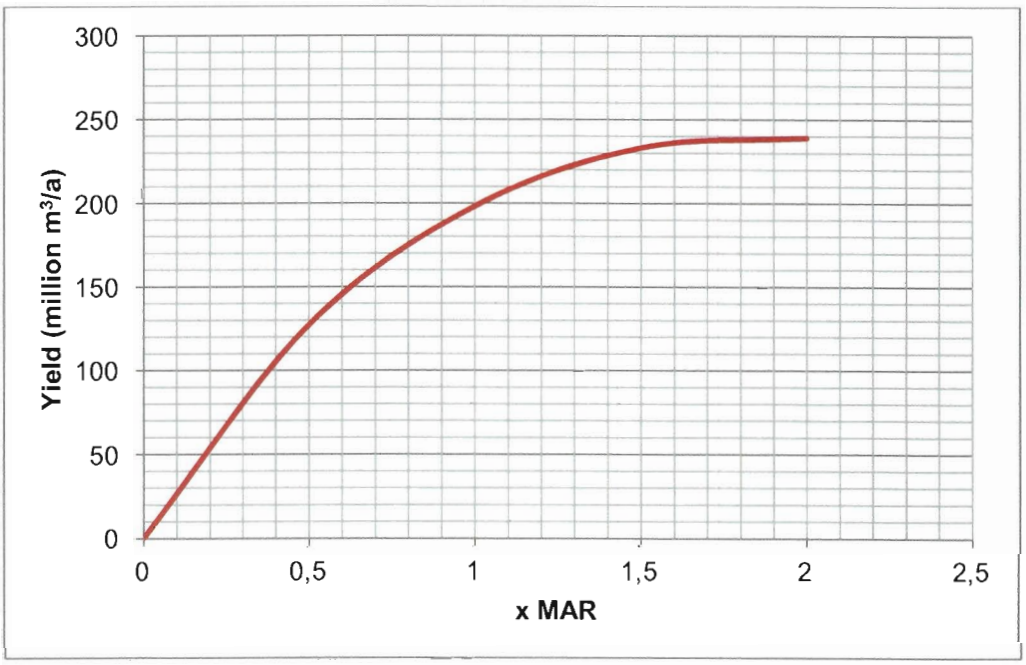

Figure 4.5: Storage-yield curve for New Biggin Site

5. YIELD ANALYSIS

The system model was configured and run for all the scenarios as described in Section 4. The analysis was completed in December 2010 and the results, which are included in **Appendix D**, were used by the EWR team for their assessments. Following this original analysis, the forestry water demands were revised in March 2011 and the investigation is documented in a technical note included in **Appendix E.** The yield analysis results obtained following the revision of forestry demands in March 2011 are presented in the section below.

5.1 PRESENT DAY SYSTEM

The current water demand at Port Shepstone is 16,6 million m^3/a which is supplied from the Mzimkhulu River abstraction works at St Helen's Rock. Present day land and water use requirements derived from the catchment hydrology were imposed on the system and EWRs were included for each quaternary catchment. The present day scenario excluded the Cwabeni off-channel storage Dam which is currently being investigated at a Feasibility level to supplement the current Port Shepstone demand.

The mean annual runoff at each of the EWR sites for the present day configuration is presented in **Table 5.1**.

Table 5.1: Mean Annual Runoff at EWR sites for Natural and Present Day Flows

EWR Site	Natural (million m^3/a)	Present (million m^3/a)
Callaway	261	186
Pierr	110	86
Coleford	117	100
Creighton	870	755
Middle Mzimkhulu	1 085	883
Welverdiend	195	158
Oribi	43	28
Gibraltar	1 384	1 152
Estuary	1 453	1 176

5.2 FUTURE DEMAND

5.2.1. Scenario 1: All small growers

Scenario 1 has increased forestry area for all small growers of 29 400 ha, there is no increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. For the unmitigated case without off-channel storage at Cwabeni, the mean annual flows at the EWR sites are shown in **Table 5.2**.

Table 5.2: Mean Annual Runoff at EWR sites for Scenario 1 unmitigated

EWR Site	Natural (million m^3/a)	Present (million m^3/a)	Fs1uR (million m^3/a)
Callaway	261	186	184
Pierr	110	86	86
Coleford	117	100	100
Creighton	870	755	746
Middle Mzimkhulu	1 085	883	865
Welverdiend	195	158	137
Oribi	43	28	27
Gibraltar	1 384	1 152	1 103
Estuary	1 453	1 176	1 127

5.2.2. Scenario 2

Scenario 2 has increased forestry area for all small growers in the Bisi and Middle Mzimkhulu catchments of 21 050 ha, there is no increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. For the unmitigated case without off-channel storage at Cwabeni, the mean annual runoff at the EWR sites are shown in **Table 5.3**.

Table 5.3: Mean Annual Runoff at EWR sites for Scenario 2 unmitigated

EWR Site	Natural (million m^3/a)	Present (million m^3/a)	Fs2uR (million m^3/a)
Callaway	261	186	185
Pierr	110	86	86
Coleford	117	100	100
Creighton	870	755	754
Middle Mzimkhulu	1 085	883	875
Welverdiend	195	158	137
Oribi	43	28	28
Gibraltar	1 384	1 152	1 113
Estuary	1 453	1 176	1 138

5.2.3. Scenario 3

Scenario 3 has increased forestry area for all large and small growers throughout the catchment of 50 350 ha, as well as 20% increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. For the unmitigated case without off-channel storage at Cwabeni, the mean annual runoff at the EWR sites are shown in **Table 5.4**.

Table 5.4: Mean Annual Runoff at EWR sites for Scenario 3 unmitigated

EWR Site	Natural (million m^3/a)	Present (million m^3/a)	Fs3uR (million m^3/a)
Callaway	261	186	180
Pierr	110	86	83
Coleford	117	100	99
Creighton	870	755	726
Middle Mzimkhulu	1 085	883	836
Welverdiend	195	158	128
Oribi	43	28	27
Gibraltar	1 384	1 152	1 062
Estuary	1 453	1 176	1 086

6. CONCLUSIONS AND RECOMMENDATIONS

The Mzimkhulu River system was modelled for the period 1920 to 2007 in the WRYM-IMS using updated hydrology estimates and including EWRs for the PES extrapolated to each quaternary sub-catchment for the present day system. The original scenario analysis was completed in December 2010 and was used by the EWR team for their assessment of the Reserve. In March 2011, the methodology for determining the plantation forestry demands in the catchment model were revised and as a result, the forestry demands increased. The revised demand estimates were updated in the yield model and the results are presented in Section 5 of this report.

Various future development scenarios were configured to assess the impact of increased land and water use requirements on catchment MAR and mitigating the impacts of increased water use with potential dam sites on the Ngwangwane River and the Bisi River. The first scenario looked at developing all small grower forestry areas that had timber potential covering a total area of 29 400 ha. The second scenario looked only at developing small grower forestry in the Bisi and Middle Mzimkhulu River catchments covering an area of 21 050 ha. The third scenario looked at developing all grower forestry areas, an area of 50 350 ha as well as increasing irrigation by 20% throughout the catchment. The fourth scenario looked at developing land use as for scenario 3 as well as the development of a significant water resource. For all of these scenarios, rural and urban water requirements were projected to 2030 with an average increase in demand of 60% from present.

For the first and third scenario, a dam at Site 12 on the Ngwangwane was considered to mitigate the impacts of forestry on downstream EWRs by providing the requirements at Gibraltar directly from the dam storage. For the second scenario, a dam at Site 19 on the Bisi River was provided to mitigate the impacts of forestry development in the upper catchment on the downstream EWR at Gibraltar. For the fourth scenario there was a dam at Site 19 and or Site 12 to mitigate for the EWR, as well as an additional significant water resource development at Underberg and New Biggin which were analysed separately.

The impacts of increased plantation forestry and irrigation can be mitigated by providing relatively small volumes, with a dam operated to maintain present day flows or to meet the EWR flows determined by the specialist study for the PES. Additionally, dams would provide some surplus yield which could be exported or used for supply within the catchment.

