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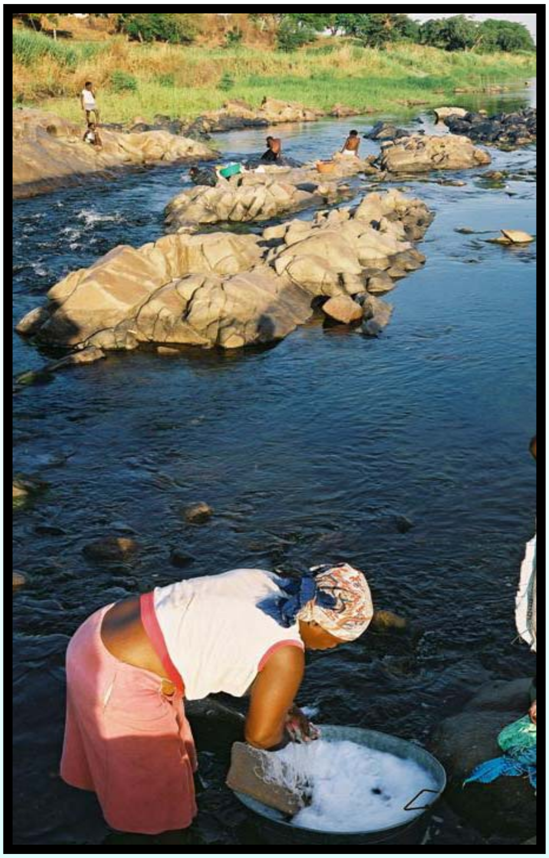
water & forestry

Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA



KOMATI CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY

MAIN REPORT

February 2006

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REPUBLIC OF SOUTH AFRICA

DIRECTORATE: RESOURCE DIRECTED MEASURES

KOMATI CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY – MAIN REPORT

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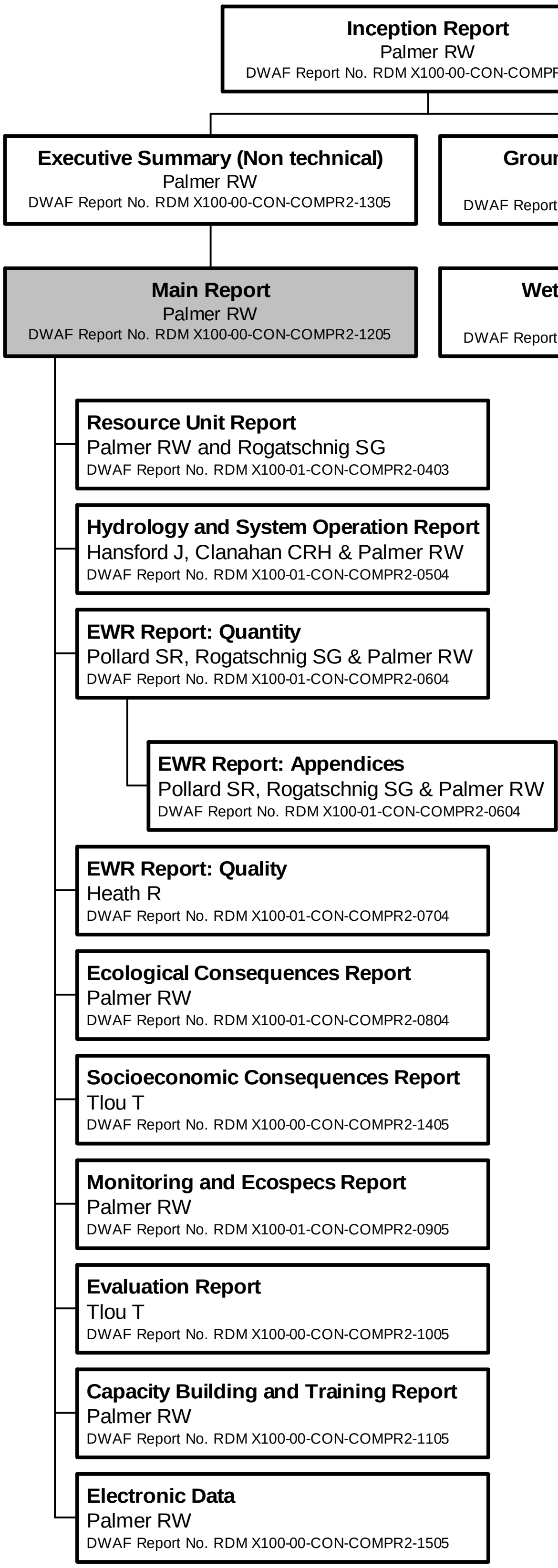
REPORTING LAYOUT



EXECUTIVE SUMMARY

KOMATI CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY –

MAIN REPORT

Background

The Komati River Catchment was identified by the Department of Water Affairs and Forestry (DWAF) as a priority catchment for a comprehensive Reserve determination due to high water demands. Planned extensions to irrigation have been put on hold and a substantial portion of the population in the catchment does not have access to basic level of services. The Komati River is a shared watercourse, so international obligations have to be taken into consideration in the management of the system.

This report presents the main findings of a comprehensive assessment of the Ecological Water Requirement (EWR) component of the Reserve, conducted over three years between April 2003 and March 2006. The study was commissioned by the D: RDM and undertaken by AfriDev Consultants. The study produced several reports, as indicated in the reporting layout (page iv). This report highlights the main findings only.

Aims

The main aim of this study were:

- *To recommend a comprehensive Ecological Water Requirement (EWR), for water quality and quantity, for various reaches of the Komati River system.*
- *To assess the need for groundwater and wetland EWR assessments, based on a desktop, scoping level studies.*
- *tTo train persons from persons from previously disadvantaged communities in specific aspects of assessing EWRs.*

Study Area

The Study Area for this project was initially defined by the D: RDM as the Komati River Catchment (X1) within South Africa. In January 2005 the Study Area was expanded to include the Swaziland portion of the Komati River Catchment. The initial Study Area was delineated into ten ecologically distinct units, referred to as Resource Units. These are stretches of river that are sufficiently unique to warrant their own EWR. By including Swaziland into the Study Area there was one additional Resource Unit, between Maguga Dam and Balekane Bridge. There were sufficient funds to assess the water requirements of seven sites only. Resource Units were therefore prioritized in terms of their strategic importance, and sites were selected in the most important Resource Units.

Approach

This study followed the generic eight step process for Reserve determination, illustrated in Figure A.

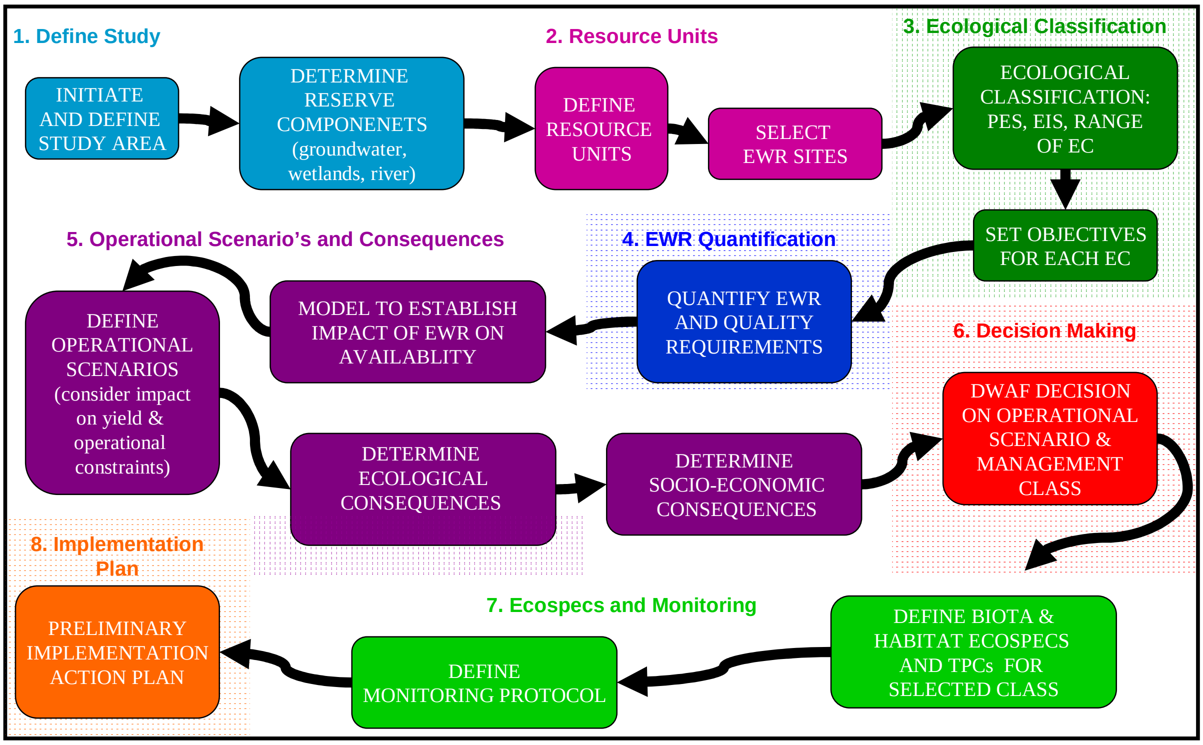


Figure A. Diagram illustrating the eight-step process that was followed for the Komati Ecological Water Requirement Study.

Schedule

This study was initiated in May 2003, and was finalised in March 2006.

System Operation

An understanding of system operation is critical for developing a practical EWR that can be implemented. The report therefore presents a detailed description of system operation of the two main operations regions: 1) upper Komati, comprising Nooitgedacht and Vygeboom Dams and associated infrastructure and 2) lower Komati, comprising Maguga and Driekoppies Dams and associated infrastructure.

Groundwater and Wetland Scoping

The primary aim of the Groundwater and Wetland Scoping Study was to clarify the need for an assessment of the groundwater and wetland components of the EWR for the Komati River Catchment within South Africa. The Stud Area was delineated into five Groundwater Units / Wetland Ecotypes, based on the underlying geology. Detailed investigations of the groundwater and wetland EWR were recommended, and a proposed Scopes of Work for these studies was presented. Due to the incompleteness of the data available for the study and the low *confidence levels of the data, a methodology for additional data collection and classification was proposed.*

Hydrology

The basis for the time series derived for the EWR sites was daily observed records for the streamflow gauges in the catchment that were obtained from DWAF, daily simulated time series prepared by Prof. D Hughes for Maguga Dam IFR study, and simulated monthly time series derived for the Water Resources Yield Model (WRYM). The flood analyses were based on the peak discharge data supplied by DWAF for the streamflow gauges. Daily streamflow records and peak discharge data were obtained from DWAF for the streamflow gauges in the catchment.

Water Quality

Water quality is generally not the driver of the overall EcoStatus of rivers in the Study Area, as parameters such as flow and the status of the riparian vegetation are more instrumental in determining the health of the river. The river is generally in a Good to Fair condition in terms of water quality, with poor quality occurring at the lower Komati River.

Ecological Classification

Ecological Classification, or EcoClassification, refers to the categorisation of the Present Ecological State (PES) of various biophysical attributes compared to the natural (or near natural), reference condition. A six point classification was used, ranging from Category A (Unmodified), to Category F (Critically Modified). The purpose of EcoClassification is to recommend an attainable Ecological Category (EC), plus alternatives categories, where appropriate, based on an understanding of causes of deviations of the PES from the reference conditions. Field surveys conducted in 2003 found that the upper Komati River Catchment was generally in a good ecological condition (Category B). The middle reaches were generally in a fair condition (Category C), with the notable exception of the Gladdespruit River, which was in a poor condition (Category D). The lower reaches where highly degraded (Category E). The overall picture was thus one of a river system that deteriorates in the lower reaches. The Recommended EC (REC) was the same as the PES for all Resource Units apart from the lower Komati (Resource Units D and E), in which an improvement from a Category E to Category D was recommended.

Ecological Water Requirements

Ecological Water Requirement (EWR) refers to the flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. The assessment was based at site-specific data, collected over a range flows. Data analysis focussed on the relationships between discharge and habitat availability and key ecosystem processes. This process did not consider whether these flows could be supplied or managed, and impacts on users were not considered. The EWR that were recommended for the recommended and alternative Ecological Categories constituted between 10.9 and 45.3% of the natural MAR. These values represent the limits of flow reduction to be used in yield models.

Operational Scenarios

Operational Scenarios refer to flow scenarios that are realistic in the sense that they incorporate the availability of water, operational constraints and user demands. The development of operational scenarios is the next logical step that follows the quantification of the EWR. The development of operational scenarios is an iterative process in which the severity of impacts, complexity and budget constraints determined the number of iterations required. The EWR (quantity) scenarios for a range of ECs were used as the basis for developing an initial set of scenarios, and modified as required.

Four scenarios without EWR requirements were evaluated: two including Mozambique requirements and two excluding Mozambique requirements. The reason for various scenarios without the EWR requirements was that the operational management of the system is subject to phased implementation. The system is unlikely to be managed like this in future as once Maguga Dam has sufficient water it will be managed together with Driekoppies Dams, and international treaty requirements will need to be adhered to. Three scenarios with the EWR requirements were assessed initially: the Recommended EC and the alternative categories "up" and "down". These scenarios were further split into those that included full floods, and those excluding floods that could not be met because of system constraints. See Figure B.

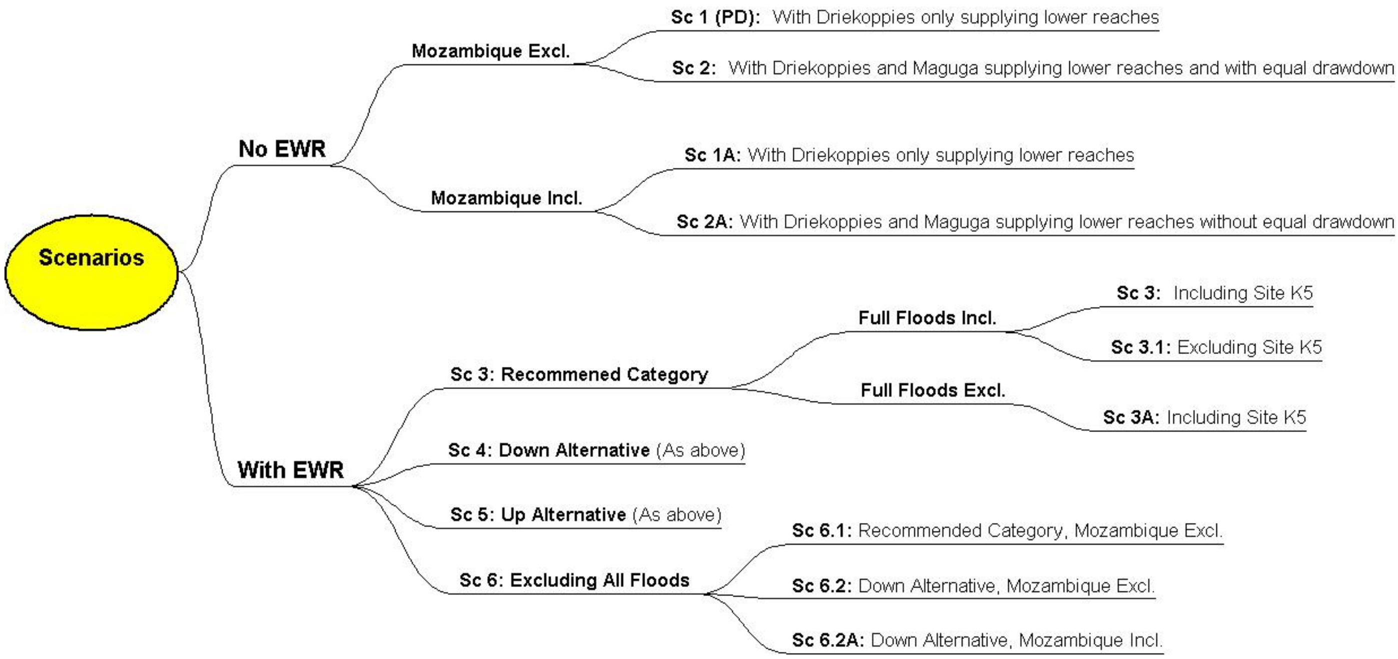


Figure B: Operational Scenarios developed for the Komati River Catchment.

Ecological Consequences

Having developed various operational scenarios, in which the EWR may have been modified to account for system constraints and impacts on yield, the next step in the process was to assess the ecological and water quality consequences of the various operational scenarios. The results of the ecological consequences assessment indicate that while some ecosystem components were detrimentally impacted by certain scenarios, the EcoStatus was unaffected by all scenarios that included EWR requirements (Figure C).

Consequences of Yield

Having assessed the ecological consequences of the various scenarios, the next step in the process was to assess the consequences for water availability within the catchment, or yield. The Water Resources Yield Model (2000) was used to assess the impacts that the EWR Scenarios will have on the available yield of the system. With user requirements based on best available data and associated assurance of supplies (e.g. 70% of the irrigation requirements were allocated at high assurance (98%), while the remainder was allocated at low assurance (80%). The total user requirements that were included in the model are summarised in Figure D. The results show that the full requirement cannot be supplied, even without the EWR. Scenario 2 provides the most water for users at 92% of the user requirement, but this scenario does not provide for the EWR, while Scenario 6.1 and 6.2 supply 90% of the requirement.

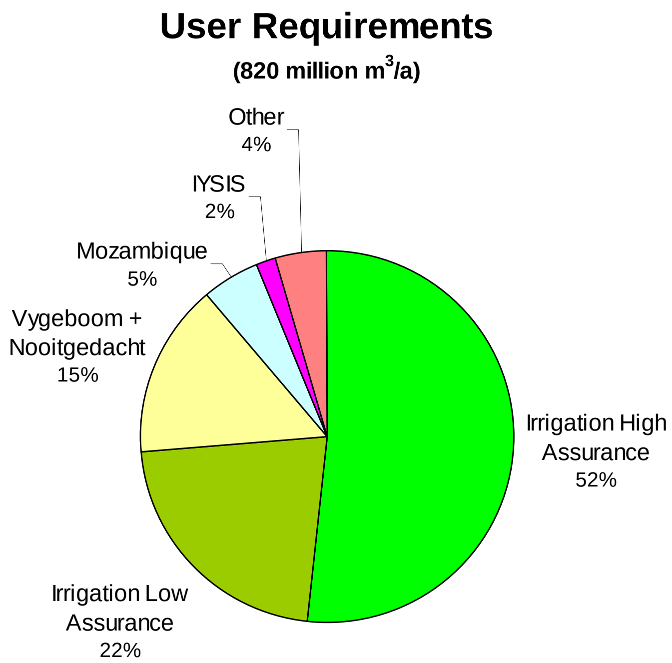


Figure D. Water requirements for various user sectors in the Komati River Catchment.