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MZIMKHULU SYSTEM (DWA, 2010)

APPENDIX A
HYDROLOGY FILES FOR WRYM
(See Disc included in front of report)

APPENDIX B

AREA-CAPACITY-ELEVATION RELATIONSHIPS FOR POTENTIAL DAM SITES

Table B 1: Area-capacity-elevation characteristics for Site 12 - Ngwangwane

Elevation	Volume	Surface Area	Storage as proportion of natural MAR (244 x million m^3/a)
1 317	488,0	18,8	2,0
1 285	366,0	15,1	1,5
1 257	244,0	11,0	1,0
1 226	122,0	6,4	0,5
1 200	50,3	3,2	0,2
1 180	9,3	0,9	0,0
1 160	0,1	0,1	0,0
1 155	0,0	0,0	0,0

Table B 2: Area-capacity-elevation characteristics for Site 19 - Bisi

Elevation	Volume	Surface Area	Storage as proportion of natural MAR (226 x million m^3/a)
712	452,0	18,0	2,0
680	339,0	14,5	1,5
652	226,0	10,7	1,0
611	113,0	6,4	0,5
600	86,3	5,3	0,4
580	17,7	1,6	0,1
560	0,3	0,1	0,0
555	0,0	0,0	0,0

Table B 3: Area-capacity-elevation characteristics for Underberg Dam

Elevation	Volume	Surface Area	Storage as proportion of natural MAR (244 x million m^3/a)
1 520	4,63.3	29,5	1,9
1 500	193,1	16,9	0,8
1 480	24,4	2,4	0,1
1 460	0,0	0,0	0,0

Table B 4: Area-capacity-elevation characteristics for New Biggin Dam

Elevation	Volume	Surface Area	Storage as proportion of natural MAR (226 x million m^3/a)
1 471	630,0	41,1	2,0
1 454	472,5	31,5	1,5
1 439	315,0	21,7	1,0
1 420	153,4	11,2	0,5
1 400	58,8	4,6	0,2
1 380	17,9	1,6	0,1
1 360	0,0	0,0	0,0

APPENDIX C
MZIMKHULU SYSTEM DIAGRAM

APPENDIX D
SYSTEM YIELD ANALYSIS:
ORIGINAL RESULTS DECEMBER 2010

YIELD ANALYSIS RESULTS: DECEMBER 2010

CURRENT SUPPLY SYSTEM

The current water demand at Port Shepstone is 16,6 million m^3/a which is supplied from the Mzimkhulu River abstraction works at St Helen's Rock. Present day land and water use requirements derived from the catchment hydrology were imposed on the system and EWRs were included for each quaternary catchment. Two scenarios were run for the present supply system. The present day scenarios that excluded the Cwabeni off-channel storage Dam which is currently being investigated at a Feasibility level and the "present day OCS" that included the Cwabeni OCS dam to supplement the current Port Shepstone demand.

The mean annual runoff for the two present day scenarios at the each of the EWR sites is presented in **Table D 1.**

Table D 1: Mean Annual Runoff at EWR sites for Natural and Present Day flows

EWR site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	Present day OCS MAR (million m^3/a)
Callaway	261	189	189
Pierr	110	89	89
Coleford	117	102	102
Creighton	870	773	773
Middle Mzimkhulu	1 085	905	905
Welverdiend	195	162	162
Oribi	43	30	30
Gibraltar	1 384	1 179	1 171
Estuary	1 453	1 203	1 213

Table D 2 presents a summary of the surplus incremental historic firm yields for each quaternary sub-catchment with and without EWR. The historic firm yield for a run-of-river system is the maximum volume that can be abstracted on a reliable basis, i.e. in every month of the period of record. It is clear that when taking into consideration the EWR, there is no surplus yield at the quaternary sub-catchment level.

Table D 2: Surplus run-of-river-yield (incremental) per quaternary sub-catchment including and excluding EWR

QUAT	Cumulative MAR: Present day (million m^3/a)	EWR (Cumulative) (million m^3/a)	Incremental MAR (million m^3/a)	Incremental MAR less EWR (million m^3/a)	EWR (Incremental) (million m^3/a)	Incremental surplus yield excluding EWR (million m^3/a)	Surplus yield including EWR (million m^3/a)
T51A	149	50	149	99	50	0,4	0,0
T51B	224	52	76	28	48	0,0	0,0
T51C	423	92	92	19	73	3,0	0,0
T51D	60	18	60	42	18	0,5	0,0
T51E	107	35	47	16	31	0,1	0,0
T51F	102	23	102	78	23	0,0	0,0
T51G	84	25	84	59	25	0,0	0,0
T51H	113	35	113	77	35	0,0	0,0
T51J	344	96	46	1	45	2,0	0,0
T52A	829	180	66	3	62	0,0	0,0
T52B	43	13	43	29	13	0,0	0,0
T52C	906	199	34	1	33	0,0	0,0
T52D	926	199	20	4	17	0,0	0,0
T52E	46	18	46	28	18	1,7	0,0
T52F	77	31	77	46	31	4,0	0,0
T52G	178	83	55	4	52	3,4	0,0
T52H	202	77	24	6	18	0,0	0,0
T52J	1 160	285	32	2	30	1,2	0,0
T52K	23	6	23	17	6	0,4	0,0
T52L	34	9	11	6	5	0,2	0,0
T52M	1 224	348	30	2	28	0,7	0,0

FUTURE DEVELOPMENT SCENARIOS

The projected future water demand for Port Shepstone in 2030 is 27 million m^3/a which will be supplied from the Mzimkhulu River abstraction works at St Helen's Rock. Future land and water use requirements presented in the previous section were imposed on the system, and EWRs were included for each quaternary catchment for the present ecological state (PES). In total, eleven future development scenarios were run as presented in Section 4 of the main report. The scenarios assessed the impacts of increased land and water use with and without mitigation provided by one of two dam options in a given scenario.

The resultant mean annual runoff at the each of the EWR sites for the various future development scenarios is presented in the sections below as well as the surplus yield available from the dam options.

- **Scenario 1: All small growers**
  Scenario 1 has increased forestry area for all small growers of 29 400 ha, there is no increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. For the unmitigated case (U), two scenarios were run with and without the OCS

at Cwabeni. For the mitigated cases (M), scenarios were run with a dam at Site 12 on the Ngwangwane for various sizes to meet the EWR at Gibraltar.

The dam was operated to meet the total flow EWR at Gibraltar. The surplus yield was assumed to be utilised in or exported from the catchment.

The MAR at the EWR sites for each of the scenario 1 cases is summarised in **Table D 3**. The dam sizes and surplus yield from the dam at Site 12 are summarised in **Table D 4**.

Table D 3: Mean Annual Runoff at EWR sites for Scenario 1

EWR Site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	FS1U (million m^3/a)	FS1U_OCS (million m^3/a)	FS1M1 (million m^3/a)	FS1M2 (million m^3/a)	FS1M3 (million m^3/a)
Callaway	261	189	189	189	188	188	188
Pierr	110	89	89	89	89	89	89
Coleford	117	102	102	102	102	102	102
Creighton	870	773	768	768	681	765	766
Middle Mzimkhulu	1 085	905	891	891	806	887	889
Welverdiend	195	162	141	141	140	140	141
Oribi	43	30	29	29	29	29	29
Gibraltar	1 384	1 179	1 135	1 130	1 047	1 131	1 133
Estuary	1 453	1 203	1 162	1 161	1 074	1 157	1 160

Table D 4: Site 12 dam characteristics for Scenario 1 mitigated

Dam at Site 12	FS1M1	FS1M2	FS1M3
Capacity (million m^3)	122	42	9
Capacity as proportion of MAR	0,5	0,17	0,04
Surplus yield (million m^3/a)	84	1	0

- **Scenario 2: Small growers in the Bisi catchment**

Scenario 2 has increased forestry area of 21 050 ha for small growers only in the Bisi River catchment, there is no increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. A dam at Site 19 on the Bisi River was included to mitigate the impacts of increased plantation forestry in these quaternary sub-catchments on the EWR at Gibraltar. The surplus yield from the dam is exported or assumed to be used within the catchment.

The MAR at the EWR sites for each of the Scenario 2 cases is summarised in **Table D 5**. The dam sizes and surplus yield from the dam at Site 19 are summarised in **Table D 6**.

Table D 5: Mean Annual Runoff at EWR sites for Scenario 2

EWR Site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	FS2M1 (million m^3/a)	FS2M2 (million m^3/a)	FS2M3 (million m^3/a)
Callaway	261	189	189	189	189
Pierr	110	89	89	89	89
Coleford	117	102	102	102	102
Creighton	870	773	771	771	770
Middle Mzimkhulu	1 085	905	896	896	895
Welverdiend	195	162	140	140	140
Oribi	43	30	30	30	30
Gibraltar	1 384	1 179	1 108	1 137	1 139
Estuary	1 453	1 203	1 135	1 164	1 166

Table D 6: Site 19 dam characteristics for Scenario 2 mitigated

Dam at Site 19	FS2M1	FS2M2	FS2M3
Capacity (million m^3)	113	42	11
Capacity as proportion of MAR	0,5	0,19	0,05
Surplus yield (million m^3/a)	32	3	0

- **Scenario 3: All growers forestry**

Scenario 3 has increased forestry area for all growers throughout the Mzimkhulu catchment of 50 350 ha, as well as 20% increase in irrigated agriculture. Future urban and rural water use is for the projected 2030 demands. For the unmitigated case (U), two scenarios were run with and without the off-channel storage (OCS) at Cwabeni and for the mitigated cases (M), scenarios were run with a dam at Site 12 on the Ngwangwane for various sizes to meet the EWR at Gibraltar. The surplus yield from the dam is exported or assumed to be used within the catchment.

The resultant MAR at the EWR sites for the unmitigated and mitigated cases is summarised in **Table D 7**. The dam sizes and surplus yield from the dam at Site 12 are summarised in **Table D 8**.

Table D 7: Mean Annual Runoff at EWR sites for Scenario 2

EWR Site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	FS3U (million m^3/a)	FS3U_OCS (million m^3/a)	FS3M1 (million m^3/a)	FS3M2 (million m^3/a)	FS3M3 (million m^3/a)
Callaway	261	189	185	185	185	185	185
Pierr	110	89	87	87	87	87	87
Coleford	117	102	101	101	100	100	100
Creighton	870	773	754	754	676	750	753
Middle Mzimkhulu	1 085	905	868	868	791	863	865
Welverdiend	195	162	132	132	131	131	132
Oribi	43	30	29	29	29	29	29
Gibraltar	1 384	1 179	1 101	1 096	1 021	1 096	1 099
Estuary	1 453	1 203	1 127	1 126	1 047	1 122	1 125

Table D 8: Site 12 dam characteristics for Scenario 3 mitigated

Dam at Site 12	FS3M1-1	FS3M2	FS3M3
Capacity (million m^3)	122	48	13
Capacity as proportion of MAR	0,5	0,20	0,06
Surplus yield (million m^3/a)	76	2	0

- **Scenario 4: All growers forestry and additional water resources development**

Scenario 4 was developed in order to explore the impacts of a significant water resource development, either for export of water or to meet significant new demands. The resulting EWR impacts are presented in the Riverine Ecological Water Requirements Report *(Report No. WMA 11/T50/00/3009, Volume 5)* and the Estuarine Ecological Water Requirements Report *(Report No. WMA 11/T50/00/3009, Volume 6*). The additional scenario has the same land and water use as for Scenario 3 i.e. all growers forestry, 20% increased irrigation and 2030 rural and urban water use. Scenario 4a has a 1,5 MAR dam at Underberg as well as 0,17 MAR dam at Site 12 on the Ngwangwane and 0,18 MAR dam at Site 19 on the Bisi to meet the EWR at Gibraltar. The dam at Underberg exports its surplus yield out of the catchment.

Scenario 4c was also an additional scenario developed in order to obtain a bigger impact on the river flows following the preliminary analysis by the Reserve team of the impacts of the above scenarios on the EWRs in the catchment. The results of which are presented in Riverine Ecological Water Requirements Report *(Report No. WMA 11/T50/00/3009, Volume 5)* and the *Estuarine Ecological Water Requirements Report (Report No. WMA 11/T50/00/3009, Volume 6).* The additional scenario has the same land and water use as for Scenario 3, i.e. all large grower forestry, 20% increased irrigation and 2030 rural and urban water use. In addition a 1,5 MAR dam at New Biggin farm to meet the EWR at Creighton and exporting its historical firm yield and a 0,5 MAR dam at Site 19 on the Bisi to meet the EWR at Gibraltar, also exporting or utilising its surplus yield. This was further split into scenario 4c full and scenario 4c low to meet the full and low flow EWRs at Creighton and Gibraltar respectively.

The MAR at the EWR sites for each of the scenarios 4 cases is summarised in **Table D 9**. The dam size and surplus yields from the dams at Underberg and New Biggin are summarised in **Table D 10** and **Table D 11**.

Table D 9: Mean Annual Runoff at EWR sites for Future Scenario 4

EWR Site	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	FS4a (million m^3/a)	FS4c_full (million m^3/a)	Fs4c_low (million m^3/a)
Callaway	261	189	71	198	198
Pierr	110	89	87	87	87
Coleford	117	102	100	100	100
Creighton	870	773	580	528	523
Middle Mzimkhulu	1085	905	698	649	642
Welverdiend	195	162	131	130	131
Oribi	43	30	29	29	29
Gibraltar	1 384	1 179	925	852	836
Estuary	1 453	1 203	951	878	862

Table D 10: Dam characteristics for Scenario 4a

Scenario 4a Dams		FS4a (million m^3/a)
Capacity (million m^3)	Dam at Underberg	366
Capacity as proportion of MAR		1,5
Surplus yield (million m^3/a)		180

Table D 11: Dam characteristics for Scenario 4c

Scenario 4c Dams		FS4c
Capacity (million m^3)	Dam at New Biggin	473
Capacity as proportion of MAR		1,5
Surplus yield (million m^3/a)		228

APPENDIX E
TECHNICAL NOT ON PLANTATION FORESTRY DEMANDS REVISED IN MARCH 2011

TECHNICAL NOTE: HYDROLOGY AND SYSTEMS ANALYSIS IN THE MZIMKHULU CATCHMENT

Bisi River Catchment

The comparison of present day to natural flows indicates that in the Bisi catchment, comprising quaternary sub-catchments T52E, T52F, T52G, T52H, the impact on low flows is not as significant as the impacts on total flows, nor as high as one might expect from a catchment with large areas of plantation forestry. **Table E 1** summarises the differences from natural to present day for total MAR and low flow MAR which is the sum of flows in June, July and August months. The difference in total MAR in the Bisi sub-catchments is between -13% and -21% and the difference in low flow is -18% to -9%.

Table E 1: Percentage change in MAR from Natural to Present day

Quat	Natural MAR (mcm/a)	Present day MAR (mcm/a)	Natural Low Flow MAR (mcm/a)	Present Day Low Flow MAR (mcm/a)	% Change in MAR natural to present'	% Change in Low Flow MAR natural to present'
T51A	157,04	149,33	4,77	4,47	-5%	-6%
T51B	87,35	75,89	2,73	1,20	-13%	-56%
T51C	116,97	92,29	5,02	3,10	-21%	-38%
T51D	65,93	60,55	2,83	1,50	-8%	-47%
T51E	59,93	46,58	2,68	1,61	-22%	-40%
T51F	116,67	101,77	3,63	2,96	-13%	-18%
T51G	91,44	83,57	2,93	2,98	-9%	2%
T51H	123,43	114,01	5,44	4,92	-8%	-10%
T51J	51,69	47	3,60	2,98	-9%	-17%
T52A	93,94	65,85	5,44	2,50	-30%	-54%
T52B	50,24	43,59	3,31	2,87	-13%	-14%
T52C	48,09	34,7	3,22	2,08	-28%	-35%
T52D	28,88	23,19	3,10	1,96	-20%	-37%
T52E	56,49	45,39	4,74	4,32	-20%	-9%
T52F	96,55	76,09	8,21	7,44	-21%	-9%
T52G	64,98	54,68	5,00	4,55	-16%	-9%
T52H	27,63	24,13	2,62	2,15	-13%	-18%
T52J	34,54	31,9	3,09	2,81	-8%	-9%
T52K	33,27	25,37	3,33	2,35	-24%	-29%
T52L	14,94	10,97	1,27	0,86	-27%	-32%
T52M	32,51	28,91	2,83	2,46	-11%	-13%
T51	**870,45**	**770,99**	**33,62**	**25,72**	**-11%**	**-24%**
T52	**582,06**	**464,77**	**46,15**	**36,34**	**-20%**	**-21%**
Total	**1 452,51**	**1 235,76**	**79,77**	**62,06**	**-15%**	**-22%**

In order to verify the results for the differences obtained from natural to present day flows in the Bisi sub-catchments, where plantation forestry is the primary land use, the forestry water use estimates were investigated further in the following section.

Forestry seasonal unit use

The seasonal unit use for forestry is shown in **Figure E 1** for T51 and T52 catchments. The Bisi quaternary sub-catchments (T52E, T52F, T52G) are ranked as the first (T52G), fifth (T52E) and seventh (T52F) highest users overall and the first (T52G), third (T52E) and fourth (T52F) highest users for low flows (June, July, August).