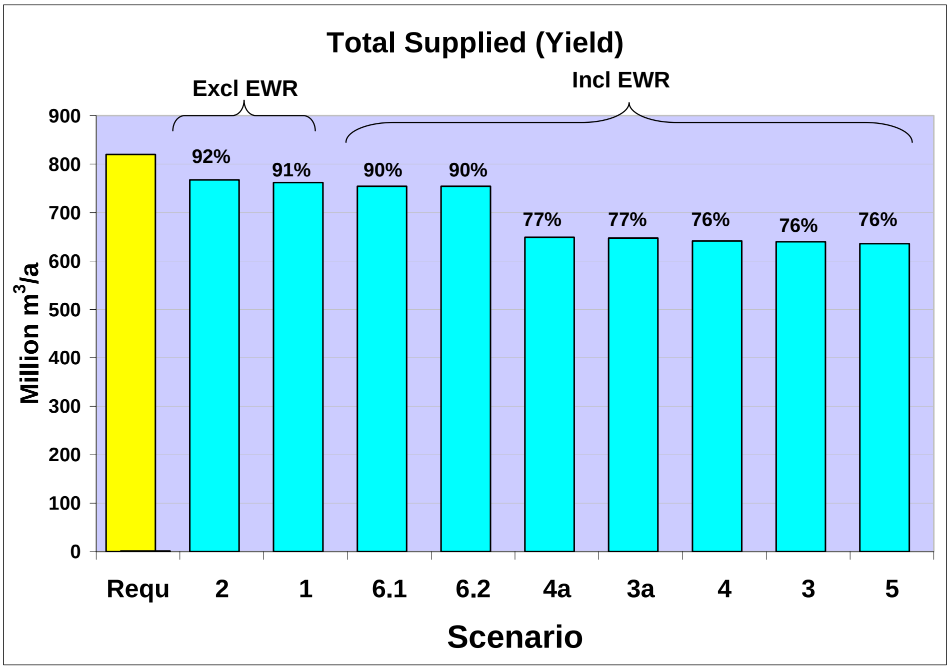


Figure E. Total water supplied (in million m^3/a) to users for various flow scenarios in the Komati River Catchment. (Requ = User Requirement.)

Modelling results indicate that there is a 8% deficit in water availability without the implementation of the EWR (ie 92% supplied). Implementation of the recommended EWR results in an additional deficit of 16%, irrespective of the ecological category (ie 76% supplied). Modifying the EWR to exclude floods that cannot be met makes little difference to the yield (1%), but modifying the results to exclude all floods makes a significant difference to the yield (14%). The overall degree of curtailment on existing users for various operational scenarios mirrors the socioeconomic impacts.

Socioeconomic Consequences

The criteria of the economic impacts of water re-allocations between users are measured in terms of the following macroeconomic variables:

- *Impacts on profit (i.e. the impact on surpluses generated by each water user)*
- *Economic growth (i.e. the impact on Gross Domestic Product [GDP])*
- *Impact on capital formation*
- *Income distribution (i.e. the impact on low-income, poor households and the total income households)*

After determining the magnitude of change for each water user individually, the model ranks water users in accordance with their contribution to these economic variables.

Three scenarios were identified for the valuation of the impact of the ecological flows of each scenario of the water availability to the water using sector in the Komati River Catchment.

The findings indicated that the more water that is left in the river, the more severe the impact on the economic and social welfare of the Komati River Catchment. An optimised scenario was then developed that would achieve the ecological objectives of maintaining the present ecological state of the river, while reducing the negative impact on the economic activity and the loss of employment.

Recommended Scenario

The relative impacts of the various scenarios on ecology, goods and services and economics are illustrated in Figure F. The figure shows that the best balance between ecological sustainability and social and economic development is achieved with Scenario 6.2a. It was therefore recommended that Scenario 6.2a be accepted because of its least impacts, and because it also meets South Africa and Swaziland's international obligations on sharing water with its downstream neighbour Mozambique.

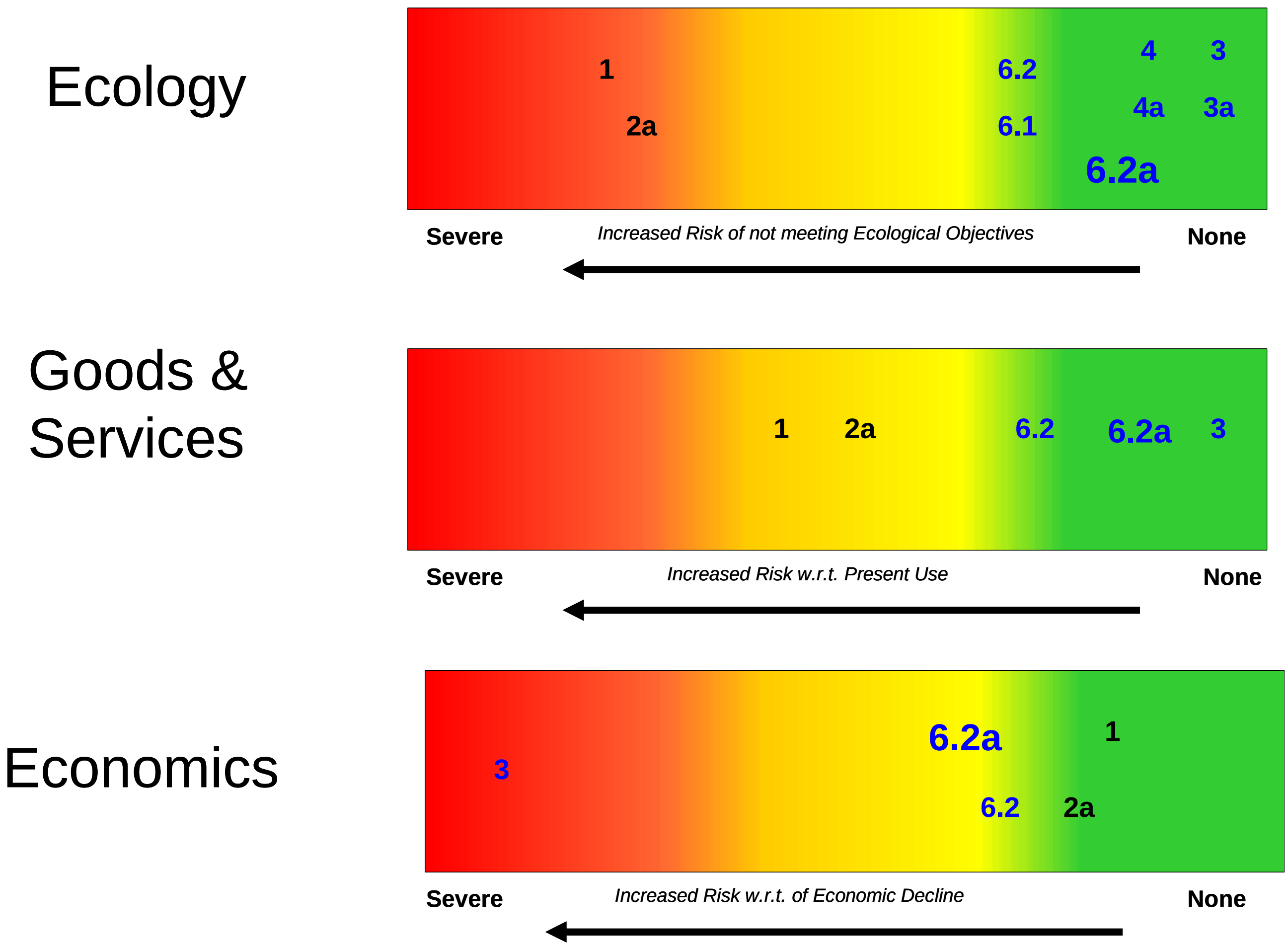


Figure F. Comparison of consequences of various scenarios across major study components.

Ecological Reserve

The final results of the Ecological Reserve are summarised in Table . The table shows the total annual EWR requirement and associated supply under Scenario 6.2a at each EWR site. The table also lists the full EWR for the REC, and the final total Ecological Reserve requirement at each EWR site. The Ecological Reserve constituted between 11.63 and 35.60% of the nMAR. The evaluation of a Reserve for a water abstraction licence at any point in the Komati River System can now be determined by extrapolating the flow regime up or downstream from an existing EWR site.

Table A. Mean Annual Flows at various sites for Ecological Water Requirement (EWR) under 1) Scenario 6.2a, 2) the supply under Scenario 6.2a 3) the full EWR, and 4) the recommended Ecological Reserve, expressed in million m3/a and as a percentage of the natural Mean Annual Runoff (nMAR).

		Mean Annual Flow (million m^3/a)				% nMAR	
Site	nMAR (MCM)	EWR Sc6.2.a Requirement	EWR Sc6.2.a Supply	Full EWR Requirement	Ecological Reserve	Full EWR	Ecological Reserve
K1	181.17	19.17	142.48	43.75	42.92	24.15%	23.69%
K2	527.16	34.37	310.50	94.40	92.71	17.91%	17.59%
K3	1016.48	110.61	289.53	192.52	141.42	18.94%	13.91%
M1	857.1	132.85	476.89	248.93	224.73	29.04%	26.22%
L1	321.65	27.99	221.76	37.94	37.42	11.80%	11.63%
G1	37.73	7.56	26.40	9.60	7.60	25.44%	20.14%
T1	60.59	8.69	48.65	21.54	21.57	35.55%	35.60%

EcoSpecs and Ecological Reserve Monitoring

The final step in the study was to define EcoSpecs and Thresholds of Potential Concern (TPCs) to monitor the implementation of the Ecological Reserve. The essential requirements of a monitoring programme are clearly defined baseline conditions against which future changes may be compared, and clearly defined objectives. The study assessed the suitability of available data for defining baseline conditions for monitoring the Ecological Reserve in the Komati River, and recommended additional baseline data requirements, where needed;

Capacity Building

The study included a capacity building component by including Previously Disadvantaged Individuals and training them on a tutorship basis. Five trainee-mentor partnerships were established. Trainees were selected largely from HDIs as persons who had relevant skills and who were interested in the Reserve determination process. Specific training objectives were set for each trainee and who then received on-the-job training.

In addition, a dedicated two-day training and awareness workshop was held on the EWR process. This training workshop was intended specifically for DWAF officials, but was also attended by study team trainees and others.

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ABBREVIATIONS

BBM	Building Block Methodology
D: RDM	Directorate: Resource Directed Measures
DRIFT	Downstream Response to Imposed Flow Transformations
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirement
GIS	Geographical Information System
HFS-R	Habitat Flow Stressor Response
IFR	Instream Flow Requirement
IYSIS	Inyoni Yami Swaziland Irrigation Scheme
KOBWA	Komati Basin Water Authority
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NGDB	National Groundwater Database
nMAR	Naturalised Mean Annual Runoff
NWA	National Water Act
PES	Present Ecological State
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Unit
SAM	Social Accounting Matrix
SAM	Social Accounting Matrix
SI	Socio-cultural Importance
SPATSIM	Spatial and Time Series Information Model
TPC	Thresholds of Potential Concern
WMA	Water Management Area
WRYM	Water Resources Yield Model

GLOSSARY

ASSURANCE	Percentage of time at which a flow is equalled or exceeded.
BIOTA	A collective term for all the organisms (plants, animals, fungi and bacteria) in an ecosystem.
BIOTOPE	The place in which a certain assemblage of organisms live.
CATADROMOUS	Moving from freshwater to the sea to breed.
DIABASE	A dark, grey-green, fine-grained gabbro with a characteristics texture, in which the interstices of tabular plagioclase crystals are filed by augite.
DOLOMITE	The mineral $CaMg(CO_3)_2$; also the rock that consists mainly of this mineral.
DYKE	A vertical or semi-vertical wall-like igneous intrusion which cuts across the bedding planes of a rock.
ECOLOGICAL CATEGORY	A category indicating the potential management target for the river. Values range from Category A (unmodified, natural) to Category D (largely modified). This term replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Class (EMC). The reasons for these changes are explained in the proceedings of a workshop to clarify the terminology used in Reserve determinations (DWAF 2003). A distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment.
ECOLOGICAL IMPORTANCE	A measure of the value of a river for conservation.
ECOLOGICAL RESERVE	The quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource (Chapter 1:1(xvii)(b) NWA, 1998).
ECOLOGICAL WATER REQUIREMENT	This term refers to both quality and quantity (i.e., once the water quality component is incorporated into the flow recommendation). Ecological Water Requirements are used as input into Scenario Modelling
ECOSPECS	Ecological specifications. These are specifications of ecological attributes (e.g., water quality, flow, biological integrity), that define the Ecological Category. EcoSpecs refer to ecological

	information, whereas Resource Quality Objectives include economic and social objectives.
ECOSTATUS	An overall assessment of the Ecological Category (A-F), based on a subjective integration of specialist indices (water quality, fish etc).
ENDHOREIC	Closed drainage e.g. a pan.
EWR SCENARIO	Ecological Water Requirement Scenario. These are alternative ecological flows which incorporate ecological and water quality implications. This term replaces the term Ecological Reserve Scenario.
FERRICRETE	a very hard soil horizon made up of cementation of iron oxides at or near the land surface.
FLOODPLAIN	Wetland inundated when a river overtops its banks during flood events resulting in the wetland soils being saturated for extended periods of time.
FRESHET	Small flow pulse.
GNEISS	A highly metamorphosed rock of a granular texture and with a banded appearance.
GRANITE	A course-grained igneous rock that consists largely of quartz, alkali feldspar, and plagioclase feldspar.
GROUNDWATER	Subsurface water in the zone in which permeable rocks, and often the overlying soil, are saturated under pressure equal to or greater than atmospheric.
HABITAT	The place in which a plant or animal lives. (See BIOTOPE.)
HIGH FLOW	This term refers to the peaks in the daily hydrograph, determined graphically from daily time series of flows (see low flows).
HYDRAULICS	The branch of science and technology concerned with the mechanics of fluids, especially liquids.
HYDROLOGY	Science dealing with properties, distribution and circulation of water in the biosphere.
INSTREAM FLOW REQUIREMENTS (IFR)	The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to the quantity component of river flow requirements only.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.
LOW FLOW	The component(s) of the daily hydrograph between high flows, determined graphically from daily time series of flows. The low flow component of the flow regime and has a similar meaning to base flows, i.e., it excludes events (floods) (see high flows).
MIGMATITE	A metamorphic rock injected with igneous material.

OPERATIONAL SCENARIO	This term refers to flow scenarios devised on the basis of issues other than ecological, i.e., availability of water, operational constraints in the system, other demands etc.
PALUSTRINE	non-tidal wetlands dominated by persistent emergent plants (e.g. reeds) emergent mosses or lichens, or shrubs or trees.
PRESENT ECOLOGICAL STATE (PES)	The degree to which present conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Values range from Category A (largely natural) to Category F (critically modified).
QUARTZITE	A rock comprised essentially of quartz.
REFERENCE CONDITION	The natural ecological conditions for a particular Resource Unit. The reference conditions define "protected" water resources and may be used to calibrate the other categories.
REFUGIA	An area where a population is maintained during unfavourable conditions.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified EWR, where operational limitations and stakeholder consultation are taken into account.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection. This term takes into account the management classes and the requirements of other users. These components are not addressed in this project. This term takes into account the management classes and the requirements of other users. These components are not addressed in this project.

RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements.
RIPARIAN	Pertaining to the river bank.
SECTOR	A 5km stretch of river used to quantify Habitat Integrity.
VADOSE	Unsaturated zone – zone of oxidation between the surface, and the groundwater interface.
WETLAND	Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which under normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

1. INTRODUCTION

1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the natural environment. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the Reserve for water resources.

The Reserve is defined as the quantity and quality of water required (a) to satisfy basic human needs and (b) to protect aquatic ecosystems. The basic human needs component of the Reserve is fairly easy to quantify as it is based on an average water consumption per capita and standard drinking water standards. The quantity and quality of water needed to protect aquatic ecosystems is more difficult to quantify and the methods of doing so are under continual development and improvement.

The Directorate: Resource Directed Measures (D: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before license applications are processed. Water resources in the Komati River Catchment (Water Management Area 5) are fully allocated and the full implementation of the Reserve will almost certainly result in curtailment of water allocations once the compulsory licensing process is implemented. This highlights the need for an accurate assessment of the Reserve requirements.

Reserve requirements are specific to South African legislation, yet effective management of the water resources in the Komati River cannot be achieved without taking Swaziland into account, particularly the operation of Maguga Dam and the IYSIS diversion weir. The recently signed Inco-Maputo Interim Agreement between South Africa, Swaziland and Mozambique, provides a sound basis for regional cooperation (TPTC Inco-Maputo Agreement 2002a). The agreement concerns not only the quantity of water, but also the quality and reliability of flows to sustain the watercourses and their associated ecosystems, including the estuary.

Implementation of the Reserve in the Komati River Catchment can be achieved now that the Driekoppies and Maguga Dams are complete, but this assumes that the Reserve will also be implemented in the upper reaches, where much of the water for the ecological Reserve originates (Tlou & Matji 2004). The National Water Resources Strategy suggests delaying the implementation of the Reserve in the Komati River Catchment until the water requirement of Eskom may be less (Tlou & Matji 2004).

This report presents the main findings of a comprehensive assessment of the Ecological Water Requirement (EWR) component of the Reserve, conducted over three years between April 2003 and March 2006. The study was commissioned by the D: RDM and undertaken by

AfriDev Consultants. The study produced several reports, as indicated in the reporting layout (page iv). This report highlights the main findings only.

1.2 PREVIOUS IFR STUDIES

Several desktop assessments of instream flow requirements (IFR) in the Komati River Catchment have been made, but only five studies in which primary data were collected had been undertaken prior to this study. These were:

- ***Bruwer 1993:*** In 1993 the Tennant Method (Tennant 1976) of assessing Instream Flow Requirements (IFRs) was applied to various nodes along the lower Komati and Lomati Rivers as part of an initial assessment of the IFR downstream of the proposed Driekoppies Dam (Bruwer 1993). The method used is limited because it provides an annual total volume only, and does not indicate how the flows should be allocated over an annual cycle.

- ***Ninham Shand 1994:*** A detailed assessment of IFRs was undertaken in 1994 as part of the environmental mitigation plan for Driekoppies Dam (Ninham Shand 1994). One site was selected in the Lomati River immediately downstream of Driekoppies Dam, and two sites were selected on the Komati River downstream of the Lomati River confluence, but upstream of the Crocodile River. The main shortfalls of this study were the limited biological data collected and unreliable hydraulics.

- ***AfriDev et al. 1999:*** A comprehensive assessment of IFRs in the Komati River between Maguga Dam and the Lomati River confluence was undertaken in 1997 and 1998 as part of the environmental mitigation plan for Maguga Dam (AfriDev *et al.* 1999). The assessment was based on a comprehensive application of the Building Block Method, in which the past Ecological Importance and Sensitivity, the Present Ecological State and the Desired Future State formed important components of the assessment (King and Louw 1998). Baseline data on riparian vegetation and limited data on geomorphology were collected on one occasion, while detailed seasonal data were collected on aquatic invertebrates and fish. The main limitation for use in the operation of Maguga Dam of this study was that no alternative scenarios were considered, and the recommendations were never integrated into the system operations and translated into operational rules. The recommendations were therefore never implemented.

- ***IWR Environmental 2001***. A rapid assessment was made of the IFR in quaternary catchment X11J (Gladdespruit) in 2003.