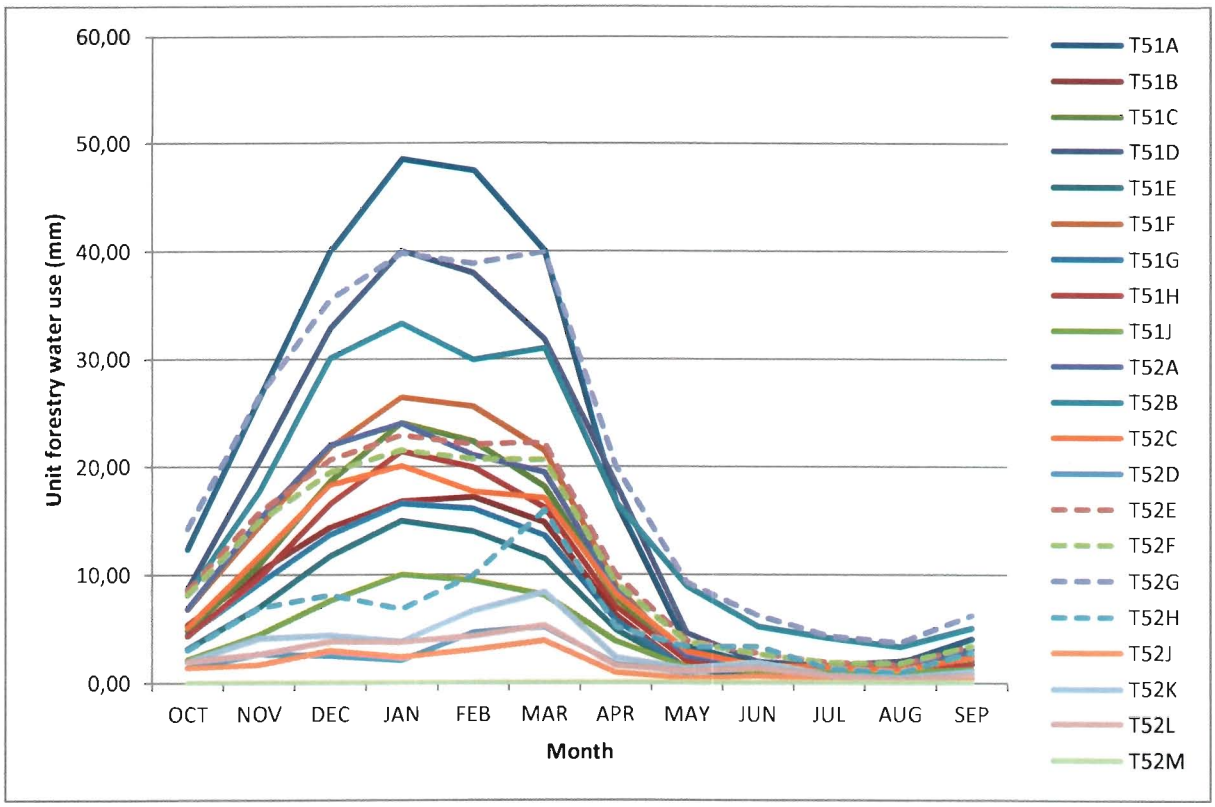

Figure E 1: Forestry seasonal water use in the Mzimkhulu Catchment

Bisi catchment natural runoff

The natural seasonal unit runoff in the Mzimkhulu catchment is shown in **Figure E 2** which indicates that the high flows in the Bisi quaternary sub-catchments are in the middle range compared to the rest of the catchment, but the low flows are higher than most other catchments ranked first (T52G), third (T52E) and fourth (T52F) out of twenty-one catchments.

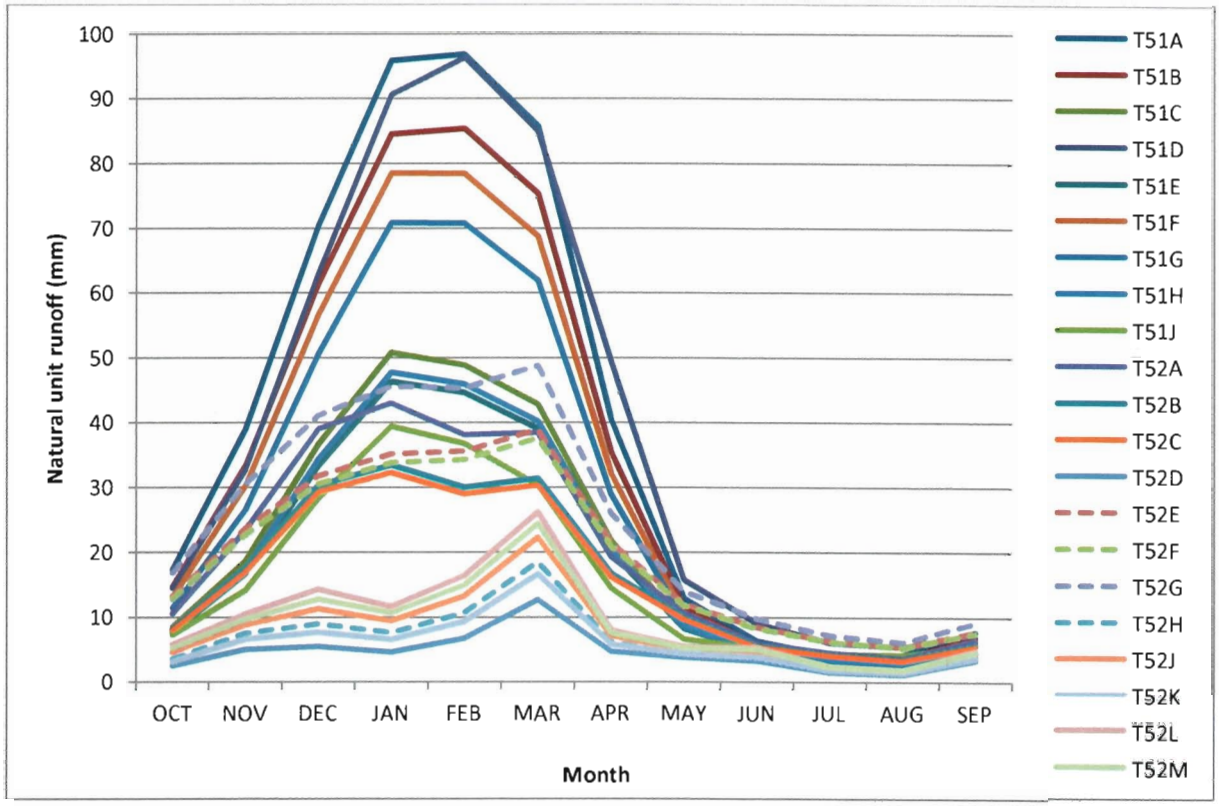

Figure E 2: Natural unit runoff in the Mzimkhulu catchment

Other land use impacts on streamflow

Despite the high impacts of forestry on the Bisi streamflows, these appear to be localized to the area under afforestation, while the effects of these impacts are not being picked up further downstream when one looks at the difference in natural and present-day flows. Incremental runoff downstream of the forestry areas will also contribute to augmenting the streamflows in these catchments. Therefore, other land uses in the catchment were checked to determine their impacts on the present day flows. **Figure** Error! Reference source not found. **E 2** provides a summary of the areas of land use in the catchment. All areas other than plantation forestry were added together and labelled as "all other areas" and expressed as a percentage of the quaternary sub-catchment area. The other areas include irrigation, alien vegetation, farm dams and wetlands. **Figure E 3** shows the relationship between all other areas as a proportion of the quaternary area and the percentage change in low flow from natural to present day.

The trend shows that the higher the proportion of other land use areas in the catchment, the larger the difference between natural and present day low flows. The Bisi catchments are highlighted in red on the plot showing that the percentage of other land uses in those catchments is not very high and therefore the impact on present day flows is relatively low.

Table E 2: Land use areas as percentage of quaternary sub-catchment area

Quat	Catchment area (km^2)	MAP (mm)	Plantation area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm dam Area (km^2)	Farm dam Capacity (million m^3)	Wetland area	All other areas (excl. wetlands)	Plantation area as % quat area	Alien veg area as % quat area	Irrigation area as % quat area	Wetland area as % quat area	All other areas as % quat area	% Change in MAR natural to present'	% Change in Low Flow MAR natural to present
T51A	326,6	1080	6,5	3,7	4,7	2,3	2,87	0,81	10,73	2%	1%	1%	0%	3,3%	-5%	-6%
T51B	207,5	1032	18,5	2,4	26,1	3,8	7,74	2,59	32,40	9%	1%	13%	1%	15,6%	-13%	-56%
T51C	463,7	859	68,7	15,6	29,8	4,5	7,69	5,80	49,98	15%	3%	6%	1%	10,8%	-21%	-38%
T51D	138,8	1073	10,1	1,1	11,0	4,3	3,12	0,33	16,45	7%	1%	8%	0%	11,9%	-8%	-47%
T51E	259,8	917	37,8	9,0	21,5	2,5	2,54	3,44	32,98	15%	3%	8%	1%	12,7%	-22%	-40%
T51F	302,3	948	16,7	4,6	19,5	3,1	6,01	4,68	27,22	6%	2%	6%	2%	9,0%	-13%	-18%
T51G	263,3	884	15,6	4,6	8,9	1,7	6,22	6,21	15,25	6%	2%	3%	2%	5,8%	-9%	2%
T51H	520,0	928	29,5	14,6	1,1	0,2	0,34	9,26	15,94	6%	3%	0%	2%	3,1%	-8%	-10%
T51J	263,3	871	17,8	10,1	0,3	0,0	0,01	3,51	10,39	7%	4%	0%	1%	3,9%	-9%	-17%
T52A	387,0	899	87,2	15,6	31,0	1,7	11,49	2,64	48,32	23%	4%	8%	1%	12,5%	-30%	-54%
T52B	256,1	851	16,8	11,8	0,0	0,0	0,00	5,00	11,78	7%	5%	0%	2%	4,6%	-13%	-14%
T52C	253,7	839	72,5	14,3	8,8	0,2	0,27	1,04	23,35	29%	6%	3%	0%	9,2%	-28%	-35%
T52D	527,0	778	78,8	44,1	11,5	1,0	0,98	1,82	56,58	15%	8%	2%	0%	10,7%	-20%	-37%
T52E	235,9	881	60,6	5,9	0,1	0,3	0,16	3,68	6,29	26%	3%	0%	2%	2,7%	-20%	-9%
T52F	417,5	867	128,9	14,3	0,4	0,1	0,03	3,48	14,72	31%	3%	0%	1%	3,5%	-21%	-9%
T52G	216,5	979	24,0	13,7	0,0	0,0	0,01	0,58	13,73	11%	6%	0%	0%	6,3%	-16%	-9%
T52H	349,8	845	9,3	17,7	0,1	0,1	1,36	2,94	17,85	3%	5%	0%	1%	5,1%	-13%	-18%
T52J	366,2	857	12,8	14,3	0,0	0,1	0,16	0,22	14,41	3%	4%	0%	0%	3,9%	-8%	-9%
T52K	468,5	839	112,7	20,6	4,4	1,7	2,00	1,47	26,79	24%	4%	1%	0%	5,7%	-24%	-29%
T52L	132,9	979	7,6	4,1	2,9	0,5	1,14	0,23	7,53	6%	3%	2%	0%	5,7%	-27%	-32%
T52M	312,3	877	0,4	11,5	0,0	0,1	0,09	0,05	11,58	0%	4%	0%	0%	3,7%	-11%	-13%

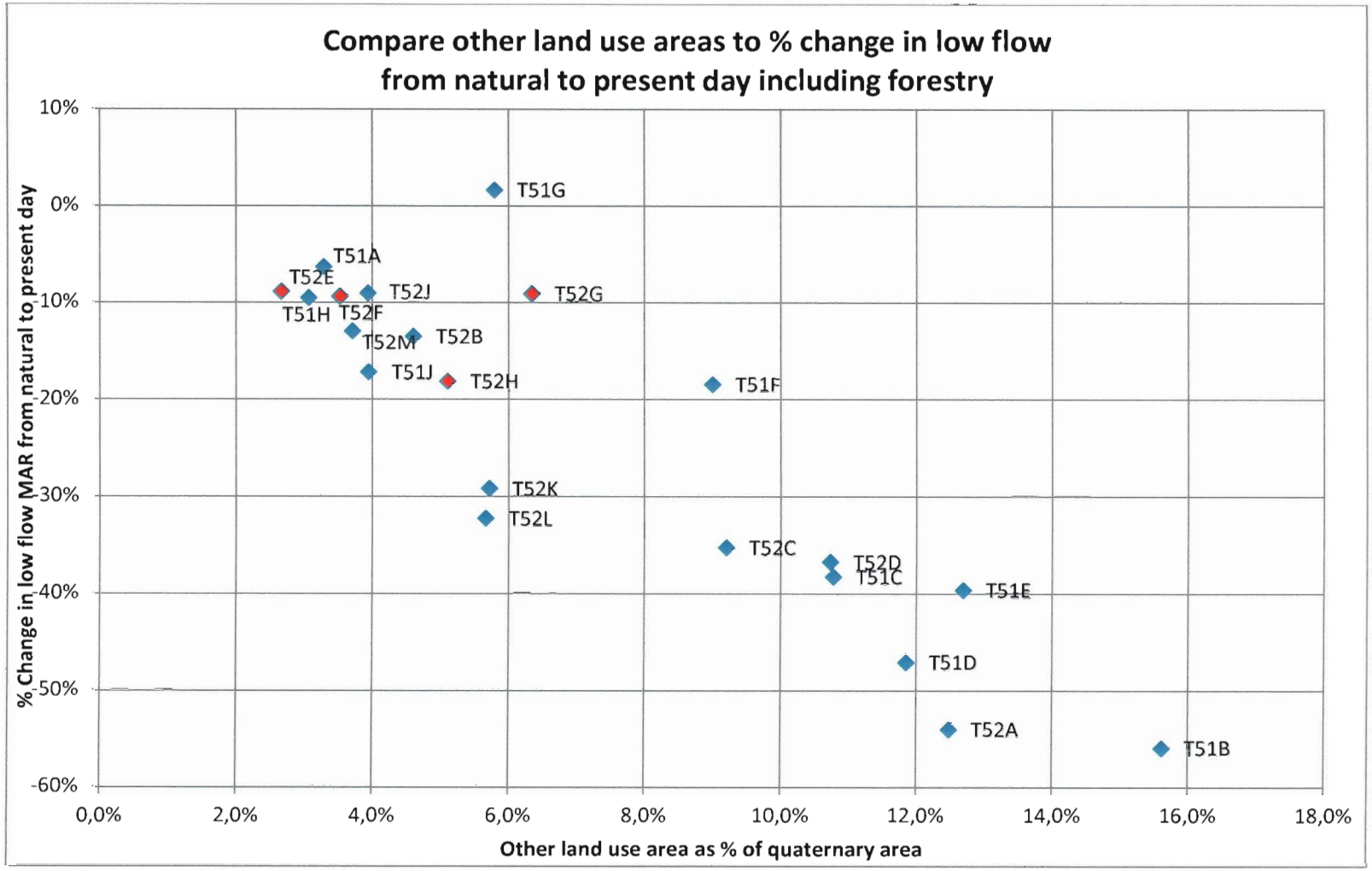

Figure E 3: Relationship between other land use areas and percentage change in low flows

Modelling plantation forestry water use

As part of further investigation to evaluate the forestry water use estimates, the inputs to the WRSM catchment model for forestry streamflow reduction were compared to the outputs to check that the model was producing the expected results.

In the WRSM2000 model, plantation forestry is modelled as a flow reducing activity (FRA), using the user-defined algorithm option to estimate the percentage streamflow reductions as required for the user-defined method. An alternative interpretation of the Gush Tables which use the Agricultural Catchment Research Unit (ACRU) hydrology at quinary catchment scale as their baseline, was used. Because of the differences in ACRU and Pitman hydrology, the impacts of runoff reductions can result in errors. Therefore, the current accepted methodology is to accept the reduction in runoff from the Gush Tables as a proportion of the ACRU (Acocks) hydrology, and apply these proportions to the hydrology that has been accepted by DWA for licensing purposes. This approach was also followed in this study. The calculations take into account the current areas and genus distribution in each quaternary sub-catchment, as well as the reduction in runoff relative to the current hydrology as simulated in this study using WRSM2000.

Previous work done in the Mzimkhulu catchment by Steven Mallory on a quaternary and, more recently, on a quinary level, informed the estimates for this study. Mallory's calculations were based on the WR90 hydrology and a different distribution of genus to the current study in each quaternary sub-catchment. His estimates were adjusted to take into account the current areas and genus distribution in the catchment, as well as the reduction in runoff relative to the current hydrology which has been extended in the WRSM2000.

Table E 3 provides a summary of plantation forestry areas and species distribution for the current extent of forestry in the Mzimkhulu catchment.

Table E 3: Summary of plantation forestry areas and genus breakdown per quaternary sub-catchment

Quaternary	Plantation area (km^2)	Pine	Eucalyptus	Wattle
T51A	7	92%	1%	7%
T51B	19	78%	22%	0%
T51C	69	32%	63%	5%
T51D	10	78%	22%	0%
T51E	38	61%	33%	6%
T51F	17	52%	47%	1%
T51G	16	96%	4%	0%
T51H	29	29%	71%	0%
T51J	18	43%	57%	0%
T52A	87	79%	13%	8%
T52B	17	0%	100%	0%
T52C	73	3%	68%	30%
T52D	79	12%	59%	29%
T52E	61	97%	3%	0%
T52F	129	91%	9%	0%
T52G	24	72%	21%	7%
T52H	9	0%	100%	0%
T52J	13	0%	100%	0%
T52K	113	6%	78%	17%
T52L	8	0%	80%	20%
T52M	0	0%	100%	0%
T51 total	**221**	**51%**	**46%**	**3%**
T52 total	**611**	**30%**	**56%**	**14%**
Total	**833**	**39%**	**52%**	**9%**

The final reductions for MAR and low flows that were input to the model are shown in **Table E 4** as well as the actual reductions obtained.

Although there are some differences between the input value and the actual modelled reduction, these are considered to be within acceptable limits. In the Bisi catchments, the actual modelled reduction in total flow is 57% for T52E, 55% for T52F, 82% for T52G and 86% for T52H. The actual modelled reduction in low flow is 32% for T52E, 32% for T52F, 62% for T52G and 76% for T52H

Table E 4: Plantation forestry percentage reductions

Quaternary sub-catchment	MAR reduction (%)	Actual modelled reduction (%) MAR	Low flow reduction (%)	Actual modelled reduction (%) Low flow
T51A	48%	51%	23%	33%
T51B	22%	22%	16%	19%
T51C	44%	45%	42%	28%
T51D	42%	43%	37%	27%
T51E	31%	31%	29%	18%
T51F	34%	34%	27%	27%
T51G	24%	24%	22%	20%
T51H	43%	43%	43%	29%
T51J	26%	26%	26%	22%
T52A	50%	52%	42%	31%
T52B	100%	99%	100%	98%
T52C	56%	57%	49%	34%
T52D	45%	44%	39%	37%
T52E	56%	57%	37%	32%
T52F	55%	55%	41%	32%
T52G	81%	82%	71%	62%
T52H	83%	86%	68%	76%
T52J	19%	19%	19%	15%
T52K	53%	52%	47%	43%
T52L	23%	25%	27%	24%
T52M	-	-	-	-
Average	**47%**	**47%**	**40%**	**35%**

Table E 5 shows how the low flow reductions compare to the low flow reductions from the Gush tables. The reductions for low flow used in this study are much lower than those defined by Gush despite the correction for the hydrology used in the study.