- ***Singh et al. 2003:*** A rapid assessment was made of the IFR immediately downstream of Driekoppies Dam in 2003. The assessment was based on a once-off site visit and limited hydraulics.

1.3 OBJECTIVES OF THIS STUDY

The objectives of this study were as follows:

- **Groundwater Scoping:** To clarify the need for a groundwater study, based on a review of available information, focusing on the significance of groundwater to wetlands and surface flows, and the importance of groundwater to current and potential users in the catchment;

- **Wetlands Scoping:** To clarify the need for a wetland study, based on a review of available information, focussing on the ecological importance of wetlands in the catchment, and the links between wetlands, rivers and groundwater;

- **Delineate Resource Units:** To delineate the Study Area into Resource Units and to describe how and why Resource Units were selected;

- **Select Sites:** To select suitable sites needed to determine the EWR within each Resource Unit, and to describe how and why the sites were selected.

- ***Present Ecological State (PES):*** To define Reference Conditions and classify each Resource Unit in which EWR sites were selected, in terms of the PES of the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), and to integrate the PES results of individual ecological components into an overall EcoStatus;

- ***Recommended Ecological Category (REC) and alternatives:*** To recommend an Ecological Category and alternative categories, based on the results of the PES, an assessment of the trends (changes) that are likely to take place assuming no change in current conditions, the Ecological Importance and Sensitivity (EIS), Socio-cultural Importance (SI), as well as an assessment of practicality of improving ecological conditions;

- ***Ecological Water Requirements:*** To recommend and motivate specific low and high flows for maintaining ecological conditions within a specific ecological category, and to present the results in the form of assurance rules for each selected EWR site for each month of the year and for each EC assessed;

- **Operational Scenarios:** To develop a range of practical, operational flow scenarios, taking into account the user demands, system constraints, international obligations and EWR variations.

- ***Ecological and Socioeconomic Implications:*** To assess the ecological and socioeconomic implications of the various operational flow scenarios, and to recommend a scenario in which the impacts on ecology and socioeconomics are minimised.

- ***Ecological Reserve***: To define the Ecological Reserve, based on the recommend operational scenario;

- ***Monitoring*****:** To assess the suitability of available data for defining baseline conditions for Ecological Reserve monitoring; to recommend additional baseline data requirements, if needed; to define the Ecological Specifications (EcoSpecs) and associated Thresholds of Potential Concern (TPCs) for each monitoring site;

- **Capacity Building:** To train persons from previously disadvantaged communities in specific aspects of assessing Ecological Water Requirements.

2. STUDY AREA

2.1 GENERAL DESCRIPTION

The Study Area for this project was originally defined by the D: RDM as the Komati River Catchment (X1) within South Africa. In January 2005 the study was extended to include Catchment X1 within Swaziland. The study focussed on the Komati River and main tributaries, namely: Lomati, Teespruit, Gladdespruit and Seekoeispruit (see Figure 2-1). Catchment X1 covers the Komati River Catchment until its confluence with the Crocodile River near Komatipoort, which covers a total area of about 11 209 km^2. The area comprises three main physiographic regions:

1) **Highveld,** characterised by grassland vegetation, low gradient headwater streams and moderate rainfall. Landuse here is dominated by small-stock grazing and dryland maize, with a high potential for coal mining;

2) **Middleveld,** characterised by open savanna vegetation, high gradient foothill streams and high rainfall. Landuse here is dominated by silviculture, ecotourism, mining, small stands of irrigated agriculture and large-stock grazing;

3) **Lowveld,** characterised by open savanna, low gradient sand-bed streams and low rainfall. Landuse here is dominated irrigated agriculture (mainly sugarcane) and large-stock grazing.

2.2 CLIMATE

The Study Area has a summer rainfall, with most rainfall occurring between October to April. The Mean Annual Precipitation varies from about 550 mm near Komatipoort in the east, to about 1400 mm in the Barberton Mountainlands, north of Swaziland (Africon 2003). Mean annual Class A-pan evaporation varies between 1 700 and 1 900 mm (Africon 2003). Frost occurs in the winter throughout the catchment, except in the far eastern parts. The period of heavy frost stretches from June to early August (Africon 2003). The coefficient of variation (CV) for the MAP is 24 % (Africon 2003).

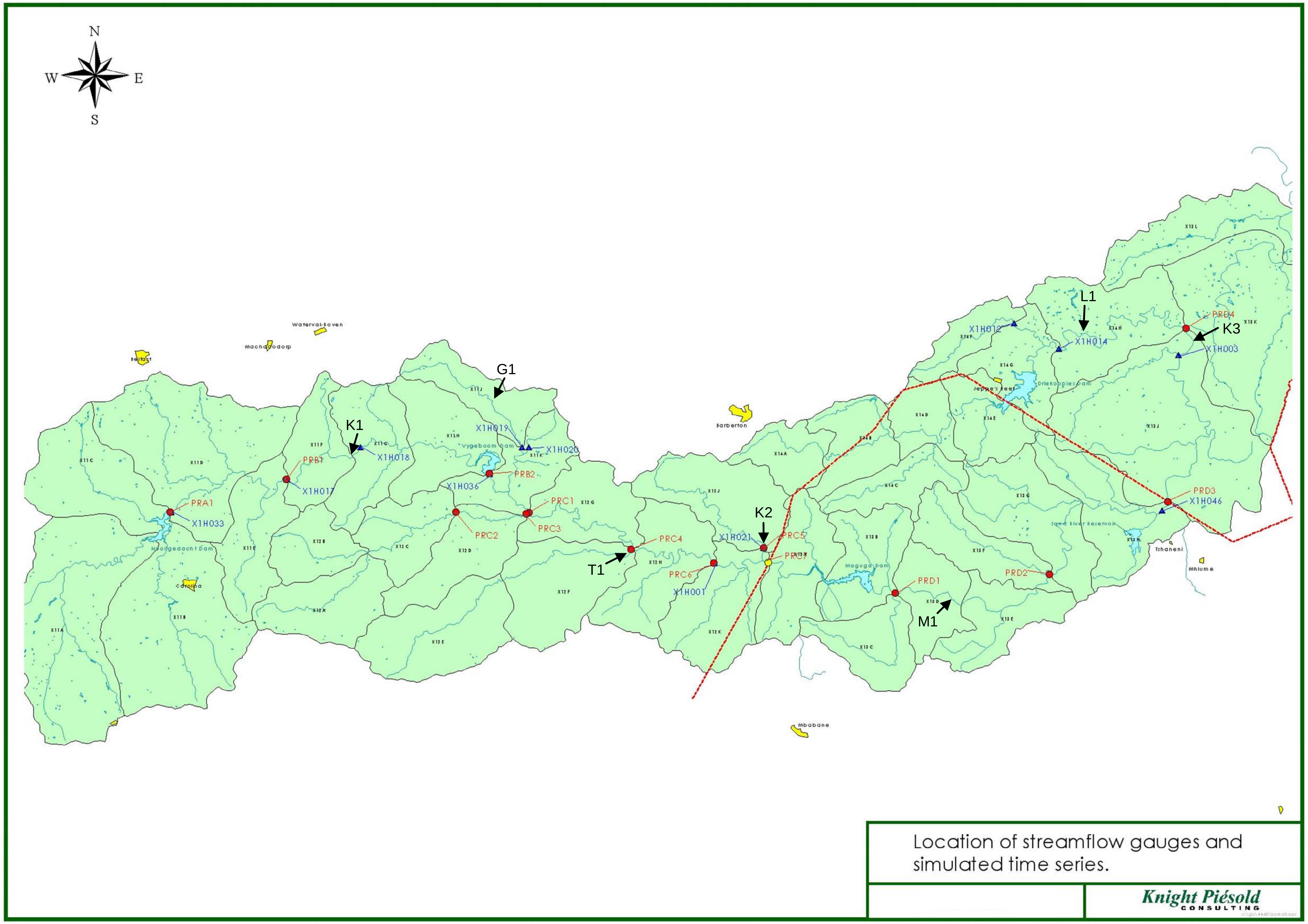

Figure 2-1. General locality map of the Komati River Catchment in South Africa and Swaziland, showing the main towns, rivers, dams, quaternary catchments, gauging weirs, key points used in the hydrological analysis, and EWR sites.

2.3 SYSTEM OPERATION

For operational purposes the Study Area is divided into two operational segments: Upper Komati and Lower Komati. The following section summarises the operation of these two regions.

a) Upper Komati

Bulk water management in the upper Komati River is driven mainly be two large dams (Nooitgedacht and Vygeboom), and two diversion weirs (Gemsbokhoek and Vriesland). The system was designed mainly to provide water for cooling of power stations, located in the adjacent Olifants River Catchment. The operating rules are designed to maximise yield, and this is achieved by first using water from Vygeboom Dam (the lowermost dam) and supplying the balance from the Gemsbokhoek Weir, and then Nooitgedacht Dam (the uppermost dam). Water is also diverted from the Gladdespruit into the Vygeboom Dam, via the Vriesland Diversion Weir. The volume of water that is abstracted from the system depends on the available water through inter-basin transfers from the incremental catchment of the east-Vaal Subsystem, which includes the upper Vaal, upper Usutu and upper Vaal Rivers. At times water is imported from the adjacent Usutu River Catchment into Nooitgedacht Dam, but for most of the time transfers from Nooitgedacht and Vygeboom Dams to the Olifants River Catchment constitute the main water use of this sub-area. There is a large afforested area which has a significant impact on the available yield. The other significant water use is irrigation, while domestic water use is very limited. Under current operating conditions, there is an apparent surplus of water available in this sub-area. However, making provision for the Ecological Reserve results in a deficit. The key issue in this sub-area is the transfer of water out of the Komati River Catchment into the Olifants River Catchment.

b) Lower Komati

There are two main dams in the Lower Komati River System: Maguga Dam (in Swaziland) and Driekoppies Dam, both operated by the Komati Basin Water Authority (KOBWA). Both dams were built with the primary intention of providing irrigation water, mainly for sugarcane. Under the current demand scenario, Maguga Dam is predicted to be drawn down to dead storage roughly every four to eight years, and at times can remain at these levels for periods of up to three years. Driekoppies Dam is situated on the Lomati River, and its main purpose is to stabilise river flows, provide for the increase in primary water demand, to allow for moderate increase in irrigation development, and assure water supplies to existing irrigation and urban development in the lower Komati Basin. Until such a time as Maguga Dam has sufficient water to supply the lower Komati River, Driekoppies Dam is being used to supply demands as far as Komatipoort. This means that baseflows in the lower Lomati River are higher than usual. A large number of weirs were built in the lower Komati and Lomati Rivers, mainly between 1984 and 1992. Some of the weirs are over 7m high, and are therefore significant storage facilities, but most do no have adequate outlet discharge capacities. The weirs therefore pose significant problems to the management of these rivers, particularly during low-flows, when it becomes increasingly difficult to meet downstream requirements and international obligations. The diversion canal at IYSIS Weir, in Swaziland, has a maximum capacity of about 9.7 m^3/s, which means that the weir can, at times, divert the entire flow of the Komati River.

3. METHODS

3.1 APPROACH

This study followed the generic 8-step process to Reserve determination, detailed in Figure 3-2.

3.2 LEVEL OF DETAIL

This study followed comprehensive methods for EcoClassification and for quality and quantity determination. The level of detail for the wetlands and groundwater components were at a scoping level only.

3.3 SCHEDULE

This study was conducted over a three year period, starting with calls for tender in December 2002 (Figure 3-1). Consultants were appointed in April 2003, and an Inception Report was drafted in May 2003. The Inception Report was accepted in July 2004, although the Study Area was delineated into Resource Units and sites were selected in August 2003. Primary data collection took place between August 2003 and April 2004. The EWR was quantified at Specialist Meetings held in October 2004 and February 2005. Operational scenarios were developed during a series of meetings between October 2004 and May 2005. The ecological and economic consequences of the various scenarios were assessed at a workshop held in September 2005. A decision on the resource classification was taken in September 2005, and this was followed by a Specialist Meeting on Monitoring and EcoSpecs in November 2005. Reports were finalised in March 2006.

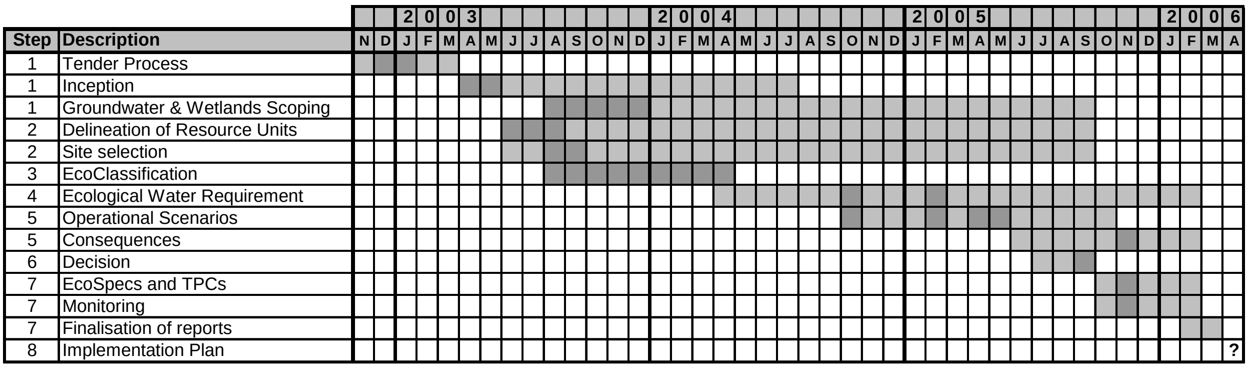

Figure 3-1. Summary of the study schedule.

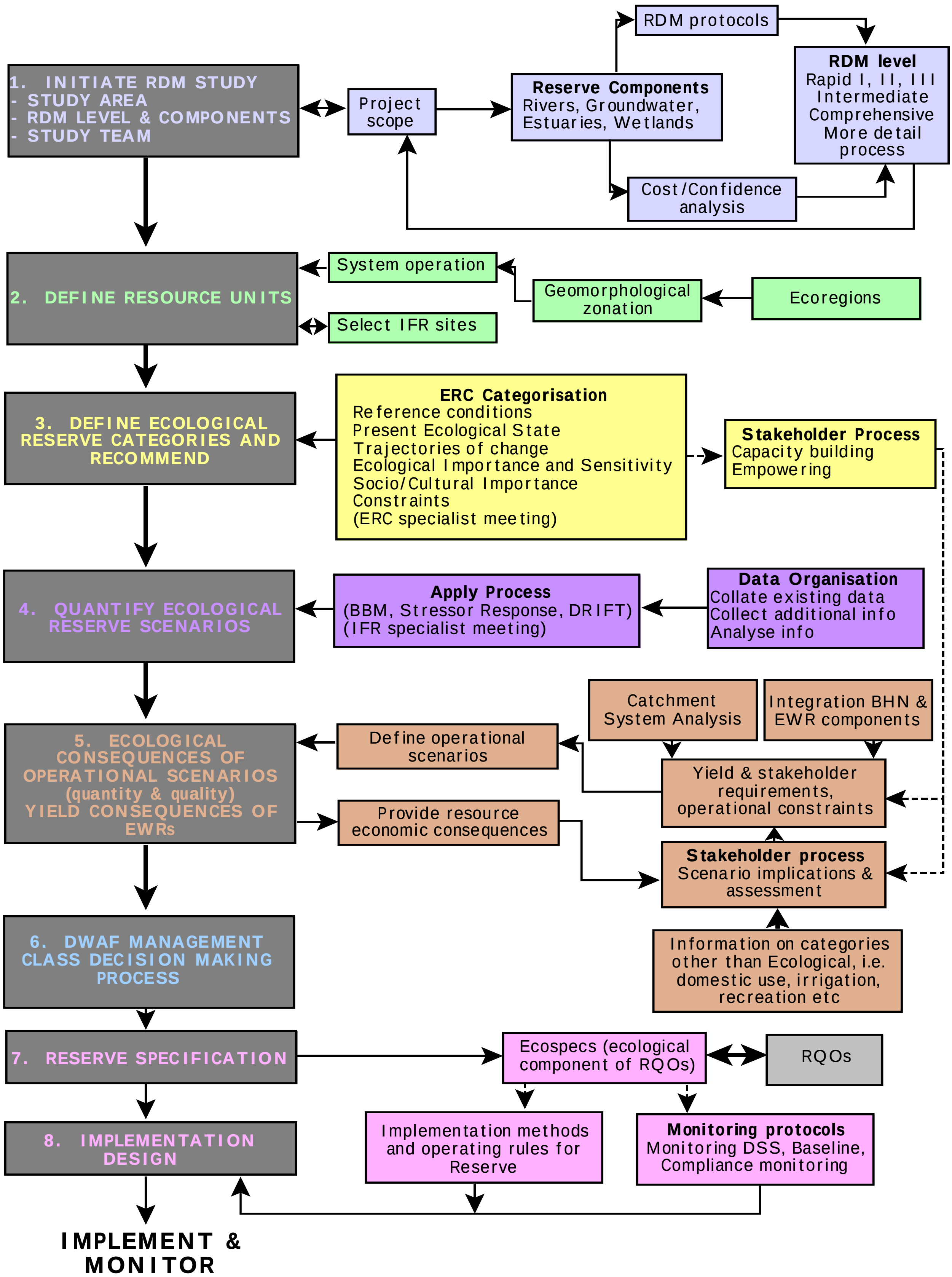

Figure 3-2: The generic 8-step Ecological Reserve Procedure (from DWAF 2003).

3.4 ASSOCIATED STUDIES

3.4.1 Letaba EWR

This study was conducted in parallel to an equivalent study on the Letaba River, conducted by Pulles, Howard and de Lange Inc. Both studies were managed by the same management team, Tlou & Matji. This ensured that the methods used on the two projects were standardised.

3.4.2 Komati Basin Water Authority

The Komati Basin Water Authority (KOBWA) initiated a study to monitor EWRs in the lower Komati and Lomati Rivers (AfriDev 2004). The study involved quarterly monitoring on five occasions of selected indicators, starting in November 2003. Components monitored included water quality, riparian vegetation, aquatic invertebrates, fish and geomorphology, and this information contributed to the EWR study.

3.4.3 Mpumalanga Parks Board

The Mpumalanga Parks Board collected additional data on fish and invertebrates from selected sites in the Komati Basin as part of their routine monitoring. The focus of the work was to quantify the impacts of diversion weirs, such as Tonga, on the abundance and diversity of fish and aquatic invertebrates. This provided useful information on how the biota responds to changes in flow caused by weirs.

3.4.4 EcoClassification

Parallel to these studies, DWAF RQS and Water for Africa were developing comprehensive procedures and developing rule-based models to determine the Ecological categories of the driver and response components as well as the integrated state, the EcoStatus (Kleynhans *et al.* 2005).

3.5 ASSUMPTIONS AND LIMITATIONS

- ***Basic Human Needs:*** This study did not assess the Basic Human Needs component of the Reserve, as this fell beyond the Terms of Reference.

- ***Stakeholders:*** Stakeholder involvement was not included in this study as this fell beyond the Terms of Reference. However, the Swaziland Water Resources Branch and KOBWA participated in a Steering Committee.