Table E 5: Plantation forestry low flow percentage reductions from Gush

Quat	LOW FLOWS					
	Acocks (AMLF) (mm)	Eucalypts (EMLFR) (mm)	Pine (PMLFR) (mm)	% Use Eucalypts	% Use Pine	Actual modelled reduction (%) Low flow
T51A	22,5	16,7	11,6	74%	52%	33%
T51B	14,7	11,2	7,8	76%	53%	19%
T51C	13,4	12,1	8,3	90%	62%	28%
T51D	16,3	13,4	10,5	82%	64%	27%
T51E	12,4	10,8	7,1	87%	57%	18%
T51F	15,4	12,6	9,1	82%	59%	27%
T51G	13,7	12,1	9,0	88%	66%	20%
T51H	11,5	10,1	7,0	88%	61%	29%
T51J	9,6	8,8	5,5	92%	57%	22%
T52A	12,3	11,0	7,3	89%	59%	31%
T52B	7,7	7,5	4,5	97%	58%	98%
T52C	5,8	5,5	3,5	95%	60%	34%
T52D	6,1	6,1	4,9	100%	80%	37%
T52E	8,9	8,6	4,8	97%	54%	32%
T52F	9,8	7,3	5,7	74%	58%	32%
T52G	7,0	6,7	4,5	96%	64%	62%
T52H	2,8	2,8	2,2	100%	79%	76%
T52J	4,3	4,3	3,5	100%	81%	15%
T52K	4,5	4,5	3,7	100%	82%	43%
T52L	14,3	12,7	9,0	89%	63%	24%
T52M	8,1	6,6	3,0	81%	37%	-
Average				89%	62%	35%

The intention of the forestry modelling in this study was to use the Stephen Mallory estimates as a target for the reductions in the Mzimkhulu catchment because they were derived used the best available methodology at the time. Mallory used WR90 hydrology and the current study had updated hydrology to 2007, there was also a different distribution of genus in some of the catchments while most were comparable to the distributions used by Mallory. The reductions that were derived using the same methodology as Mallory are compared to those reductions obtained by Mallory for his work using the ACRU quinary data sets and are summarised in **Table E 6**.

Table E 6: Estimated streamflow reductions due to forestry compared to Mallory's estimates

Quat	Natural total unit runoff (mm)	Forestry total unit use (mm)	Total Flow reduction used in WRSM	Mallory % reduction total MAR	Natural Low flow (mm)	Low flow Forestry unit use (mm)	Low Flow reduction used in WRSM	Mallory % Use Low flow
T51A	480,8	243,6	48%	45%	14,6	4,8	23%	21%
T51B	421,0	90,7	22%	25%	13,1	2,5	16%	19%
T51C	252,3	113,7	44%	46%	10,8	3,0	42%	45%
T51D	475,0	203,6	42%	43%	20,4	5,6	37%	38%
T51E	230,6	71,5	31%	36%	10,3	1,9	29%	33%
T51F	385,9	133,0	34%	36%	12,0	3,2	27%	28%
T51G	347,3	84,5	24%	27%	11,1	2,3	22%	24%
T51H	237,4	101,8	43%	46%	10,5	3,0	43%	46%
T51J	196,3	51,2	26%	26%	13,7	3,0	26%	26%
T52A	242,8	126,5	50%	72%	14,0	4,4	42%	63%
T52B	196,2	193,4	100%	100%	12,9	12,7	100%	100%
T52C	189,6	107,6	56%	59%	12,7	4,3	49%	53%
T52D	54,8	24,3	45%	46%	5,9	2,2	39%	41%
T52E	239,4	135,8	56%	73%	20,1	6,3	37%	64%
T52F	231,3	127,9	55%	69%	19,7	6,3	41%	61%
T52G	300,2	244,7	81%	100%	23,1	14,3	71%	88%
T52H	79,0	67,7	83%	84%	7,5	5,7	68%	69%
T52J	94,3	18,3	19%	19%	8,4	1,3	19%	19%
T52K	71,0	37,2	53%	54%	7,1	3,1	47%	48%
T52L	112,4	27,6	23%	23%	9,6	2,3	27%	28%
T52M	104,1	0,0	-	-	9,1	0,0	-	-
Average			**47%**	**51%**			**40%**	**46%**

For most of the quaternary sub-catchments, the estimated reductions compare well to Mallory's work, except in quaternary sub-catchments T52A, T52E, T52F and T52G. The reductions for the current distribution of genus in the Bisi sub-catchments were lower than expected due to the dominance of Pine trees in these catchments as opposed to Eucalypts which were dominant in Mallory's work.

Additional adjustments to SFR

Following the analysis and review of streamflow reduction estimates due to plantation forestry in the Bisi quaternary sub-catchments, the source calculations for streamflow reduction due to plantation forestry were reviewed and revised to better represent the low flow reductions in the Mzimkhulu catchment. The revised reductions for low flows and MAR are shown in **Table E 7** compared to those obtained initially. The catchment model (WRSM2000) was re-run for the present day with the revised reductions to obtain updated plantation forestry demands from which future demands for potential forestry areas were calculated shown in **Table E 8**. As a result of these updates, the present day flows have also changed and are shown in **Table E 9.**

Table E 7: Revised streamflow reduction estimates in the Mzimkhulu catchment

Quat	MAR reduction	Revised MAR reduction	Difference	Low Flow Reduction	Revised Low flow reduction	Difference
T51A	48%	43%	-1%	23%	52%	-4%
T51B	22%	47%	1%	16%	58%	-3%
T51C	44%	71%	9%	42%	80%	-7%
T51d	42%	57%	4%	37%	68%	8%
T51E	31%	63%	3%	29%	67%	-6%
T51F	34%	62%	3%	27%	70%	-5%
T51G	24%	68%	2%	22%	66%	-4%
T51H	43%	73%	7%	43%	80%	-8%
T51J	26%	71%	1%	26%	77%	3%
T52A	50%	54%	26%	42%	64%	18%
T52B	105%	87%	6%	100%	97%	9%
T52C	56%	78%	10%	49%	88%	8%
T52D	45%	75%	-19%	39%	95%	-22%
T52E	56%	66%	12%	37%	55%	24%
T52F	55%	71%	8%	41%	61%	24%
T52G	81%	59%	42%	71%	72%	19%
T52H	83%	86%	-11%	68%	100%	-28%
T52J	19%	80%	-4%	19%	100%	-8%
T52K	53%	78%	-19%	47%	97%	-24%
T52L	23%	54%	-6%	27%	85%	-13%
T52M	0%	0%	0%	5%	0%	-5%
Average	**45%**	**64%**	**19%**	**38%**	**73%**	**35%**

Table E 8: Revised plantation forestry demands in the Mzimkhulu catchment

Quat	Plantation area (DWA2010) (km^2)	DWA2010 Final Hydrology (million m^3/a)	Present day forestry demand: revised estimates (million m^3/a)	Scenario 1: Small growers demand (million m^3/a)	Scenario 3: Large growers demand (million m^3/a)
T51A	6,54	1,6	1,4	1,4	1,4
T51B	18,54	1,6	3,9	3,9	3,9
T51C	68,74	7,9	12,3	13,6	17,4
T51D	10,07	2,0	2,7	2,7	2,7
T51E	37,84	2,7	5,5	5,9	7,4
T51F	16,74	2,2	4,0	4,0	4,0
T51G	15,65	1,3	3,7	3,7	3,7
T51H	29,49	3,0	5,2	9,4	14,4
T51J	17,82	0,9	2,5	4,5	7,9
T52A	87,18	10,5	12,1	14,6	16,1
T52B	16,82	3,3	2,9	5,2	9,2
T52C	72,50	7,4	10,2	13,4	15,4
T52D	78,75	1,9	3,2	3,6	3,7
T52E	60,61	8,6	10,1	14,3	18,6
T52F	128,87	16,1	20,8	32,1	35,4
T52G	23,97	5,8	4,2	12,8	15,2
T52H	9,27	0,6	0,7	2,3	2,9
T52J	12,79	0,2	1,0	1,1	1,0
T52K	112,72	4,4	6,4	7,4	7,7
T52L	7,62	0,2	0,1	0,1	0,1
T52M	0,39	0,0	0,0	0,0	0,0
Total	**832,91**	**82,0**	**112,7**	**155,8**	**188,0**

Table E 9: Revised present day flows in the Mzimkhulu catchment

Quat	Present day MAR: Final Hydrology (million m^3/a)	Present day MAR: Revised forestry demands (million m^3/a)
T51A	149	149
T51B	76	74
T51C	92	88
T51D	61	60
T51E	47	44
T51F	102	100
T51G	84	81
T51H	114	112
T51J	47	45
T52A	66	65
T52B	44	44
T52C	35	32
T52D	23	22
T52E	45	44
T52F	76	71
T52G	55	56
T52H	24	24
T52J	32	31
T52K	25	23
T52L	11	11
T52M	29	29
T51 total	**771**	**753**
T52 total	**465**	**452**
Catchment total	**1 236**	**1 206**