- ***EWR Sites****:* Ideally, the EWR within each Resource Unit should be based on data collected from at least one site within each Resource Unit. However, in this study EWR sites could not be selected in all Resource Units because of funding constraints.

- ***Hydraulics:*** This study was conducted during a prolonged drought, and so confidence in high flow assessments was low as no high flows for hydraulic calibration purposes were experienced during the course of the study.

- ***Hydrology:*** The hydrology data used in this study were based on time series used by Ninham Shand, from hydrology data generated by Chunnet Fourie. These were the best available hydrological data at the time, and although the time series were representative of the sorts of flows that would be expected, it was acknowledged that demand patterns are likely to be significantly different to what was included in the model. A study to revise the hydrology of the Komati River was commissioned by DWAF in 2005, but the results were not available in time for this study.

  The Water Resource Yield Model (2000) was used to assess the impact on yield of the EWR for the Recommended Ecological Category (REC), and alternative categories. A limitation of the model is that output is presented as monthly flows. This makes it difficult to distinguish between high and low flow components that were specified as EWR requirements during months where both low flows and high flows were specified. Therefore, this did not pose a significant problem for assessing the dry season low flow component because monthly flows could be converted to m^3/s. However, dry season requirements for the Komati River did include some small floods, so the stress duration curves for the scenarios do not exactly equate to stresses that were recommended by the ecologists.

  The system was modelled with and without the lowest point in the river, at Komatipoort, included as an EWR demand, but it was acknowledged that supplying an EWR to the lower reaches was probably ecologically unjustified, as most of the river downstream of Tonga has been converted into a series of standing pools by a large number of weirs.

  Another assumption of the hydrology modelling was that the releases made from the dams were assumed to be met at EWR sites (i.e., the model assumed no attenuation in peak flow with distance downstream). This assumption is clearly inaccurate for sites that are located far downstream of dams, such as K3 (Tonga). Furthermore, the maximum outlet capacities used in the model assumed that the dams were at full supply.

- ***Classification System.*** No classification system as required by the National Water Act exists for integrating the results of the ecological and socioeconomic consequences to decide on the Management Class.

- ***Monitoring Plan.*** This report provides the basis for developing a monitoring plan, but it does not address monitoring requirements or implementation as this requires the development of operational rules, negotiation with and commitment by relevant management agencies, and a comprehensive Decision Support System that allocates responsibilities, and specifies the actions that should be taken in the event of non-compliance. These aspects fell beyond the scope of this study.

4. GROUNDWATER SCOPING

4.1 INTRODUCTION

Groundwater forms an integral part of the hydrological cycle, and plays a key role by contributing to river baseflows and supplying water to vegetation. A comprehensive assessment of EWR should therefore include an assessment of groundwater contributions and its ecological functions.

4.2 AIMS

The primary aim of the Groundwater Scoping Study was to clarify the need for an assessment of the groundwater component of the EWR for the Komati River Catchment within South Africa. The specific aims of the study were:

- to review and assess the availability and reliability of available relevant information on groundwater in the Study Area;
- To assess the importance of groundwater in the Komati River Catchment in terms of current use, proposed future use, contribution to surface flow and the degree of groundwater stress;
- To assess at a reconnaissance level of detail, the interaction between groundwater and surface water resources;
- To delineate Groundwater Resource Units;
- To prepare a Scope of Work for an appropriate level of study for the future use of the groundwater Ecological Water Requirement, should this be necessary.

4.3 METHODS

The study was largely literature-based, and the main sources of information were:

- hydro-geological, topographical and geological maps;
- aerial photographs;
- the National Groundwater Database (NGDB);
- hydrochemical data;
- aquifer parameters, recharge, base flow (ecological role);
- groundwater vulnerability;
- review of population census data and population density maps. This gave an indication of the reliance of communities on groundwater.
- land-use information, such as large-scale agricultural, industrial and mining related activities reliant on groundwater.

The groundwater characteristics of the catchment were investigated by reviewing aspects such as the different types of aquifers present across the catchment and the characteristics of each aquifer; the yields of the boreholes intercepting the identified geological units, water level data recorded in boreholes, the hydrochemistry of the aquifer units as observed in the boreholes, recharge to the groundwater system from rainfall and baseflow (i.e., the groundwater component of river flow).

4.4 RESULTS

4.4.1 Data Available

This study highlighted major shortfalls in that the data available from the NGDB, and this formed the basis of recommending more detailed assessment.

4.4.2 Catchment Characteristics

From the data that were available, the following characteristics for the catchment could be derived:

Aquifers: The Komati River Catchment displays different types of aquifers, including Karoo, granite, dolomite and quaternary aquifers. Shallow weathered aquifers occur for most part of the catchment. Secondary aquifers include the deep fractured aquifers of the sedimentary, igneous and metamorphic rocks of the catchment geology. Quaternary aquifers as observed to the north of Carolina, the Pretoria Group, Barberton Sequence and migmatites and gneisses to the east of the catchment represent major aquifers. These aquifers represent homogenous aquifer systems that are susceptible to contamination.

Yields: The Ecca and Pretoria Group sediments have average yield of 1.22l/s. The gneiss, migmatite and granite aquifers have an average yield of 0.83l/s. Aquifers in the Barberton lithologies have yields ranging from 3.5 to 24.7l/s which are unrealistic for the aquifer type, whilst the eastern catchment aquifers of the Lowveld granites and the Lebombo Group have yields of 0.4 and 1.4 l/s respectively.

Water levels: The western areas display average levels of 10 to 15 m in the Karoo and Pretoria sediments. The central areas underlain by gneisses, migmatites and granites as well as the Barberton lithologies have average water levels of 15 m. The Lowveld granites and the Lebombo lithologies display average water levels of 22 m (70 % of boreholes) and 32 m (90 % of boreholes) respectively. Therefore there is a general trend of deepening water levels from the west to the east.

Water quality: The water quality data indicates elevated conductivities and nitrates in the eastern part (Lebombo lithologies).

Recharge: Groundwater recharge is, on average, between 5 and 10 % of the Mean Annual Rainfall for the area. However, the contribution of rainfall to recharge of the groundwater is less than 3 % in the eastern part of the catchment. These recharge values are unusually high There are possible errors with the recharge data.

Baseflow: The baseflow component to rivers is negligible in the eastern part of the catchment. The aquifers of the Barberton lithologies and the migmatites, gneisses and granites, Pretoria Group show higher baseflow values than the Ecca Group aquifers. This implies that the contribution of the groundwater to stream flow or surface flows is greatest for the Barberton lithologies. Similar contributions are evident by aquifers in the migmatites and gneisses and granites and the Pretoria Group lithologies. The Ecca Group lithologies have a lesser contribution to surface water flows. There is little or no contribution of the Lebombo lithologies to the baseflow component of rivers.

4.5 IMPORTANCE OF GROUNDWATER IN THE CATCHMENT

Census data for 1996 and 2001 was reviewed. The general trend from the census data is a decreased reliance on groundwater from 1996 to 2001. However, this does not relate to quantities abstracted by the existing users. Not much information is available on abstraction volumes in the different aquifers.

In the Nkomazi Local Municipality (Lebombo lithologies), the number of people involved in agriculture and forestry doubled between 1996 and 2001. The increased nitrate concentration for this part of the catchment can be related to the increased use of fertilizers and livestock grazing along riverbeds.

The use of flush and chemical toilets increased across the catchment. Increasing use of septic tanks, bucket and pit latrines and no sanitation was observed for the following local municipalities: Nkomazi, Umjindi and Carolina. This can account for the increased nitrate concentrations in the east of the catchment.

There is coal mining around Carolina, where most (85 %) of the recorded boreholes have water levels shallower than 15 m. The coal mining areas around Carolina pose a serious threat to the water quality in the Komati Catchment. This threat is lessened by slow migration rates and low aquifer permeability. Long-term effects on the baseflow could however be severe.

The current and future status of mining activities within the catchment can be determined through a detailed and extensive desk study that will form part of the methodology used for the comprehensive Ecological Water Requirement study for groundwater.

4.5.1 Interaction between Groundwater and the Surface Water Resources

The Highveld sediments display perched water tables in the vadose zone, forming seeps. This leads to the formation of open plain wetlands. There is a direct contribution to surface water in this respect.

The Lowveld granites are highly fractured and intruded by diabase/dolerite. This leads to the formation of underground dams, springs and large seep zones at the surface. There is a direct contribution to surface water.

The Lebombo lithologies contribute groundwater in the form of baseflow to rivers (Figure 4-1). The groundwater is intersected by the river and flows out on a rocky base. The groundwater to surface water relationship in the Barberton lithologies, gneiss, migmatite and granite in the west of the catchment is unknown and warrants further investigations.

4.5.2 Preliminary Delineation of Groundwater Resource Units

A preliminary delineation of Groundwater Resource Units (Figure 4-2) was based on the geological formations, and their contribution to the surface water bodies. A geological classification is appropriate, due to the varying nature of aquifers according to geologic formation, and the observed interaction with the surface water bodies. The Study Area was divided into five Groundwater Units as follows:

A – Escarpment Complex (Ecca and Pretoria Groups and Dolomites);
B – Gneiss (Includes migmatite and granite);
C – Barberton Mountainland System;
D – Lowveld Granite; and
E – Lebombo Group (includes Karoo lithologies).

4.6 RECOMMENDATIONS

The following recommendations were made:

1. A detailed investigation of the groundwater EWR was recommended and a proposed Scope of Work for this was presented. Due to the incompleteness of the data available for the study and the low confidence levels of the data, a methodology for additional data collection and classification was proposed.
2. The GIS, NGDB and Hydrochemical Databases should be streamlined with a similar structure so that data are consistent for a given area and databases are complete.
3. Water quality and water levels of the different aquifers distributed across the catchment should be monitored.
4. A hydrocensus of existing boreholes in areas of mining, industries along river courses or any land use activity impacting on the groundwater system should be undertaken to identify suitably positioned monitoring points.
5. Major aquifer systems such as the dolomites to the east of the Pretoria Group sediments need to be monitored in terms of fluctuating water levels and water quality, and the hot springs of the Badplaas area need to be specially investigated.
6. Monitoring of water levels and water quality needs to be undertaken.

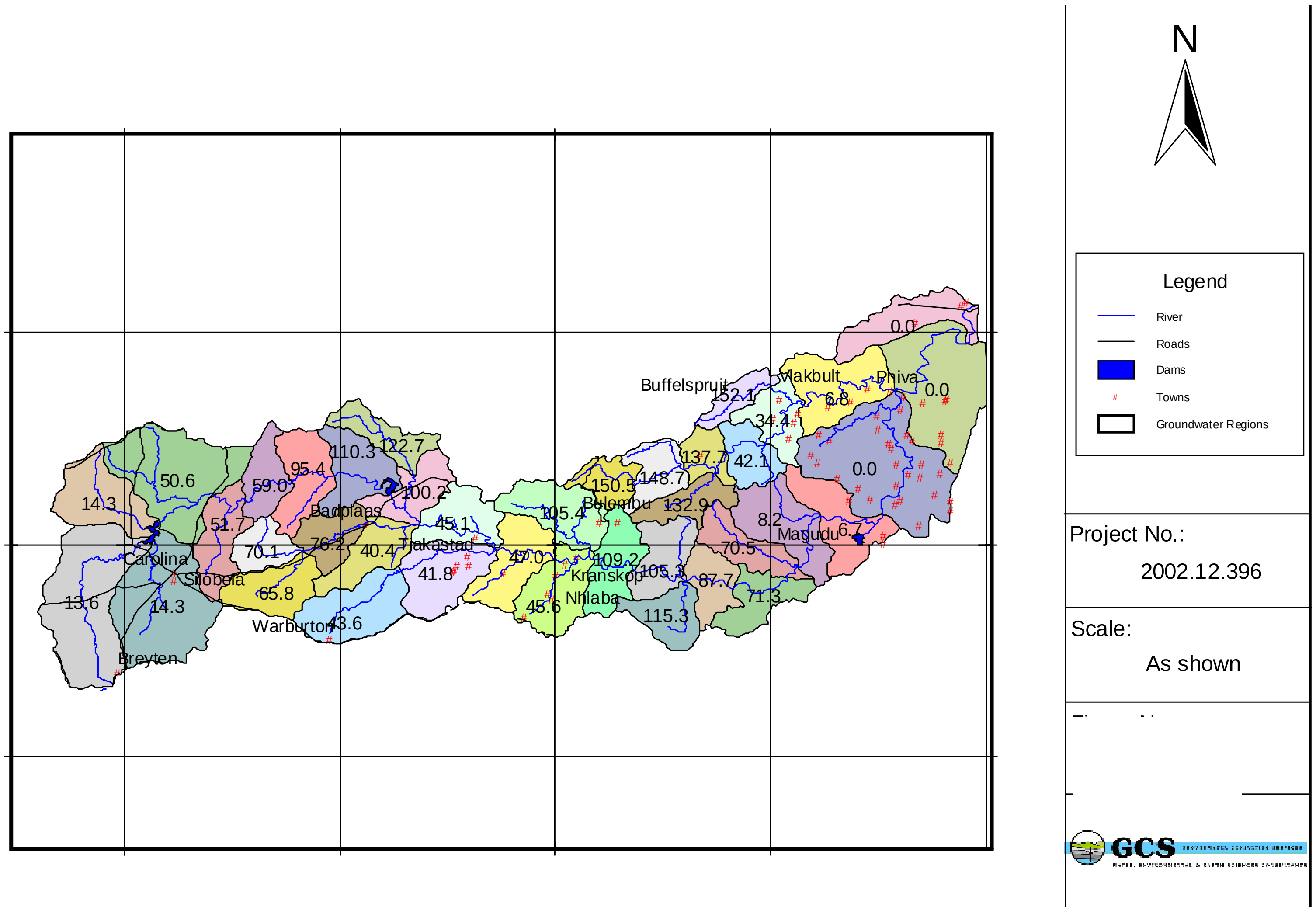

Figure 4-1. Map of The Komati River Catchment, showing the contribution of each quaternary catchment to baseflows, expressed in mm/a.

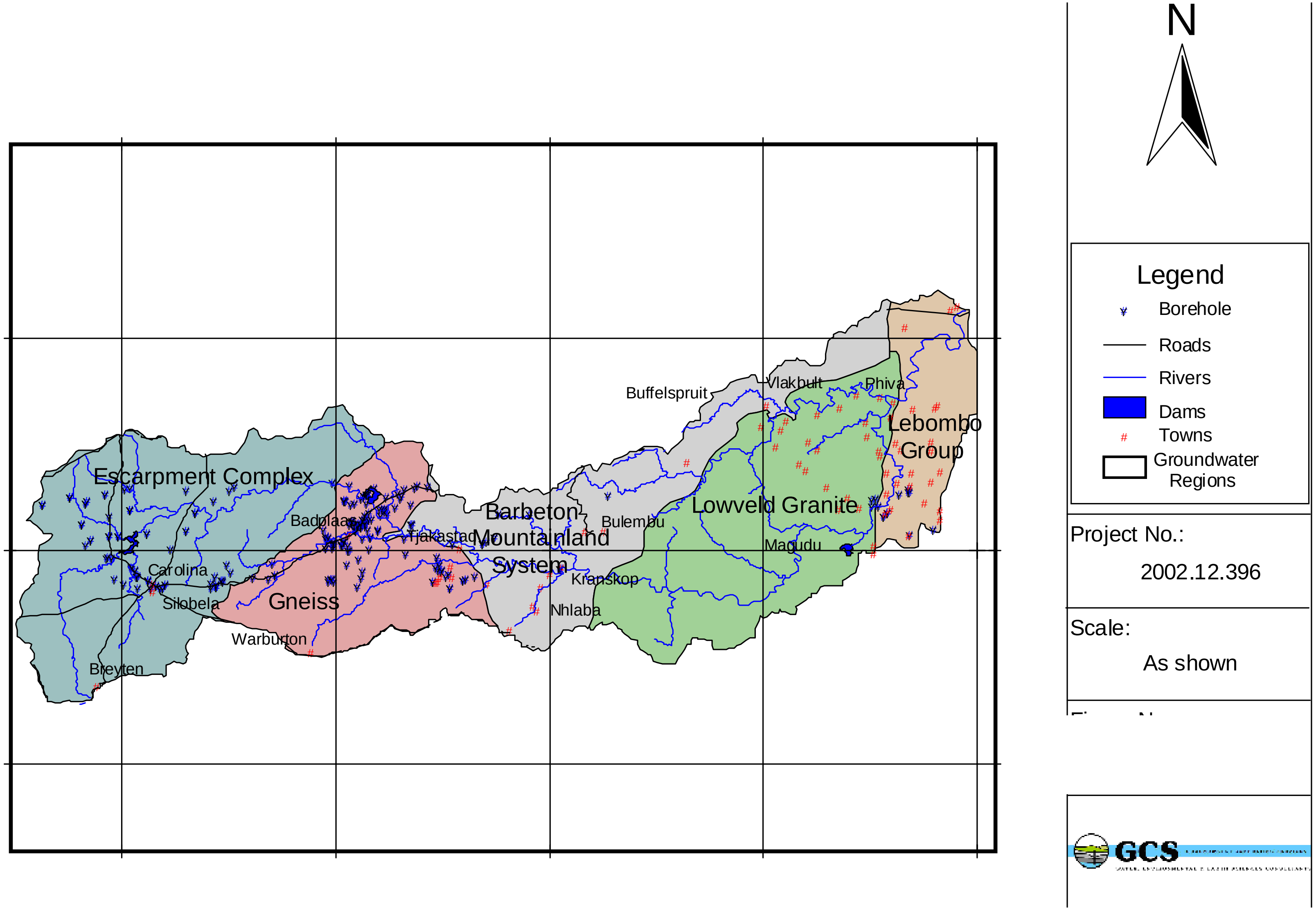

Figure 4-2. Map of The Komati River Catchment showing preliminary delineation of groundwater Resource Units.

5. WETLANDS SCOPING

5.1 INTRODUCTION

Wetlands form an integral part of aquatic ecosystems and the hydrological cycle, and can play a key role by contributing to river baseflows and providing habitats that support aquatic biodiversity. A comprehensive assessment of EWR should therefore include an assessment of wetlands and their ecological functions.

5.2 AIMS

The primary aim of this Scoping Study was to clarify the need for an assessment of the wetland component of the EWR for the Komati River Catchment within South Africa. The specific aims of the study were:

- to review and assess the availability and reliability of available relevant information on wetlands in the Study Area;
- to assess the distribution, diversity and function of wetlands in the catchment and the interaction between surface and groundwater resources;
- to assess the ecological importance and sensitivity of wetlands in the Study Area;
- to assess the social importance of wetlands in the Study Area;
- to delineate the Study Area into ecologically similar wetland zones (Wetland Ecotypes), and;
- To develop a Scope of Work for more detailed assessment, should this be necessary.

5.3 METHODS

The study was largely literature-based and shortfalls in the data were identified. The methods used to determine the wetland component of the catchment included:

- An assessment of available geological maps, hydrogeological maps, topographical maps and aerial photographs;
- An assessment of the National Groundwater Database, hydro-chemical data, aquifer parameters, recharge, base flow (ecological role) and wetland vulnerability.

Population census data and population density maps were reviewed. These gave an indication of the reliance of communities on groundwater, which will have an impact on the associated wetlands. Land-use information such as large-scale agricultural, industrial and mining related activities that rely on, or impact on wetlands, was sourced.

The wetland characteristics of the catchment were investigated by reviewing aspects such as the different types and classes of wetlands present across the catchment from the 1:50 000 scale topocadastral maps and other existing projects, and analyzing the characteristics of each class within an identified geological unit. In addition, the interaction of the wetlands with the groundwater zone was noted. Water chemistry and potential impacts on wetlands by industry and/or mining were also noted.

5.4 RESULTS

Importance of Wetlands in the Catchment

The general trend from the 1996 and 2001 census data was a decreased reliance on groundwater, and thus a lowering of the impact on wetlands though the groundwater systems. However, this does not relate to the surface runoff and impacts relating to increases in the population and the increase in industrial, mining and forestry undertakings. In the Nkomazi Local Municipality (Lebombo lithologies), the number of people involved in agriculture and forestry doubled between 1996 and 2001. The increased nitrate concentration in the groundwater for this part of the catchment can be related to the increased use of fertilizers and livestock grazing along riverbeds and wetland environments.

Interaction between Wetland and the Surface Water Resources

The results of a two-day field trip helped to delineate the processes involved in the interaction of the wetlands with the surface water regime. The sediments associated with the highveld area display perched water tables in the vadose zone, forming seeps that contribute to the formation of open plain wetlands. There is a direct contribution to surface water in this situation. The Lowveld granites are highly fractured and intruded by diabase/dolerite. This leads to the formation of underground dams, springs and large seep zones at the surface. There is a direct contribution to surface water. The groundwater is intersected by the river and flows out on a rocky base. The groundwater to surface water relationship in the Barberton lithologies, gneiss, migmatite and granite in the west of the catchment is unknown and warrants further investigation.

The baseflow component of wetlands to the stream flow is negligible in the eastern part of the catchment associated with the Lebombo formations, as well as in the far western portion, were the area is dominated by endorheric pans. The central part of the catchment associated with wetlands derived from/sustained by the Barberton lithologies, the migmatites, gneisses and granites, and the Pretoria Group, show higher baseflow values than the Ecca Group lithologies. This implies (at this level of study) that the contribution of the groundwater to stream flow or surface flows though the wetland system is greatest for the Barberton lithologies.

Wetland Classification

The Komati River Catchment has a number of differing wetland types that contribute to the system. These include the Palustrine class wetlands of the “Hillside Seepage” type, and some “Pans”, typically associated with the sedimentary deposits that are underlain at shallow depths by ferricrete layers, “Drainage line” wetland types associated with the granite and meta-sediments within the lower lying areas of the catchment, and often associated with intrusive bodies within the host lithologies that force groundwater to surface as springs and day-lighting water within the drainage lines, and “Flood Plain” wetlands, associated with the areas within the river course associated with the river dynamics. There are also some very specific contributions from wetland environments that are specific to geological formations, such as the dolomites and basic intrusives.

Preliminary Delineation of Wetland Ecotypes

A preliminary delineation of the Wetland Ecotypes (Figure 4-2) was based on the geological formations underlying the catchment and their contribution to the surface water bodies. A geological classification is appropriate, due to the varying nature of the wetlands according to geologic formation and the observed interaction with the surface water bodies. Five Wetland Ecotypes were designated. These were:

A – Escarpment Complex (Ecca and Pretoria Groups and Dolomites);
B – Gneiss (Includes migmatite and granite);
C – Barberton Mountainland System;
D – Lowveld Granite, and;
E – Lebombo Group (includes Karoo lithologies)

5.5 RECOMMENDATIONS

The lack of sufficient and reliable data was the main reason for the additional investigations proposed, and in particular, the mapping of the wetlands and the designation of wetland types. The methods for wetland EWR assessment are not available for all wetland types but are under development, so the proposed Scope of Work was divided into two phases: Phase I focuses on delineation, classification, EcoStatus assessment, the recommended Ecological Categories, and developing a Scope of Work for the second phase. Phase II includes the EWR assessment, ecological and socio-economic implications, monitoring and implementation.

6. HYDROLOGY

6.1 INTRODUCTION

The basis for the time series derived for the EWR sites was daily observed records for the streamflow gauges in the catchment that were obtained from DWAF, daily simulated time series prepared by Prof. D Hughes for ther Maguga Dam IFR study, and simulated monthly time series derived for the Water Resources Yield Model (WRYM). The flood analyses were based on the peak discharge data supplied by DWAF for the streamflow gauges. Daily streamflow records and peak discharge data were obtained from DWAF for the streamflow gauges in the catchment. Relevant information regarding these gauges is listed in Table 6-1.

Table 6-1. Streamflow gauges in the Komati River Catchment.

Gauge	Name	River	Catchment area (km^2)	Period	Percent complete
X1H033	Nooitgedacht	Komati	1 570	1 Aug 1959 to 2 Dec 2002	95
X1H017	Waterval	Komati	2 400	26 Oct 1971 to 2 Dec 2002	96
X1H018	Gemsbokhoek	Komati	2 582	1 Aug 1972 to 25 Sep 1972	98
X1H036	Vygeboom	Komati	3 112	30 Jun 1972 to 7 Feb 1974	100
X1H001	Hooggenoeg	Komati	5 499	1 Oct 1909 to 2 Dec 2002	92
X1H003	Tonga	Komati	8 614	4 Oct 1939 to 12 Nov 2002	94
X1H014	Lomati	Lomati	1 119	2 Aug 1968 to 11 Feb 2003	87
X1H012	Rusoord	Mhlambanyati	114	12 May 1967 to 18 Dec 1991	88
X1H019	Vriesland	Gladdespruit	186	7 Sep 1973 to 27 Aug 2002	98
X1H020	Vriesland	Poponyane	48	15 Sep 1973 to 3 Dec 2002	97
X1H021	Diepgezet	Mtsoli	295	8 Oct 1975 to 4 Jun 2002	97

The observed records for these gauges are not stationary due to development in the catchment, particularly large dams and abstractions. Simulated daily streamflow time series for the period 1960 to 1995 were obtained from Prof. D Hughes. The location of these time series is shown on Figure 2-1 and the statistics of the present day (1995) and natural time series are summarised in Table 6-2.

Monthly streamflow time series were determined in the 1980's for the Komati River catchment by Chunnet Fourie and Partners (now BKS) for the period 1921 to 1987. These time series were extended by Ninham Shand to the end of the 1995 hydrological year, as part of the Maguga Dam study for KOBWA. In 2002 Knight Piésold extended the time series to the end of the 1999 hydrological year as part of a study for the Swaziland Government Water Resources Branch. The above information formed the basis for generating streamflow time series at the EWR sites.

Table 6-2. Summary of simulated daily streamflow time series at selected nodes.

Catchment*	MAR (Mm^3)	
	Natural	Present day
PRA1	63.356	48.944
PRB1	129.392	78.525
PRB2	266.731	200.411
PRC1	314.918	112.993
PRC2	87.197	71.618
PRC3	114.003	95.270
PRC4	506.153	271.903
PRC5	73.479	54.589
PRC6	547.780	313.089
PRC7	673.609	419.113
PRD1	801.014	526.651
PRD2	939.773	652.164
PRD3	974.462	562.918
PRD4	987.077	560.710

* Catchment locations are shown in Figure 2-1.

6.1.1 Streamflow Time Series

Streamflow time series are required at the EWR sites to assess the temporal and seasonal variation in flow. Monthly natural and present day time series were generated for all the EWR sites using information from the Komati Catchment System Analysis Model. Daily flow records and simulated flows were used to generate daily present day time series at the EWR sites.

Streamflow Time Series

The WRYM system analysis model, set up for the Maguga Dam study with water demands updated in 2001, was modified to allow streamflow time series to be generated at the EWR sites and other key locations. The statistical properties of the natural and present day time series are summarised in Table 6-3.

Table 6-3. Statistical properties of streamflow time series.

Location	Naturalised time series			Present day time series		
	MAR (Mm^3/a)	Standard Dev (Mm^3)	Seasonal Index	MAR (Mm^3/a)	Standard Dev (Mm^3)	Seasonal index
EWR SITES						
K1	181.17	107.08	33.46	128.48	58.68	27.31
K2	527.16	280.83	31.93	304.82	229.86	34.47
K3	1016.48	561.28	30.28	384.87	464.54	40.10
K4	1370.69	779.34	30.25	541.09	652.43	39.65
G1	37.73	20.31	32.09	26.40	15.08	31.61
L1	321.65	203.67	29.27	218.48	172.14	25.79
T1	60.59	31.50	31.62	48.65	25.97	30.95
M1	857.10	451.29	29.88	599.90	343.48	21.74
SEGMENT BOUNDARIES *						
8	60.21	54.29	39.48	Usage small and unknown		
28	240.75	135.71	32.72	188.05	87.53	28.59

48	673.35	349.65	30.38	433.84	291.60	31.32
L6	266.24	157.56	28.63	152.45	101.45	28.27
L29	354.21	238.20	30.14	159.11	208.79	38.74
LK33	1016.48	561.28	30.28	384.87	464.54	40.10
LK44	1397.87	810.38	30.45	421.07	692.30	51.63
G8	38.30	20.21	32.14	11.96	10.98	47.46
T8	60.59	31.50	31.62	48.65	25.97	30.95
S8	111.17	57.04	31.51	Usage small and unknown		

* Segment boundaries are described in the Resource Unit Report.

6.1.2 Flow Variation Based on Monthly Time Series

The natural annual variation in flow in the Komati River is shown in Figure 6-1. The figure shows that annual variability is relatively high with the annual standard deviation approximately 60% of the MAR and the lowest annual flow a bit more than a third of the nMAR.

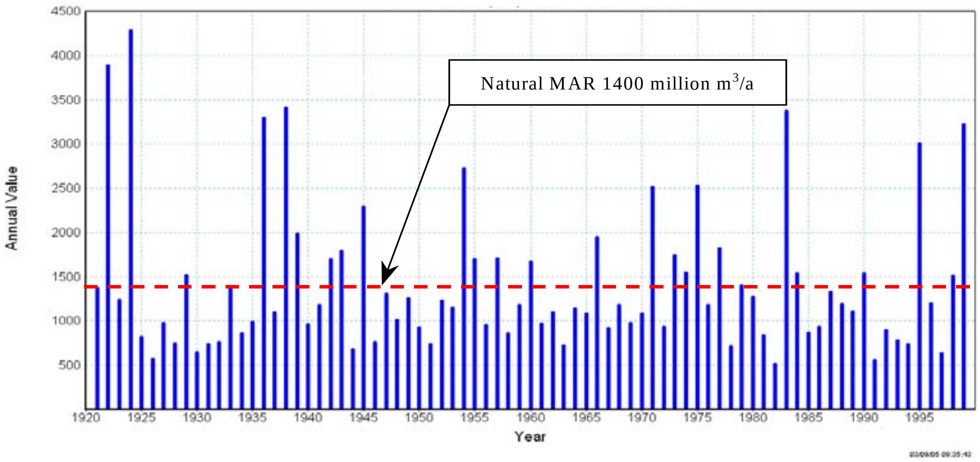

Figure 6-1. Simulated natural annual flow in the Komati River.

Figure 6-2 shows the annual flow duration curve for the Komati River at the Mozambique border. Approximately two thirds of the time annual flow is less than the nMAR. The simulated monthly natural and present day time series and the plot of simulated natural and present day annual flows are included in Appendix F.

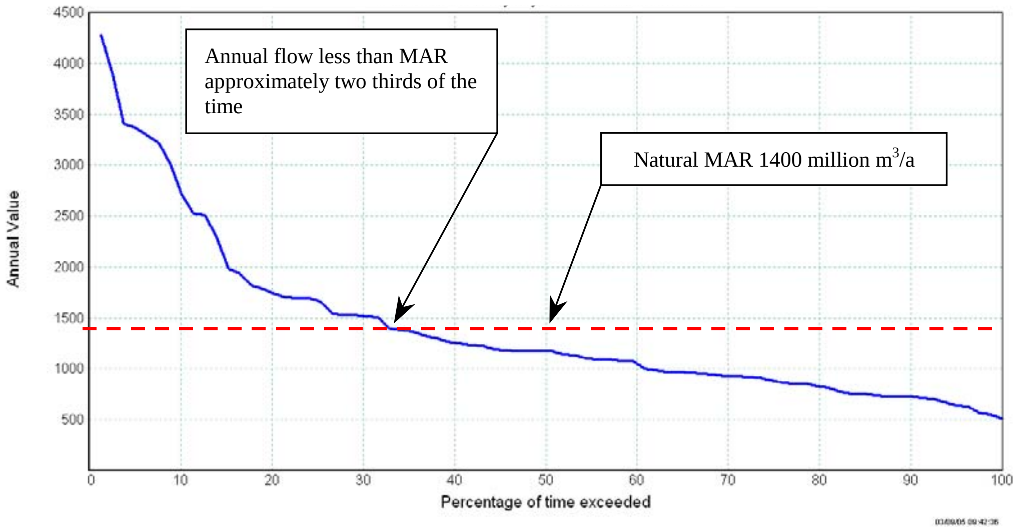

Figure 6-2. Annual flow duration curve for the Komati River.

6.1.3 Daily Streamflow time series

Daily present day streamflow time series were generated for EWR sites K1, K2 and T1 using the simulated daily streamflow supplied by Prof. D Hughes. For the other EWR sites no simulated time were available. Daily time series were derived from the observed records for these sites. The daily information is available in digital format as text files or in the SPATSIM database set up for the project.

6.1.4 Flood Analysis

Analyses were done to estimate flood peaks at the seven EWR sites using the available streamflow data. Monthly instantaneous peak discharges were provided by DWAF for five gauges. The periods of these records are listed in Table 6-4.

Table 6-4. Gauges analysed in flood peak analysis.

Gauge No.	Period of peak discharge data		Number of years
	start	End	
X1H001	1909	2001	93
X1H003	1939	2001	63
X1H017	1971	2002	32
X1H033	1959	2002	44
X1H036	1972	2002	31

6.1.5 Flood peak discharge analysis

Statistical analysis of the flood peaks was done using the PC program RegFlood for Windows. The aim of the statistical analysis was to determine a suitable relationship between flood peak discharge and catchment area for a range of return periods that could be used to estimate return period floods at each of the EWR sites.

Daily observed records were used to estimate the likely duration of flood flows. Storms resulting in flood events last from a few hours to a few days. Inspection of the observed daily average flow records shows that increased flows occur over a period of two to three weeks, and even longer for the largest events. This is because flood events are preceded and followed by periods of rainfall. Accordingly, typical flood events can be considered to result in elevated flows from one to two weeks in duration, with the time to peak discharge about a third of the duration.

6.1.6 Occurrence of floods

The peak discharge record for gauge X1H001 was used to assess, on the basis of historic events, the likelihood of a flood of given magnitude occurring in a particular month. The peak discharges were normalised by dividing by the 1:5 year flood peak and plotted to show the percentage of months that the normalised value was exceeded.

7. DELINEATION

7.1 INTRODUCTION

This chapter concerns the second step in the generic eight-step EWR process, which is to delineate the Study Area into Resource Units, and to select EWR sites. River ecosystems are spatially diverse, so the EWR may differ from place to place, depending on various factors such as the structure of the river bed, the natural water quality, topography, groundwater contributions and system operation etc. It is therefore necessary to delineate the Study Area into discrete units, each of which are sufficiently ecologically distinct to warrant their own EWR. These units are referred to as Resource Units (RUs).

7.2 METHODS

Delineation of Resource Units

The delineation of the Study Area into RUs was based on standard methods developed for EWR assessment in South Africa. This included a general knowledge of the Study Area, discussions with various people with local knowledge of the area, plus information on key drivers including Ecoregions (incorporating vegetation, climate, geology and physiography), system operation and hydrology, tributary characteristics, Habitat Integrity, geomorphological characteristics, groundwater zonation and water quality zonation, plus practical considerations of scale and size. Maps showing relevant features were overlain on each other to assist in identifying suitable and practical Resource Unit boundaries. The assessment of Habitat Integrity was based on helicopter surveys conducted in July 1997 (lower Komati River only) and June 2003 (upper reaches, main tributaries and lower reaches).

Selection of EWR Sites

The process for selecting suitable EWR sites was based on the method described in the BBM Manual (King *et al.* 2000). The process involved examination of aerial video footage of the river, followed by a reconnaissance site visit by two members of the study team intended to confirm suitability and determine access, followed by a site visit by a team of specialists in hydraulics, fluvial geomorphology, fish, aquatic invertebrates and riparian vegetation. The sites that were chosen represented the best compromise among reliable hydraulic characteristics, critical areas for ecological maintenance, close proximity to flow gauges, high diversity of aquatic habitats and biota, least impacted areas, ease of access, strategic importance, water demands and availability of historical data. Sites that had been used in previous EWR studies were considered in terms of their suitability, but none were found to be suitable.

7.3 RESULTS

The delineation of the Komati Catchment into RUs integrated knowledge on ecoregions, system operation, habitat integrity, geomorphology, groundwater and water quality. A brief outline is provided below:

Ecoregions

The Study Area included five revised Level 1 Ecoregions and a further eight Level II Ecoregions (*sensu* Kleynhans *et al.* 2005). Ecoregions within the Study Area followed broad topographical and altitudinal changes from west to east as follows:

- Highveld (11.02 and 11.04)
- Northern Escarpment Mountains (10.02 and 10.03)
- North Eastern Highlands (4.05 and 4.06)
- Lowveld (3.05 and 3.06)
- Lebombo Uplands (12.01)

Habitat Integrity

a) Instream

Instream Habitat Integrity of the Komati River ranged from *Natural* (Category A) in the upper reaches to *Seriously Modified* (Category E) in the lower reaches and downstream of Nooitgedacht Dam. The most serious impacts in the upper reaches were related to water abstraction and flow modifications caused by Nooitgedacht and Vygeboom Dams, while the most serious impacts in the lower reaches were related to inundation by weirs.

b) Riparian

Riparian Habitat Integrity of the Komati River ranged from *Natural* (Category A) in the upper reaches to *Critically Modified* (Category F) in the lower reaches. The most serious impacts were related to vegetation removal and inundation.

Geomorphology

The main Komati River was delineated into the following geomorphological macro-reaches:

- **Source Zone - upstream of Nooitgedacht Dam**. Low gradient stream draining an upland plateau, which is dominated by wetlands. The river has a combination of straight and meandering channels. The dominant morphology is pool-riffle sequence. Catchment slopes are covered in grasslands. Landuse is mainly commercial farming.

- **Lower Foothills** - downstream of Nooitgedacht Dam. Lower foothills stream with low to moderate gradient. Largely a meandering stream with a compound channel within a macro channel that may be activated only during infrequent floods.   Reach types include pool-riffle and pool-rapid morphology with a mixture of gravel, cobbles and bedrock. Catchment slopes are covered in grasslands and cultivated lands.