Table E 10: Updated comparison between natural and present day flows: Total MAR

Quat	WMSC	Natural MAR (million m^3/a)	Present day MAR (million m^3/a)	% Change in MAR natural to present'	Present day MAR Rev SFR (million m^3/a)	% Change in MAR natural to present'	% Change of % change in MAR
T51A	Upper Mzimkhulu	157,0	149	-5%	149	-5%	-2%
T51B	Upper Mzimkhulu	87,4	76	-13%	74	-15%	16%
T51C	Upper Mzimkhulu	117,0	92	-21%	88	-25%	19%
T51D	Upper Mzimkhulu	65,9	61	-8%	60	-9%	12%
T51E	Upper Mzimkhulu	59,9	47	-22%	44	-27%	20%
T51F	Ngwangwana	116,7	102	-13%	100	-14%	12%
T51G	Ngwangwana	91,4	84	-9%	81	-11%	30%
T51H	Ngwangwana	123,4	114	-8%	112	-9%	22%
T51J	Ngwangwana	51,7	47	-9%	45	-12%	33%
T52A	Middle Mzimkhulu	93,9	66	-30%	65	-31%	3%
T52B	Middle Mzimkhulu	50,2	44	-13%	44	-13%	1%
T52C	Middle Mzimkhulu	48,1	35	-28%	32	-34%	22%
T52D	Middle Mzimkhulu	28,9	23	-20%	22	-24%	21%
T52E	Bisi	56,5	45	-20%	44	-22%	14%
T52F	Bisi	96,6	76	-21%	71	-26%	23%
T52G	Bisi	65,0	55	-16%	56	-13%	-15%
T52H	Bisi	27,6	24	-13%	24	-13%	1%
T52J	Lower Mzimkhulu	34,5	32	-8%	31	-10%	27%
T52K	Mzimkhulwana	33,3	25	-24%	23	-30%	26%
T52L	Mzimkhulwana	14,9	11	-27%	11	-27%	2%
T52M	Lower Mzimkhulu	32,5	29	-11%	29	-11%	0%
T51	**TOTAL**	**870,5**	**771**	**-11%**	**753**	**-13%**	**18%**
T52	**TOTAL**	**582,1**	**465**	**-20%**	**452**	**-22%**	**11%**
Catchment	**TOTAL**	**1 452,5**	**1 236**	**-15%**	**1206**	**-17%**	**14%**

Table E 11: Updated comparison between natural and present day flows: Low flow MAR

Quat	WMSC	Natural Low Flow MAR (million m^3/a)	Present Day Low Flow MAR (million m^3/a)	% Change in Low Flow MAR natural to present'	Revised Present Day Low Flow MAR (million m^3/a)	% Change in Low Flow MAR natural to present'	% Change of % change in low flow
T51A	Upper Mzimkhulu	4,8	4,5	-6%	4	-7%	7%
T51B	Upper Mzimkhulu	2,7	1,2	-56%	1	-57%	2%
T51C	Upper Mzimkhulu	5,0	3,1	-38%	3	-42%	9%
T51D	Upper Mzimkhulu	2,8	1,5	-47%	1	-48%	2%
T51E	Upper Mzimkhulu	2,7	1,6	-40%	2	-43%	7%
T51F	Ngwangwana	3,6	3,0	-18%	3	-20%	8%
T51G	Ngwangwana	2,9	3,0	2%	3	0%	-116%
T51H	Ngwangwana	5,4	4,9	-10%	5	-11%	20%
T51J	Ngwangwana	3,6	3,0	-17%	3	-20%	18%
T52A	Middle Mzimkhulu	5,4	2,5	-54%	2	-56%	3%
T52B	Middle Mzimkhulu	3,3	2,9	-14%	3	-15%	11%
T52C	Middle Mzimkhulu	3,2	2,1	-35%	2	-44%	24%
T52D	Middle Mzimkhulu	3,1	2,0	-37%	2	-42%	14%
T52E	Bisi	4,7	4,3	-9%	4	-13%	45%
T52F	Bisi	8,2	7,4	-9%	7	-15%	63%
T52G	Bisi	5,0	4,5	-9%	5	-8%	-10%
T52H	Bisi	2,6	2,1	-18%	2	-19%	2%
T52J	Lower Mzimkhulu	3,1	2,8	-9%	3	-11%	25%
T52K	Mzimkhulwana	3,3	2,4	-29%	2	-38%	30%
T52L	Mzimkhulwana	1,3	0,9	-32%	1	-33%	1%
T52M	Lower Mzimkhulu	2,8	2,5	-13%	2	-13%	0%
T51	**TOTAL**	**33,6**	**25,7**	**-24%**	**25,0**	**-26%**	**9%**
T52	**TOTAL**	**46,1**	**36,3**	**-21%**	**34,8**	**-25%**	**16%**
Catchment	**TOTAL**	**79,8**	**62,1**	**-22%**	**59,8**	**-25%**	**13%**

Table E 12: Comparison of present day flows with revised forestry reductions

Present day flows: Final WRSM Hydrology (million m^3)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Low Flow
T52E	1,87	3,79	5,56	6,44	6,81	7,47	4,92	2,96	1,85	1,39	1,08	1,27	45,39	4,32
T52F	3,38	6,47	9,26	10,66	11,20	12,47	8,02	4,87	3,16	2,38	1,89	2,31	76,09	7,43
T52G	2,68	5,15	7,22	8,15	8,33	8,85	5,20	2,97	1,94	1,44	1,17	1,59	54,68	4,55
T52G cumulative	7,93	15,40	22,04	25,25	26,34	28,79	18,14	10,80	6,95	5,21	4,14	5,17	176,16	16,30

Present day flows – Revised (million m^3)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Low Flow	% Difference total flow	% Difference low flow
T52E Rev	1,78	3,63	5,34	6,18	6,55	7,21	4,75	2,84	1,75	1,32	1,01	1,20	43,57	4,08	-4%	-6%
T52F Rev	3,25	6,27	8,98	10,35	10,93	12,28	7,87	4,70	2,98	2,22	1,75	2,17	73,75	6,95	-3%	-6%
T52G Rev	2,62	5,06	7,10	8,02	8,19	8,68	5,07	2,87	1,86	1,37	1,11	1,52	53,46	4,34	-2%	-5%
T52G cumulative Rev	7,65	14,96	21,42	24,55	25,67	28,17	17,70	10,41	6,59	4,90	3,86	4,90	170,78	15,35	-3%	-6%

Absolute Difference (million m^3)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Low Flow
T52E Rev	-0,09	-0,16	-0,22	-0,26	-0,26	-0,26	-0,17	-0,12	-0,10	-0,07	-0,07	-0,07	-1,82	-0,24
T52F Rev	-0,13	-0,20	-0,28	-0,31	-0,27	-0,19	-0,15	-0,17	-0,18	-0,16	-0,14	-0,14	-2,34	-0,48
T52G Rev	-0,06	-0,09	-0,12	-0,13	-0,14	-0,17	-0,13	-0,10	-0,08	-0,07	-0,06	-0,07	-1,22	-0,21
T52G cumulative Rev	-0,28	-0,44	-0,62	-0,70	-0,67	-0,62	-0,44	-0,39	-0,36	-0,31	-0,28	-0,27	-5,38	-0,95