- **Upper Foothills** - Halfway between Nooitgedacht and Vygeboom dams. Rejuvenated upper foothills stream with moderate to steep gradient. Deeply incised valley (gorge) with a limited flood plain in places. Bedrock controlled channel with a mixture of gravel, cobble and boulder substrate. Pool-riffle and pool-rapid morphology dominates, with seasonal channels and secondary channels that may be activated during infrequent floods. Gravel and cobble dominated lateral bars are common. There are also frequent crossways, bridges and weirs in places where the topography is gentle. The catchment slopes are used for extensive grazing and limited crop farming. For a few kilometres upstream of the Vygeboom Dam, the topography is very gentle. Reach types include pool-rapid morphology over the bedrock with few active lateral channels.

- **Upper foothills** - downstream of Vygeboom Dam. Upper foothills river with moderately steep gradient. Bedrock dominated channel. Wide valley with secondary channels and a limited flood plain. Pool-rapid morphology dominates.

- **Lower foothills** - a few kilometres downstream of Vygeboom Dam to Kromdraai. Lower foothills with low gradient stream. The reach type is mainly mixed bedrock-cobble bed channel, with a long pool-rifle and pool-rapid morphology. Cascades, islands, fixed boulders, in-stream vegetation (sedges), secondary channels and irregular channels are common. Exposed bedrock extends to the valley slopes. A compound channel is present in some places, with an active channel contained within a macro channel that may be activated only during infrequent floods. There is a wide flood plain and catchment slopes are gentle and covered in grasslands, bushes and shrubs.

- **Upper foothills** - Kromdraai into Swaziland. Upper foothills stream with moderately steep gradient. The upper sections are similar to zone E above in terms of channel characteristics. The dominant morphology is mixed gravel and cobble bed channel with long pool-riffle sequence. The channel is mainly confined in steep sided valleys with a limited flood plain.

- **Lower foothills** - inside Swaziland. Lower foothills stream with low gradient and bedrock controlled channel. Slightly confined channel with terraces a limited floodplain. Terraces and sand bars are common. The morphology type includes long pools and riffles.

- **Lowland River** - from inside Swaziland to halfway before the Lomati confluence. Low gradient alluvial bed channel. Dominant morphology is regime type. There is a fully developed meandering pattern within a very wide flood plain. Landuse practice is mainly crop-farming, sugarcane and banana plantations.

- **Rejuvenated lower foothills** - upstream of the Lomati confluence to a few kilometres downstream. Rejuvenated lower foothills river with bedrock-controlled channel. Frequent weirs and water extraction for sugarcane irrigation largely modify the channel. The amount of water in the active channel is greatly reduced in some places leaving an exposed bedrock with large potholes, dykes and fixed boulders. In some areas that also results into a misfit stream flowing in a very wide and incised channel. Large pools backed by the weirs maintain a regime type morphology. Braided and anabranching patterns with numerous islands characterise the reach. There are terraces, sand bars, abandoned channels, meander scars, seasonal channels and inactive secondary channels that may be activated during infrequent flood events. The extensive flood plain is used for crop farming, sugarcane and banana plantations.

- **Lowland River** - from Elsana to Furley's Drift. The river maintains similar characteristics to the above, but flows in a slightly confined channel. Regime type morphology is dominant and is enhanced by the presence of numerous weirs. Riparian vegetation forms a thick and continuous stretch of trees, bushes, shrubs and sedges.

- **Rejuvenated lower foothills** - from Furley's Drift to the Crocodile confluence. The channel widens up further and maintains regime type morphology. Side bars in meanders and islands are common. The bedrock is exposed in a few places leading to a temporal rejuvenation of the river. The pattern becomes braided near the crocodile confluence with many islands.

Groundwater

A preliminary delineation of groundwater recognises five groundwater zones as follows:

A – Escarpment Complex
B – Gneiss (Includes migmatite and granite)
C – Barberton Mountainland System
D – Lowveld Granite
E – Lebombo Group (includes Karoo lithologies)

Water Quality

Ten water quality units were recognised within the Study Area as follows:

1 Upper Komati: Headwaters of Komati upstream and down to Nooitgedacht Dam
2 Upper Komati: Nooitgedacht Dam to Vygeboom Dam
3 Upper Komati: Vygeboom Dam to Swaziland
4 Gladdespruit
5 Seekoeispruit
6 Teespruit
7 Lower Komati: From Swaziland to the confluence with the Lomati River (Mananga to Tonga)
8 Lower Komati: From the confluence of the Lomati River to the confluence with the Crocodile River (Tonga to Crocodile Bridge)
9 Lomati: Upper Lomati to Swaziland
10 Lomati: Lower Lomati from Driekoppies Dam to the confluence with the Komati River

7.3.1 Resource Units

The area was finally delineated into the following Resource Units (Figure 7-1):

Komati River

- **Resource Unit A:** The area upstream of Nooitgedacht Dam is located within the Highveld Ecoregion, and stream geomorphology is typical Source Zone. The vegetation is dominated by North Eastern Sandy Highveld Grasslands and the instream and riparian Habitat Integrity is regarded as "Natural to Largely Natural". The gradient is flat and there are occasional small riffle areas that provide habitat for flow-dependant species. Water quality is presumed to be good at present as there is very little development in the area. The stream is characterised by large riparian floodplain wetlands which are seasonally inundated. Landuse is dominated by livestock grazing on unimproved grasslands and dryland commercial maize. Stream flows are unregulated and there are no weirs or dams in the main channel. Flows are seasonally highly variable. Resource Unit B.

- **Resource Unit B:** The Komati River between Nooitgedacht Dam and Vygeboom Dam is situated in the Northern Escarpment Mountain Ecoregion, the vegetation consists of Piet Retief sourveld, riparian vegetation is generally in a good condition, water quality is good and landuse is limited and dominated by commercial livestock grazing. Present day MAR is estimated to be 78% of the nMAR at the lower end of this Resource Unit.

- **Resource Unit C:** The Komati River between Vygeboom Dam and the Maguga Dam is situated in Lower Foothills that are characterised by periodic outcrops of exposed granite bedrock that leads to multiple (anastomosing) channels. The area is situated in the Northern Escarpment Mountain Ecoregion, riparian vegetation is generally in a moderate to good condition (Category C to B), landuse is limited and dominated by communal livestock grazing and conservation areas (Nkomazi Wilderness Area and Songimvelo Nature Reserve), and streamflows are regulated by Vygeboom Dam. Water quality is variable, with poor quality inflows from the mine-polluted Gladdespruit, and organically enriched by inputs from the lower Seekoeispruit and Teespruit. Present day MAR is estimated to be 64% of the nMAR at the lower end of this Resource Unit

- **Resource Unit Maguga**: Swaziland was initially excluded from this study as the Reserve applies to South African legislation only. However, in January 2005 Swaziland was included, as effective management and scenario modeling of the water resources in the Komati River cannot be achieved without taking into account the operational limitations and rules of Maguga Dam, and the abstraction of water in Swaziland. The inclusion of Swaziland added one more RU to the study: the stretch of Komati River between Maguga Dam and Balekane Bridge. Here the river is characterized by a steep gradient and anastomosed bedrock outcrops.

- **Resource Unit D**: The lower Komati River from the Balekane Bridge at Mananga to the confluence of the Lomati River was difficult to delineate because there are a number of discontinuities in this stretch of river, in particular the disjunction between a low-gradient, inundated lowland river in the vicinity of Mananga, and the high gradient, rejuvenated lower foothills comprising bedrock outcrops and multiple channels that characterise a 5km section of river between Ntunda and just downstream of Tonga Weir. The Tonga Weir also represents a significant discontinuity in terms of low flows and water quality. The choice of the Lomati confluence as the lower boundary of this Resource Unit was based mainly on practical considerations concerning releases from Driekoppies Dam and the much larger size of the Komati River downstream of this junction. Landuse in this Resource Unit is intensive and dominated by sugar production. Stream flows are regulated by Maguga Dam and the management of IYSIS Weir. Present day MAR is estimated to be 38% of the nMAR at the lower end of this Resource Unit.

- **Resource Unit E:** There was no difficulty in assigning the lower Komati River downstream of the Lomati River junction into a separate Resource Unit. The river here is characterised by a wide, low gradient river almost completely inundated by weirs, leaving almost no flowing water habitats. Riparian vegetation was considered *Seriously* to *Critically Modified* (Category E and F). Landuse is dominated by irrigated agriculture, mainly sugarcane, and water quality is poor. Stream flows are regulated by Maguga and Driekoppies Dams. Present day MAR is estimated to be 30% of the nMAR at the lower end of this Resource Unit.

Lomati River

- **Resource Unit L:** The upper Lomati River (upstream of Swaziland) falls within Northern Escarpment Mountain Ecoregion. The area is presumed to have excellent water quality. The present day MAR is estimated to be 57% of the nMAR at the lower end of this Resource Unit, mainly because of stream flow reduction caused by plantations and abstraction from Barberton and Shiyalongubo Dams.

- **Resource Unit M:** The lower Lomati River, downstream of Driekoppies Dam, fell naturally into a single Resource Unit on account of the uniform geomorphology (lower foothills), uniform vegetation and single Ecoregion (Lowveld), uniform landuses and uniform system operation. Present day MAR is estimated to be 45% of the nMAR at the lower end of this Resource Unit.

Other Tributaries

- **Resource Unit T:** The Teespruit falls naturally into a single Resource Unit on account of the uniform geomorphology (mostly Upper Foothills), uniform and unmodified Habitat Integrity (Category A/B) and uniform landuses (mostly livestock grazing). The river is unregulated and water quality is assumed to be good, except for the lower reaches where there is moderate organic enrichment caused by a water treatment plant and non-point sources associated with scattered homesteads. A characteristic feature of this

Resource Unit is the large numbers of lateral seepage wetlands, usually situated upstream of doleritic intrusions. Present day MAR is estimated to be 80% of the nMAR at the lower end of this Resource Unit.

- **Resource Unit S**: The Seekoeispruit falls naturally into a single Resource Unit on account of generally uniform habitats and single geomorphological zone comprising "Lower Foothills". Most of the river is located in the Northern Escarpment Mountain Ecoregion, although the upper section is located in the Highveld Ecoregion. Bed substrates are characterised by bedrock and sand, and landuse is classified mostly as unimproved grasslands. Instream Habitat Integrity was considered Moderately Modified (Category C) for most of the river's length, while Riparian Habitat Integrity was considered Largely Modified (Category D). Water quality is likely to be reasonably good until Badplaas, where the Aventura and Badplaas settling ponds discharge treated sewage into the river, and conditions deteriorate, with the river turning green from phytoplankton. The river is largely unregulated and used fairly intensively for sand mining, brick making and washing of clothes.

- **Resource Unit G:** Delineation of the Gladdespruit presents a dilemma as the river falls naturally into two: 1) a Mountain Zone where the river is fast-flowing, steep and highly impacted by mining activities, forestry, trout hatcheries and severe encroachment of wattles, fire and severe erosion, and 2) an Upper Foothill Zone where the gradient is flatter, the vegetation is grassland and landuse is characterised by cattle grazing. The diversion of most of the medium to low-flow component into the Vygeboom Dam further divides the Upper Foothill zone into an unregulated section upstream of the Vriesland diversion weir, and a highly regulated section downstream of the weir. Despite these differences, it was decided to treat the Gladdespruit as a single Resource Unit because of its short length (40km), on the assumption that the flow requirements defined at the selected sampling site, situated about half way along the river course, will cater for the requirements further upstream and downstream. Present day MAR at the lower end of this Resource Unit is estimated to be 31% of the nMAR.

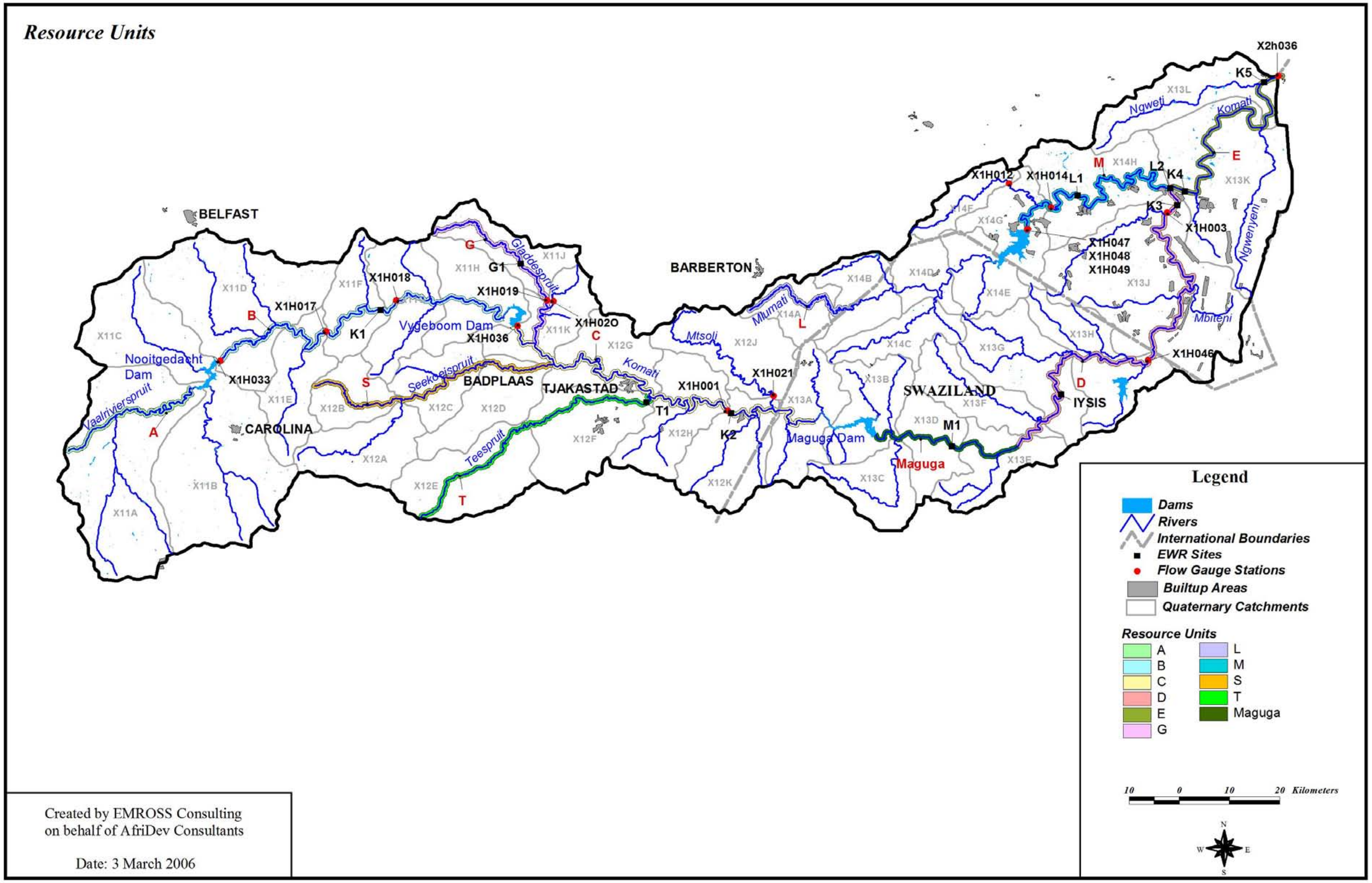

Figure 7-1. General locality map of the Komati River Catchment, showing Resource Units, EWR sites and gauging stations.

7.4 EWR SITES

There were sufficient funds to assess the water requirements of seven sites only. Sites that had been used in previous EWR studies were considered, but only one was found to be suitable (Site M1). Four sites were selected on the mainstream of Komati River and three sites were selected in the following tributaries: Lomati, Gladdespruit and Teespruit. Of the seven sites initially selected, four were in the western Komati Catchment (i.e., upstream of the Swaziland border), and three were in the eastern Komati Catchment (i.e., downstream of the Swaziland Border). One site was later included in Swaziland. All sites were considered suitable to highly suitable for assessing Ecological Water Requirements. Details of the sites that were finally selected are shown in Table 7-1. The following section describes the process of pre-selecting sites within each Resource Unit in which sites were finally selected.

a) Komati River Downstream of Nooitgedacht Dam (RU B)

The lower portion of this Resource Unit, downstream of Gemsbokhoek Weir, was first investigated for potential sites during the reconnaissance site visit. No suitable sites were found, mainly because of complex hydraulics, severe bank erosion and replacement of riparian vegetation with pine plantations and associated exotic weeds. The river upstream of Gemsbokhoek Weir has many potential and accessible sites, with instream and riparian habitats generally in good condition. However, a road runs alongside the river and crosses it at numerous places, so most of the potentially suitable sites were rejected because of the effects that the road culverts have on hydraulics and geomorphology. One site, K1, was finally recommended which was considered to provide a good compromise between hydraulics, habitat diversity and accessibility.

b) Komati River Downstream of Vygeboom Dam (RU C)

Access to the river downstream of Vygeboom Dam was difficult as most of the area falls within wilderness areas where roads are few. A site within the Nkomazi Wilderness area (Rhino Drift) was investigated and found to be potentially suitable, although the site is used as a river crossing, so the geomorphology is slightly impacted. A second potential site at the entrance gate to Songimvelo Nature Reserve was also considered, but rejected because of the complex hydraulics and impacts that cattle have had on the structure of the riparian vegetation. The site that was finally recommended, K2, was a short distance further upstream, also within the Songimvelo Nature Reserve, and a short distance downstream of gauging weir X1H001.

c) Komati River downstream of Mananga (RU D)

The most obvious choice for a site in this Resource Unit are the rapids immediately downstream of the Tonga Weir X1H003. These rapids were used during the Maguga Dam EWR study, but the hydraulics at this site was found to be highly complex. Two potential sites upstream of the Tonga Weir were investigated during the reconnaissance visit in July 2003 and found to suffer the same problems of multiple channels and complex hydraulics. The study team therefore investigated the area downstream of Tonga and the site finally chosen and surveyed (K3) was situated 2.5km downstream of the Tonga rapids. Subsequent examination of the 1997 video showed that this area had been inundated by backup from Ronel Weir, which was the reason that it had not been chosen during the Maguga Study. The area is no longer inundated because the weir was damaged in floods in January 2000 and has been rebuilt at a lower full supply level than before.

d) Komati River downstream of Lomati River confluence (RU E)

Three potential areas downstream of the Lomati River confluence were investigated during the reconnaissance visit: one situated immediately downstream of the confluence with the Lomati River, one area downstream of Furley's Drift Weir and one area downstream of the Lebombo Weir near Komatipoort. After due consideration the area immediately downstream of the Lomati River confluence was chosen as the most suitable site (K4). However, in February 2004 Site K4 became inundated by backup from Elsana Weir, making the site unsuitable as an EWR site. The area downstream of Furley's Drift Weir was rejected because of a very wide and densely vegetated riparian zone that would have made surveying the area practically impossible. The area was also inaccessible and unsafe to work because of a population of hippo. The area near Komatipoort was rejected because of the complex hydraulics and stable geomorphology. However, this site (K5) later chosen as a monitoring site to replace Site K4.

e) Lomati River downstream of Downstream of Driekoppies Dam (RU M)

Several potential sites were investigated in the Lomati River downstream of Driekoppies Dam. These included a previous EWR Site about 1km downstream of Driekoppies Dam, various sites downstream of Schoeman's Dam, a riffle near Langeloop, a riffle near Vlakbult and the area downstream of Lekkerdraai Weir near Phiva. These sites were rejected mainly because of the poor condition of the riparian zone or because the hydraulics was problematic. The site finally recommended (L1) was situated on the farm Kleindoringkop, an abandoned sugar farm.

f) Teespruit (RU T)

A number of sites were investigated in the Teespruit, but all but one were rejected because of the dominance of bedrock substrate that created complex hydraulics and provided few indicators of geomorphological change. One site in the lower Teespruit that had a simple hydraulic profile and that contained suitable cobble riffle was finally recommended (T1). The main disadvantage of this site was the absence of gauging weirs on this tributary.

g) Gladdespruit (RU G)

A site that had been used during a previous rapid assessment of the EWR of the Gladdespruit was investigated and rejected because it was on a bend, and this would have affected the reliability of the hydraulics. The final site selected was a short distance upstream, in an area that was least impacted by bank instability.