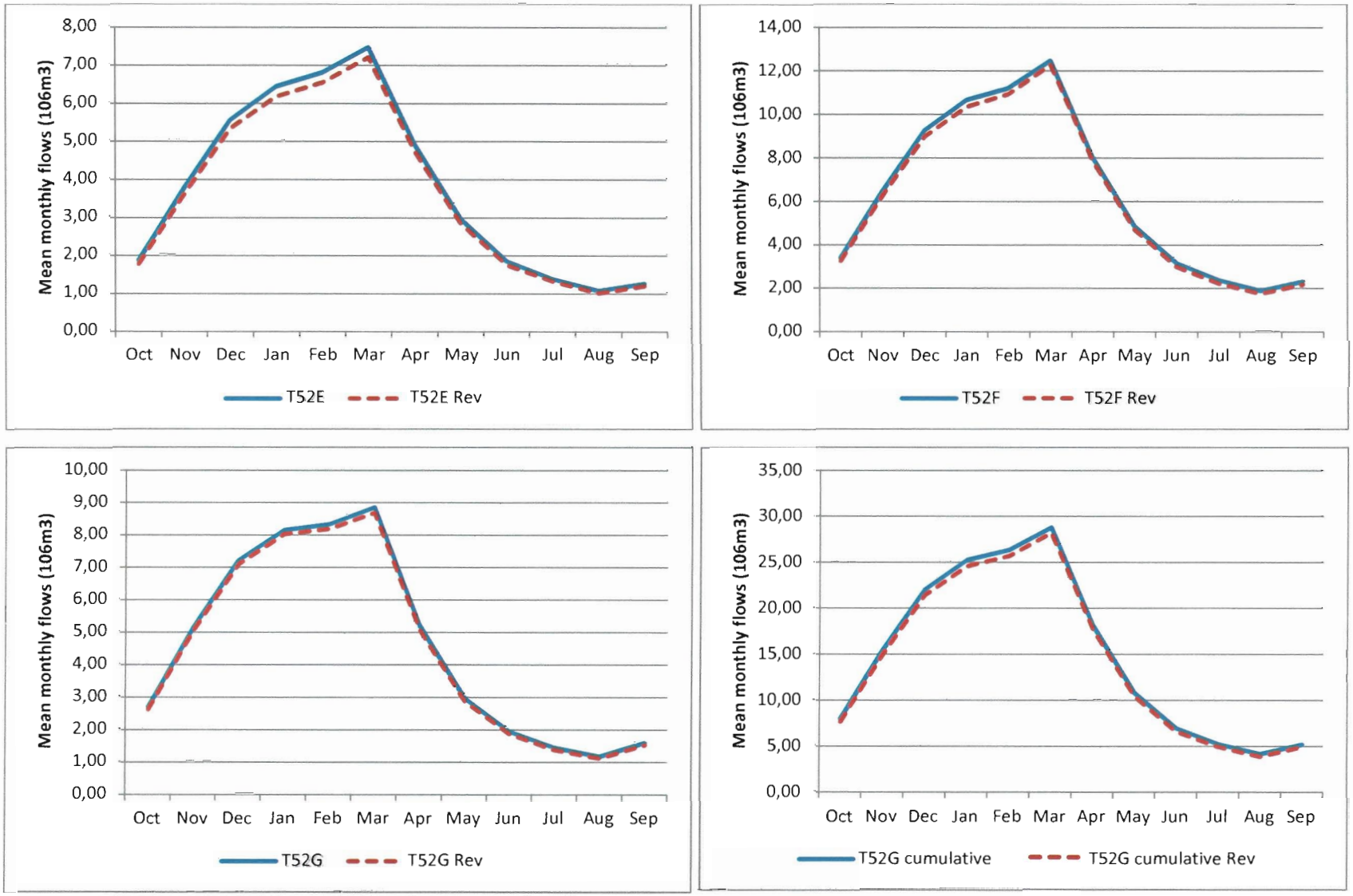

Figure E 4: Graphical comparison of present day flows with revised forestry reductions


MZIMKHULU SYSTEM (DWA, 2010)
70 - T51D Wetland Loss
377 - T51D Wetland RF
61 - RURAL
58 - STOCK
434 - T51D IRR
520 T51D Irr RF
T51D OUTFLOW
54 - T51D Wetland Loss
519 T51D Wetland RF
408 - EWR T51D
Avg 1.336 m3/s
Avg 0.583 m3/s
82 T51E Wetland Loss
84 RURAL
382 T51E Wetland RF
383 T51E Wetland RF
73 T51E Wetland Loss
75 STOCK
438 T51E FDIRR
437 T51E IRR
521 T51E Irr RF
409 - EWR T51E
356 - Pholela Dam transfer site
Avg 3.434 m3/s
45 T51C Wetland Loss
47 T51C Wetland RF
322 T51C Wetland Loss
36 T51C Wetland RF
40 STOCK
52 DOMESTIC
440 T51C IRR
439 T51C IRR
522 T51C Irr RF
Avg 8.718 m3/s
543 - NewBegin Spills
357 - New Beginnings Dam (T51C)
358 - D/s New Begin Dam
354 - Underberg Dam (T51C)
406 - EWR T51C
407 - T51C
405 - EWR T51B
Avg 10.535 m3/s
Avg 2.959 m3/s
Avg 13.494 m3/s
381T51B Wetland RF
33 T51B Wetland Loss
19 STOCK
433 T51B IRR
432 T51B IRR
523 T51B Irr RF
321 RURAL
379T51A Wetland RF
314 T51A Wetland Loss
431 T51A IRR
10 STOCK
380 T51A Irr RF
Avg 0.013 m3/s
378 T51A Wetland Rf
430 T51A IRR
1 T51A Wetland Loss
316 RURAL
404 - EWR T51A
Avg 3.146 m3/s
Avg 1.597 m3/s
Avg 0.027 m3/s
390 T51J Wetland RF
146 T51J Wetland Loss
446 T51J IRR
391 T51J Wetland RF
144 STOCK
120 DOM-COM-IND
318 - T51J fdam
348 - Dam 2 Ngwangwane (T51J)
Site 12 Ngwangwane (T51J)
527 T51J Irr RF
413 - EWR T51J
Avg 8.027 m3/s
Avg 3.125 m3/s
392 T52A Wetland RF
150 T52A Wetland Loss
154 STOCK
153 DOM-COM-IND
447 T52A IRR
528 T52A Irr RF
531 - Creighton EWR
Avg 19.270 m3/s
414 - EWR T52A
Avg 5.824 m3/s
448 T52A IRR
393 T52A Wetland RF
158 T52A Wetland Loss
355 - Mzimkhulu Dam 3 (T52A)
Avg 20.829 m3/s
97 STOCK
90 T51F Wetland Loss
384 T51F Wetland RF
441 T51F IRR
442 T51F IRR
103 RURAL
524 T51F Irr RF
110 T51F Wetland Loss
385 T51F Wetland RF
410 - EWR T51F (Coleford)
Avg 2.491 m3/s
Avg 0.750 m3/s
Avg 1.862 m3/s
411 - EWR T51G
Avg 0.803 m3/s
114 T51G Wetland Loss
386 T51G Wetland RF
117 STOCK
443 T51G IRR
525 T51G Irr RF
387 T51G Wetland RF
129 T51G Wetland Loss
126 RURAL
444 T51G IRR
412 - EWR T51H
Site 15 Gungununu (T51H)
389 T51H Wetland RF
132 T51H Wetland Loss
134 STOCK
445 T51H IRR
388 T51H Wetland RF
526 T51H Irr RF
124 T51H Wetland Loss
136 RURAL
178 T52C Wetland Loss
395 T52C Wetland RF
176 T52C FD Wetland Loss
174 STOCK
180 T52C Wetland RF
449 T52C IRR
450 T52C IRR
283 T52C Irr RF
415 - EWR T52B
Avg 0.438 m3/s
Avg 0.939 m3/s
416 - EWR T52C
Avg 22.675 m3/s
Avg 6.447 m3/s
429 Ncakubana Abstraction
451 T52D IRR
192 T52D Wetland Loss
529 T52D Wetland RF
191 STOCK
199 T52D Wetland Loss
197 T52D Wetland RF
452 T52D IRR
201T52D Irr RF
206 DOM-COM-IND
428 Mshabatshane Transfer
417 - EWR T52D
Avg 23.302 m3/s
Avg 6.462 m3/s
402 SUGAR
249 T52J Wetland RF
246 T52J Wetland Loss
457 T52J IRR
252T52J Irr RF
422 - EWR T52J
Avg 27.934 m3/s
Avg 9.196 m3/s
421 - EWR T52H
108 T52B Wetland Loss
173 RURAL
170 STOCK
394 T52B Wetland RF
210 T52E Wetland Loss
509 T52E Wetland RF
215 T52E Wetland Loss
511 T52E Wetland RF
T52e-stk.dem
453 T52E IRR
510 T52E Irr RF
230 STOCK
515 T52G Wetland RF
99 T52G Wetland Loss
455 T52G IRR
516 T52G Irr RF
204 RURAL
419 - EWR T52F
418 - EWR T52E
420 - EWR T52G
220 STOCK
512 T52F Wetland RF
235 T52F Wetland Loss
454 T52F IRR
227 T52F Wetland Loss
513 T52F Wetland RF
514 T52F Irr RF
222 RURAL
Off Channel Dam - Cwabeni
Support to St Helen's from Off Channel Dam
549 - Port Shepstone Demand
Avg 0.000 Fail
Ugu Off-channel Storage
425 Ugu Diversion
Avg 0.526 m3/s
Avg 1.132 m3/s
Avg 0.606 m3/s
Avg 0.000 m3/s
Pump Channel
Avg 37.130 m3/s
547 - Gibraltar EWR
403 SUGAR
279 RURAL
277 STOCK
Avg 37.944 m3/s
530 - EWR T52M
Avg 38.009 m3/s
Avg 0.349 m3/s
Avg 38.266 m3/s
Spill
Indian Ocean
Yield Channel @ St Helen's Rock
424 - EWR T52L
Avg 0.286 m3/s
Avg 0.783 m3/s
Mzimkhulwana
255 T52K Wetland Loss
506 T52K Wetland RF
257 T52K Wetland Loss
270 SUGAR
259 STOCK
503 T52K Wetland RF
459 T52K IRR
458 T52K IRR
504 T52K Irr RF
423 - EWR T52K
Site 5 Mzimkhulwana (T52K)
375 RURAL
508 T52L Irr RF
Avg 1.069 m3/s
507 T52L wetland RF
460 T52L IRR
401 SUGAR
263 T52L Wetland Loss
265 STOCK
Site 19 Bisi River (T52H)
151 DOMESTIC
518 T52H Irr RF
517 T52H Wetland RF
60 T52H Wetland Loss
238 STOCK
193 T52H Wetland Loss
456 T52H IRR
267 T52H Wetland RF