Table 7-1. Details of EWR sites selected in the Komati River Catchment, showing the Resource Unit (RU), 5km sector number, locality and video track location.

Site Name	River	RU	Sector	Locality	Video track log date and time
Komati River					
K1-Gevonden	Upper Komati	B	K21	25° 51'15.6"S; 30° 22' 35.9"E	25.06.2003 11h17m23s
K2-Kromdraai	Upper Komati	C	K45	26° 02'19.7"S; 31° 00'11.3"E	25.06.2003 15h48m02s
M1-Silingani ***	Middle Komati	Maguga	N/A	26° 05.970'S: 31° 23.893'E	02.07.1997 10h50m50s
K3-Tonga*	Lower Komati	D	LK32	25° 40'01.1"S 31° 48'04.8"E	02.07.1997 12h16h29
K3A-Tonga**	Lower Komati	D	LK32	25° 40'39.5"S 31° 47'26.0"E	02.07.1997 12h15h33
K4-Elsana*	Lower Komati	E	LK34	25° 38'33.6"S; 31° 48'54.8"E	26.06.2003 11h33m24s
K5-Lebombo**	Lower Komati	E	LK44	25°26'55.9"S; 31°57'28.2"E	26.06.2003 11h54m19s
Tributaries					
G1-Vaalkop	Gladdespruit	G	G4	25° 46'18.2"S 30° 37'37.8"E	25.06.2003 12h52m22s
T1-Teespruit	Teespruit	T	T8	26° 01'09.5"S; 30° 51'07.3"E	25.06.2003 14h52m12s
L1-Kleindoringkop	Lomati	M	L21	25° 38'58.0"S: 31° 37'23.5"E	Skipped in video due to tape change

* Discontinued due to inundation; **Selected for monitoring purposes only.
***This sites was included in the study in January 2005.

8. WATER QUALITY

8.1 INTRODUCTION

The Komati River Catchment was identified by DWAF as a priority catchment for a comprehensive Reserve determination, due to the stressed nature of the catchment. The catchment requires the completion of a comprehensive Reserve assessment before licensing and effective water resource planning can take place. The major stresses in the catchment are the high water demands for ESKOM, irrigation, afforestation and industry and rapidly increasing domestic water demands (Africon 2004; BKS 2003; Tlou & Matji 2004). The water shortages experienced in the area have led to intense competition for the available water resources among users. Planned extensions to irrigation have been put on hold and a substantial portion of the population does not have access to basic level of services. Furthermore the large number of dams in the Study Area not only changes the flow regime, but also impacts the water quality. This chapter presents the main results of the water quality component of the study.

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8.2 METHODS

Comprehensive methods for the PES assessment of water quality are the updated methods of September 2003 (based on the DWAF methods manual of 2002) for the water quality Reserve, while the technical determination of the benchmarks followed the Stressor-Response method described by Jooste and Rossouw (2002). Water quality consequences of operational flow scenarios were assessed using flow-concentration modeling as a tool for assessing impacts, as well as the physico-chemical approach for assessing water quality impacts as outlined in the EcoClassification manual of Kleynhans *et al.* (2005). The EcoClassification (or Ecological Classification) process refers to the determination and categorisation of the PES of various biophysical attributes of rivers compared to the natural/close to natural, reference condition (Kleynhans *et al.* 2005). This method has been developed to determine a river's EcoStatus using a systematic and quantitative approach. The state of the river is therefore expressed in terms of its following biophysical components:

- Physico-chemical Drivers: (i.e., water quality, geomorphology, hydrology). These provide a particular habitat template.
- Biological responses (i.e. fish, riparian vegetation and aquatic invertebrates).

Although the updated water quality manual was used to determine present state, the Physico-Chemical Driver Assessment Index (PAI) driver tables in the physico-chemical chapter of Kleynhans *et al.* (2005) were used to evaluate the water quality consequences of flow scenarios.

Identification of the key water quality issues were based on an assessment of DWAFs existing water quality data, supplemented by additional data collected during the study. Flow concentration modelling was used to assess the water quality consequences of selected operational scenarios at selected sites only (i.e., where there are sufficient hydrological and water quality records). Flow-concentration relationships were generated by plotting monthly median concentrations against monthly mean flow data. The derived regression relationships were used to convert the flow time-series to a time series of expected concentrations for different flow scenarios.

1.2 Results

1.2.1 Limitations in water quality data

All DWAFs long-term monitoring sites include monitoring of the major ions (Mg^+, Na^+, Ca^+, SO_4^-, Cl^-), pH and nutrients (PO_4-P, NO_2, NO_3 & NH_3) and these include sites K1, K2, K3 , G1 and L1. The water quality data available at each EWR are summarised in Table 8-1.

Table 8-1. Water quality available at selected sites in the Komati Rive r Catchment.

EWR Site	Available water quality data
K1	Data available from 1977 to 2005 at X1H018Q01
K2	Data available from 1992 to 2004 at Weir X1H001Q01
K3	Data available from 1977 to 2004 at X1H003Q01
K5	Data available from 1993 to 2005 at X1H042Q01
G1	Data available from 1977 to 2005 at X1H029Q01
S1	No data except limited data collected for this study
T1	No data except limited data collected for this study
M1	No data except limited data collected for this study
L1	Data available from 2000 to 2004 at X1HO49Q1

None of the sites had the following set of water quality variables that are required for the water quality data to be statistically analyzed per Resource Unit:

- Chlorophyll-*a (limited data only)*
- Dissolved oxygen
- Turbidity
- Inorganic salts (DWAF data were converted using Jooste's salt balance model)
- Temperature
- Toxic substances
  - Al
  - As
  - Atrazine
  - Cd
  - Cr (III)
  - Cr (IV)
  - Cu
  - Cyanide
  - Endosulphan
  - Pb
  - Hg

- o Phenol

One consequence of these limitations was that the flow concentration model was not able to be run for sites T1, S1, L1 and M1. The flow concentration model was run at the remainder of the sites, but the modelling method indicated that there was no correlation between flow and water quality at these sites (either due to for chemical constituents showing an increase in concentration with increasing flow, or the available data being too patchy for an appropriate analysis). This is because these pollutants often arise from diffuse sources in the surrounding catchment. It cannot automatically be assumed that if the flow in a river is decreased, the in-stream concentration of the pollutant will also decrease. This will depend on site-specific factors that require further investigation.

1.2.2 Water quality trends

The available water quality data were analysed statistically to determine water quality trends per site and between sites. Table 8-2 summarises the major water quality trends at each EWR site. This approach was used to generate the Physicochemical Assessment Index, well as assess the ecological consequences per flow scenario.

Table 8-2. Key water quality issues at selected sites in the Komati River Catchment.

EWR site	Water quality driver and trend
K1	The upper Komati River Catchment is generally in a good ecological condition, with the main impacts relating to dry land farming and forestry. The upstream Nooitgedacht Dam does not make any compensatory releases, so low-flows have decreased. Water temperatures are likely to have increased due to reduced low-flows, and nutrients have increased due to trout dams and tourist developments. There is large potential for opencast coal mining in this area, and this may compromise the good quality water that currently characterises the area.
K2	Although there is no cessation of flow at K2, the hydrology has changed significantly: upstream Vygeboom Dam releases minimal water and has had moderate impacts on the floods. T The main water quality issues are bacterial problems (cattle grazing, sewage effluent waste water treatment works in the Seekoeispruit and lower Teespruit, runoff from poor sanitation in the area), nutrient enrichment, and some contamination from domestic washing powders.
K3	The lower Komati River Catchment is in a poor ecological condition. The large number of weirs and associated irrigation in the lower reaches of the river has resulted in a deterioration of the water quality to such an extent that it has become enriched with nutrients and the dissolved oxygen levels become limiting to the ecology. Ecological conditions at K3 are highly impacted by frequent and extended periods of flow cessation, caused primarily by diversion of water at Tonga Weir. Clearing of bank vegetation and sand mining has reduced bank stabilisation and led to alien vegetation encroachment. The main water quality issues are nutrients (with associated benthic algal blooms) and bacterial contamination and increased water temperatures and slight salinisation when the river stops flowing.
M1	Maguga Dam has had a significant impact on this site, and instream habitat availability is impacted by dense growth of benthic diatoms possibly associated with the release of cold water.
G1	The Gladdespruit is in a largely modified condition (Category D). The main impacts

EWR site	Water quality driver and trend
	relate to trout farms, gold mines, forestry, and excessive encroachment of alien vegetation.
T1	The hydrology and geomorphology of the Teespruit have been slightly impacted due to small-scale abstractions. The water quality is in good condition, except for the lower section where there is a sewerage works with associated organic pollution
S1	The Seekoeispruit is unregulated and so the hydrology is close to natural, with small impacts related to abstraction of low-flows. The riparian zone is invaded by alien vegetation (mostly wattle), and poor landuse practices have led to erosion and embeddedness of the stream bed. The main water quality issues are associated with a number of poorly functioning sewage works, and general low level of sanitation throughout the catchment, particularly in the vicinity of Badplaas.
L1	The ecosystem at L1 is fairly healthy, although there has been a major change due to the impacts of Schoemans and Driekoppies Dam. The vegetation is greatly modified from natural, from a fairly sparsely vegetated channel under natural conditions, to a channel with a significant woody vegetation component under present conditions. Generally, the water quality is good, and the only potential impacts are due to dissolved oxygen and temperature from upstream regulation.

Water quality issues are mainly related to nutrient status and fluctuating temperature and oxygen levels due to flow regulation in the catchment. The Present Ecological State assessments for water quality are shown in Table 8-3, as well as the water quality category used to design quality EcoSpecs.

Table 8-3. Present Ecological State (PES) and Recommended Ecological Category (REC) for Water Quality at selected sites in the Komati River Catchment.

EWR Site	PES	REC
K1	B	B
K2	B/C	B/C
K3	D	D
G1	C	C
T1	C	C
M1	B/C	B/C
L1	B/C	B/C

1.3. CONCLUSIONS AND RECOMMENDATIONS

This report has provided an assessment of water quality conditions for the Komati Ecological Water Resource study. Water quality is generally not the driver of the overall EcoStatus of rivers in the Study Area, as parameters such as flow and the status of the riparian vegetation are more instrumental in determining the health of the river. The river is generally in a Good to Fair condition in terms of water quality, with poor quality occurring at the lower Komati River.

Although flow scenarios do impact on water quality, impacts are generally not significant enough to change water quality status to another category. The flow scenarios that would improve water quality in the lower reaches are those scenarios that include improved (from present) baseflows (Scenario 6). The scenarios that would improve the water quality are 3, 6.1 and 6.2.

The recommended flows for the lower Komati, which is in a bad ecological condition, are designed to restore perenniality through improved baseflows. However, these actions alone will be inadequate. There is a need to reduce irrigation return flows and inundation from weirs. The Catchment Management Agency could play a vital role in co-ordinating efforts to improve the riparian zone as a buffer, control deforestation, control cultivation and grazing in riparian zone, and reduce fragmentation caused by weirs.

The water quality data available for the EWR sites in the Komati River did not enable the flow concentration modelling to be undertaken. This was because there were not sufficiently long data sets for assessing the PES and reference condition, or because there were not sufficiently strong correlations between flows and concentrations of selected variables.

The water quality assessment methods used for the Reserve needs to be refined and a consolidate method produced. For example the assessment of water quality was conducted carrying out methods updated from DWAF (2002), as well as the EcoClassification approach as outlined in Kleynhans *et al.* (2005). Although the methods should be used together, i.e. the PES assessment using DWAF methods is used to populate the ratings tables in the EcoClassification Manual, there are no instructions in either manual as to how this procedure should take place. The EcoClassification approach will also be using a model developed by Jooste of RQS, DWAF. A water quality manual should therefore be developed which includes instructions on how all these tools must be used to conduct a water quality assessment in an EWR study.

Jooste's inorganic salt assessment method as well as the other variables that are being planned for incorporation into this model, needs to be made readily available for Reserve practitioners. The current inorganic salt model requires a manipulation to occur as the DWAF monitoring only measures salts such sodium, magnesium etc and these need then to be converted to inorganic salts. This method needs further refinement to include variables other than salts.

The water quality linkage that is currently being finalized in SPATSIM needs to be made readily available for Reserve practitioners.

9. ECOCLASSIFICATION

9.1 INTRODUCTION

EcoClassification refers to the categorisation of the Present Ecological State (PES) of various biophysical attributes compared to the natural (or near natural), reference condition. The EcoClassification process supports a scenario-based approach where a range of ecological endpoints (Ecological Categories) is considered. This provides the information needed to derive desirable but attainable future ecological objectives for the river. EcoClassification must not be confused with the Classification System as indicated in the National Water Act. The latter considers a range of different issues in Integrated Water Resources Management, one of which is ecological, in the process of determining the class of a river.

9.2 METHODS

9.2.1 Reference Conditions

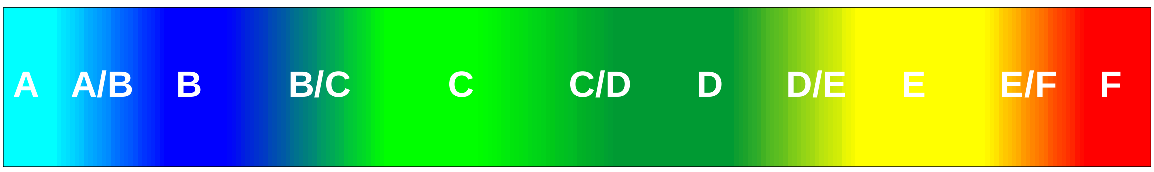
Historical data and professional judgment were used to define the Reference Conditions (Category A) for the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrate and fish).

9.2.2 Present Ecological State

Detailed data on hydrology, geomorphology, water quality, riparian vegetation, fish and aquatic invertebrates were collected for the Study Area in 2003 and 2004. Rule-based models developed by RQS were used to determine the Present Ecological State (PES) for each ecosystem component at each site (Kleynhans *et al*. 2005). Essentially the models use a swing ranking system in which key components are ranked and weighted to provide consistent results. Standard Excel spreadsheets were used in the assessments. These methods are under various stages of development and the first draft of the manual, dated June 2004, was used in this study.

The results of the rule-based models for each component were provided as Ecological Categories (ECs) ranging from Category A (*Natural*) to Category F (*Critically Modified*) (Figure 8-1). The categories represent a range along a continuum, so half categories (i.e. Category B/C) represent a condition at the border between Categories B and C (Figure 9-1).

Figure 9-1. Illustration of the distribution of Ecological Categories on a continuum from *Natural to Near-Natural* (A) to *Critically Modified* (F).



9.2.3 EcoStatus

The results of the rule-based models for individual ecosystem components were integrated into an overall assessment of Present Ecological State, or EcoStatus, using further swing rule-based models developed by RQS (Kleynhans *et al.* 2005).

9.2.4 Trends

An assessment was made as to whether the PES is stable under current development conditions, or whether it is changing. The causes and origins for the PES were identified, and specified as flow or non-flow related.

9.2.5 Ecological Importance and Sensitivity (EIS)

An assessment was made of Ecological Importance and Sensitivity (EIS) of each Resource Unit in which there was an EWR site. The assessment considered both natural and present day conditions and was based on the method developed and described by DWAF (1999). The method rates the following aspects of the biota and habitats on a scale of 0 (*Unimportant*) to 4 (*Very important*):

Biota

- Rare and endangered aquatic species
- Unique, endemic or isolated species or populations
- Presence of species that are intolerant or sensitive to changes in flow or flow related water quality changes
- Diversity of aquatic biota

Habitats

- Diversity of habitats types (i.e. pools, riffles, runs, rapids, waterfalls, riparian forests, etc).
- Presence of refugia
- Sensitivity (or fragility) of the system and its resilience (i.e. the ability to recover following disturbance) to changes in flow
- Sensitivity (or fragility) of the system and its resilience (i.e. the ability to recover following disturbance) to changes in water quality
- Importance as a migration corridor
- Importance as a conservation area (relevant to present conditions only)

9.2.6 Socio-cultural Importance

An assessment was made of Socio-cultural Importance (SI) of each Resource Unit. The method was based on a rapid method developed and described by Huggins (2003). The method rates the following aspects on a scale of 0 (*Unimportant*) to 4 (*Very important*).

Socio-cultural Importance

- People directly dependant on a healthy flowing river for water supplies
- People dependant on riparian plants for building, thatching and medicinal plants

- People dependant on the river for subsistence fishing
- People using the river for recreational purposes that requires ecologically healthy river

Cultural/Historical Values

- Sacred places on the river, and religious cultural events associated with the river
- Historical/archaeological sites on the river
- Special features and beauty spots
- General aesthetic value of the river
- Sense of place of those living proximate to the river

Conservation Aspects in a Social Context

- Potential for ecotourism
- Present recreation, and potential for recreation
- ***Ecological Importance and Sensitivity:*** The Ecological Importance and Sensitivity (EIS) of the biota and habitats were assessed.
- ***Socio-cultural Importance***: The dependence of communities on a health river system for various purposes such as subsistence fishing, collecting firewood, thatching grass, religious activities etc, was assessed, and referred to as the Socio-cultural Importance (SI).
- ***Recommended Ecological Category (REC):*** A realistic Ecological Category was recommended for each component as well as for the overall EcoStatus, based on a consideration of the PES, EIS and SI,
- ***Alternative Categories:*** Alternative categories, “up” and “down”, were identified, where appropriate.

9.2.7 Recommended Ecological Category and Alternatives

Motivated recommendations were made for a Recommended Ecological Category (REC) for each Resource Unit in which there was an EWR site. The REC was based on a combination of factors including the PES, EIS, the Socio-cultural Importance, the ecological trends and the practical feasibility of implementing recommended changes. In some cases, particularly those of the upper EWR sites (K1 and K2) the REC was initially higher than the PES. However, in light of the current strategic demands, achieving an improvement was considered unlikely, and so the overall PES (EcoStatus) category was accepted as the REC. The REC was accompanied by a number of alternative ECs for which flow scenarios were considered. These were guided by the rules as shown in Table 9-1.

The range of Ecological Categories (ECs) for which flow scenarios were provided were guided by the rules as shown in Table 9-1. This must be seen as guidelines to determine a *realistic* range of ECs, which can be addressed within the scenario-approach.

Table 9-1. Guidelines for the range of Ecological Categories (ECs) to be addressed.

PES	Alternative EC	
	Increase (Up)	Decrease (Down)
A	N/A	N/A
A/B	N/A	B/C
B	N/A	C
B/C	B	C/D
C	B	D
C/D	B/C	D
D	C	N/A
D/E	D	N/A
E	D	N/A
E/F	D	N/A
F	D	N/A

9.3 RESULTS

The Present Ecological State (PES), Ecological Importance and Sensitivity (EIS), Social Importance (SI), Recommended Ecological Category (REC) and alternative categories for each Resource Unit in the Komati River Catchment are shown in Table 9-2 to Table 9-4, and represented spatially on maps (Figure 9-1).

9.3.1 Present Ecological State

The results of the PES assessment are shown in Table 9-2. The upper Komati River Catchment is generally in a good ecological condition, with the main impacts relating to dry land farming and forestry. There is large potential for opencast coal mining in this area, and this may compromise the good quality water that currently characterises the area.

The middle Komati River Catchment is generally in a moderate ecological condition, with the notable exception of the Gladdespruit River (Resource Unit G), which is in a largely modified condition (Category D). The main impacts in the Gladdespruit relate to trout farms, gold mines, forestry, and excessive encroachment of alien vegetation. Bacterial levels are also high because of low levels of sanitation service provision and waste water treatment works in the Seekoeispruit and lower Teespruit.

The lower Komati River Catchment is in a poor ecological condition, with the stretch of river between Mananga to Komatipoort (Resource Units D and E), being the most impacted. The large number of weirs and associated irrigation in the lower reaches of the river has resulted in a deterioration of the water quality to such an extent that it has become enriched with nutrients and the dissolved oxygen levels become limiting to the ecology. The overall picture is one of a system that deteriorates in the lower reaches.

Table 9-2. Summary of the Present Ecological Status (PES), and a description of the drivers and responses for each Resource Unit.

EWR site and PES	*Summary of key drivers and responses*

KOMATI RIVER

Resource Unit A (upstream of Nooitgedacht Dam): No EWR site

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	A	A	B
GEOMORPH	B		
WATER QUALITY	A		
Response Components	Component PES	Instream PES	
FISH	B	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	B/C	B/C	

The Komati River upstream of Nooitgedacht Dam is generally in excellent ecological condition, but riparian vegetation is degraded through alien invasive plants, such as wattle.

Resource Unit B (between Nooitgedacht and Vygeboom Dams): ***K1 - Gevonden***

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	C	B/C
GEOMORPH	C		
WATER QUALITY	B		
Response Components	Component PES	Instream PES	
FISH	B/C	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	C	C	

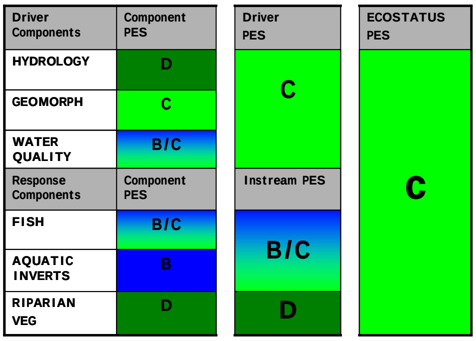
Although there is no cessation of flow at K1, the hydrology has changed significantly: Nooitgedacht Dam has not overtopped significantly since 1970s and so flood assurances have decreased, and this has affected the geomorphology. Furthermore, the dam does not make any compensatory releases, so low-flows have decreased. Forestry has also had an impact on low-flows. Water temperatures are likely to have increased due to reduced low-flows, and nutrients have increased due to trout dams and tourist developments.

Komati River: Resource Unit C (downstream of Vygeboom Dam): ***K2 – Kromdraai***

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C/D	C	C
GEOMORPH	C/D		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	B/C	B/C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

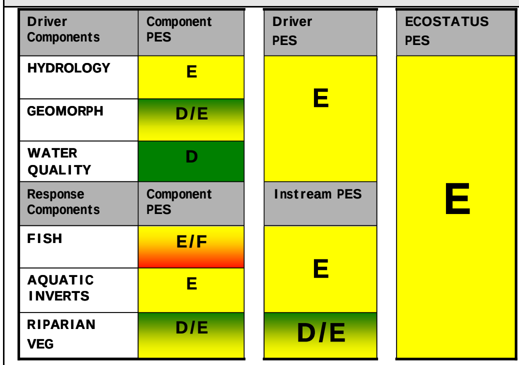
Although there is no cessation of flow at K2, the hydrology has changed significantly: Vygeboom Dam releases minimal water and has had moderate impacts on the floods. A weir upstream of K2 has also had small impacts. Aerial photographs suggest that the bed morphology has changed from sand-bed dominance in 1937, to bed-rock dominance in 2003. The main water quality issues are bacterial problems and some contamination from domestic washing powders. Groundwater is contaminated with nitrates due to poor sanitation in the area. Invertebrate taxa that require good water quality, and slow-flowing water, have disappeared. This is thought to reflect water quality problems. Of the 15 expected fish species, only eels were not collected.

Middle Komati River, Swaziland (downstream of Maguga Dam): ***M1 - Silingani***



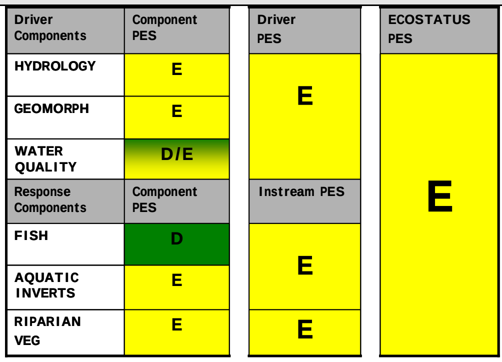
Maguga Dam has had a significant impact on this site, and instream habitat availability is impacted by dense growth of benthic diatoms possibly associated with the release of cold water. Maguga Dam is expected to impact negatively on geomorphology (sediment depletion) and associated instream habitat diversity, but these changes are not yet evident. Of the 29 species of indigenous fish expected at this site, 14 and 17 species were collected during surveys in 2003 and 2004. There has been a reduction in sensitive fish species. The invertebrate fauna has changed significantly since the completion of Maguga Dam, but there is no evidence to indicate that conditions have deteriorated. The riparian vegetation at the site is degraded, but in reasonable condition for the area as a whole.

Resource Unit D (Lower reaches): ***K3-Tonga***



Ecological conditions at K3 are highly impacted by frequent and extended periods of flow cessation, cuased primarily by diversion of water at Tonga Weir. Clearing of bank vegetation and sand mining has reduced bank stabilisation and led to alien vegetation encroachment. The main water quality issues are nutrients (with associated benthoic algal blooms) and bacterial contamination and increased water temperatures and slight salinisation when the river stops flowing. Of the 31 species of indigenous fish expected, only seven were recorded in 2003. All flow-sensitive species have disaooeared and species sensitive to poor water quality have reduced in diversity and abundancre. Fish migration is severely impacted by the large numbers of weirs. Aquatic invertebrate data show that the fauna deteriorates significantly when flows drop, and all sensitive species had disappeared during low-flows in 2003.

Komati River. Resource Unit E: No EWR site



As above, but with more weirs and sand-mining.

TRIBUTARIES

Gladdespruit - Resource Unit G: ***G1 - Vaalkop***

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	D
GEOMORPH	D		
WATER QUALITY	C		
Response Components	Component PES	Instream PES	
FISH	D	D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

The main impacts in the Gladdespruit are related to (a) a reduction in low-flow due to forestry, (b) water quality problems due to acid mine drainage from old gold mines, sulphates and raw sewerage, (c) erosion and sedimentation, (d) alien invasives and (e) trout dams. Invertebrate species sensitive to water quality have disappeared. There has been a loss of migratory fish species. The riparian zone is characterised by loss of species richness, composition and structure, and abundance of alien invasive plants.

Teespruit - Resource Unit T: ***T1 - Teespruit***

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	C
GEOMORPH	C		
WATER QUALITY	C		
Response Components	Component PES	Instream PES	
FISH	B/C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

The hydrology and geomorphology of the Teespruit have been slightly impacted due to small-scale abstractions. The water quality is in good condition except for the lower section where there is a sewerage works with associated organic pollution. Of 15 fish species expected fish, 11 were collected in 2003. Some deep habitats are shallower than expected, and catadromous species were missing due to weirs downstream. There are no historical invertebrate data, but taxa that appear to be missing are those that are sensitive to poor quality water. However, a high diversity of blackflies (6 species) indicates that water quality is within acceptable limits for aquatic ecosystems. The vegetation has experienced a moderate change in abundance and structure, mainly due to encroachment of alien vegetation.

Seekoeispruit - Resource Unit S

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C/B	C
GEOMORPH	C		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

The Seekoeispruit is unregulated and so the hydrology is close to natural, with small impacts related to abstraction of low-flows. The riparian is invaded by alien vegetation (mostly wattle), and poor landuse practices have led to erosion and embeddedness of the stream bed. This has reduced habitat availability for fish and invertebrates. The main water quality issues are associated with a number of poorly functioning sewage works and general low level of sanitation throughout the catchment, particularly in the vicinity of Badplaas.

Lomati River. Resource Unit L (upstream of Driekoppies Dam): No EWR site

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	B	B
GEOMORPH	B		
WATER QUALITY	A/B		
Response Components	Component PES	Instream PES	
FISH	B/C	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	B/C	B/C	

The Lomati River upstream of Driekoppies Dam is in an excellent ecological condition. The main impacts are related to forestry activities in the upper reaches (sedimentation, alien vegetation etc), and subsistence agriculture within Swaziland.

Lomati River. Resource Unit M (Lower reaches) ***: L1 – Kleindoringkop***

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	C/D
GEOMORPH	D		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	B/C	C	

The ecosystem at L1 is fairly healthy, although there has been a major change from reference conditions. The geomorphology is greatly modified from natural from a fairly unstable mobile channel, with large sand banks to a vegetation-stabilized channel, with a negligible sand component. These changes are attributed largely to the impacts of Schoemans Dam. The vegetation is greatly modified from natural from a fairly sparsely vegetated channel to a channel with a significant woody vegetation component. The fish comprise a greatly altered community structure in which temperate species have replaced tropical species. The PES EcoStatus measured against the original (natural) reference condition is in a Category D. The PES EcoStatus measured against modified reference conditions which include; (a) temperate fish species rather than tropical, (b) more woody material, (c) more defined channel and (d) increased natural base flows for all months (especially in the dry season) were in a Category C/D.

9.3.2 Importance

The results of the Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI) are summarised in Table 9-3. There has been a greater decline in the EIS in the lower reaches of the Komati River (Resource Unit (RU) D and E) and the Gladdespruit (RU G) and Seekoeispruit (RU S) tributaries. The SI results show that the lower Komati River (RUs D and E) was considered to be the most important area in terms of social and cultural values, followed by the Barberton Mountainlands/Songimvelo and Nkomazi Wilderness areas (RUs C and L). Areas that were considered of low social and cultural importance were the Gladdespruit (RU G) and upstream of Nooitgedacht Dam (RU A).

Table 9-3. Summary of the Ecological Importance and Sensitivity (EIS) and Social-cultural Importance (SI), for each Resource Unit (RU).

Ecological Importance and Sensitivity (EIS)	Social-cultural Importance (SI)
KOMATI RIVER	
Resource Unit A (upstream of Nooitgedacht Dam): No EWR site	
The EIS was considered *Moderate* under natural and present conditions. The confidence for this assessment was high. The naturally slow-flowing stream (low gradient) is not highly sensitive to flow changes. RU A is located within Nooitgedacht Nature Reserve.	RU A was of *Low* Socio-cultural Importance. Landuse in RU A is characterised by commercial dryland farming (mainly maize), and livestock grazing (mainly cattle). Population densities are very low and the direct dependence on the river for water supply is likely to be very low. The natural riparian zone is grassland and therefore does not supply much in terms of building materials or other natural resources. There may be some harvesting of medicinal herbs and tubers, but the scale is low. The area offers little in terms of aesthetic features, but there are a few deep pools that provide habitat for yellowfish (*Barbus polylepis*), so there is some potential for yellowfish ecotourism development. The Groblers Bridge that crosses the Komati River is registered as Natural Heritage Site. The area contains a number of San archaeological sites.
Resource Unit B (between Nooitgedacht and Vygeboom Dams): ***K1 - Gevonden***	
The EIS within the Komati Gorge was rated *Very High* under natural conditions and *High* under present conditions. The confidence for this assessment was high. The main determinants were the presence of the rare endangered fish *Chiloglanis bifurcus*, a bald ibis breeding colony and the presence of endemic fish species: *Chiloglanis emarginatus* and *Barbus argenteus.*	RU B was of *Moderate* Socio-cultural Importance. Landuse is characterised by commercial dryland agriculture, some irrigated agriculture, livestock grazing (mainly cattle), and localised ecotourism developments (fishing, walking, biking and birding). Population densities are very low. Direct dependence on the river for water supply and other harvestable resources is probably low, although there is likely to be significant commercial harvesting of medicinal herbs and tubers for sale in Gauteng. The Komati Gorge is spectacular and largely undeveloped, offering significant potential for further ecotourism development. San and other archaeological sites are present.
Komati River: Resource Unit C (downstream of Vygeboom Dam): ***K2 – Kromdraai***	
The EIS within the Somgimvelo provincial reserve was considered to be *High* both under natural and present conditions. The confidence for this assessment was high. The main determinants were the diversity of habitats, the presence of the endangered *Chiloglanis bifurcus*, hippopotamus (*Hippopotamus amphibious*), African finfoot (*Podica senegalensis*), Half-collared kingfisher (*Alcedo semitorquata*), the rare Striped Flufftail (*Sarothrura affinis*), vulnerable South African Python (*Python natalensis*), the presence of endemic fish species;. *C. emarginatus* and *Barbus argenteus* and the Yellow-striped reed frog (*Hyperolius semidiscus*). The presence of the conservation areas (Songimvelo Reserve, Nkomazi Wilderness Area and potential Transboundary Park) was also considered important at a national level.	The area was considered of *High* Socio-cultural Importance. Landuse is dominated by wilderness and poor, densely-populated rural areas. The Nkomazi Wilderness Area is a proclaimed National Heritage area. Population densities and dependence on the river are variable. Activities include harvesting of riparian timber (mainly wattle) for fuelwood and subsistence market gardening.
*Middle Komati River, Swaziland (downstream of Maguga Dam)**: M1 - Silingani***	

Ecological Importance and Sensitivity (EIS)	Social-cultural Importance (SI)
KOMATI RIVER	
The EIS in the vicinity of EWR Site M1 was rated *High* under natural and present conditions. The confidence for this assessment was high. The main determinants were the presence of the rare endangered *Opsaridium* and the presence of species intolerant to flow (*Chiloglanis, Opsaridium, Amphilius, B. eutenea) .*	The area was considered of *Very High* Socio-cultural Importance. Most of the area is within Swazi Nation Land and is considered culturally important. Rural communities are dependent on the river for irrigation, spiritual activities, drinking, washing and using various resources such as edible and medicinal plants, building materials, carving materials and firewood. Communities noted a reduction in flow which they attributed to low rainfall and weirs. In a Social Study undertaken of the area, the weirs were resented by the community because they were perceived to have altered the level of the river and affected access to the river (King 1998). Archaeological sites are present and the spiritual and aesthetic value of this area is highly significant.
Resource Unit D (Lower reaches): ***K3-Tonga***	
The EIS within the provincial reserve was considered *Very High* under natural conditions and *Moderate* under present conditions. The confidence for this assessments was high. The main determinants were the diversity of habitats, the presence of the indeterminate Black Coucal, the rare Little Bittern (*Ixobrychus minutes*), the vulnerable Eurasian Bittern (*Botaurus stellaris)*, the rare White-crowned plover (*Vanellus albiceps*), Barred minnow *(Opsaridium perengueyi)*, the hippopotamus (*Hippopotamus amphibious)*, the endangered crocodile (*Crocodylus niloticus)*, the endemic *Macrobrachium*, *Machadorythus* mayfly, tigerfish (*Hydrocynus vittatus*) (historically), intolerant species to flow (*Chiloglanis pretoriae, Opsaridium perengueyi*), species richness (27 species) and the importance as a migration corridor for eels, *Macrobracium* and local breeding migrations of fish and birds.	The area was considered to be of a *Very High* Socio-cultural Importance. Landuse of RU D is characterised by commercial subsistence agriculture and irrigated sugarcane. Population densities are very high. The use of natural resources for generating income is a very important component to household economy, particularly among women, who weave baskets and sleeping mats, and collect wild vegetables and fruits. These resources are also used for dietary and medicinal purposes and for building, fencing, firewood and wood carving. Besides bathing and swimming, certain sects, such as the Red Gown Zionists, use the river for Baptism and other rituals, including weddings. However, respondents stated that this is no longer possible because of the low level in the river, and the Red Gown must now "wait for the rains". People in the vicinity look to Maguga and Driekoppies Dams to restore flow levels.
Komati River. Resource Unit E: No EWR site	
The EIS was considered *Very High* under natural conditions and *Moderate* under present conditions. The confidence for this assessment was high. The main determinants were the loss of rare, endangered and unique species such as; Black coucal, the rare Little Bittern (*Ixobrychus minutes*), the vulnerable Eurasian Bittern (*Botaurus stellaris)*, *Opsaridium perengueyi*, hippopotamus (*Hippopotamus amphibious)*, the endangered crocodile (*Crocodylus niloticus)*, the rare White-crowned plover (*Vanellus albiceps*), African finfoot (*Podica senegalensis*), (indeterminate, declining), barred owl (rare), *Macrobrachium, Machadorythus* mayfly, tigerfish (historically), Greater leaf-folding frog (*Afrixalus fornasinii*), the presence of two flow-dependent fish species (*Chiloglanis pretoriensis, Opsaridium*), species richness (27 species	The area was considered to be of a *Very High* Socio-cultural Importance.The lower reaches of the Komati, downstream of the Lomati River confluence, is used intensively for irrigated agriculture, sugarcane in particular. This has attracted large numbers of people to the area. Direct dependence on the river by local communities is likely to be similar to RU D (ie, very important), although resources have been severely overexploited and also detrimentally impacted on by weirs.

Ecological Importance and Sensitivity (EIS)	Social-cultural Importance (SI)
KOMATI RIVER	
of fish) and the importance as a migration corridor for Eels, *Macrobrachium* and local breeding migrations of fish and birds.	

Ecological Importance and Sensitivity (EIS)	Social-cultural Importance (SI)
TRIBUTARIES	
Gladdespruit - RU G: ***G1 – Vaalkop***	
The EIS within the provincial reserve was considered *High* under natural conditions and *Low* under present conditions. The confidence for this assessment was high. The main determinants were the presence of two flow-dependent fish species (*Chiloglanis pretoriensis, Amphilius uranoscopus*), the sensitivity to flow changes and flow related water quality changes.	The area was considered of low Socio-cultural Importance. Landuse is dominated by pine plantations, mining, trout farms and extensive cattle grazing. A small portion near the confluence with the Komati River is used for irrigated agriculture. Residents in the forestry village of Mamre source their water from a tributary of the Gladdespruit, while trout lodges are supplied by boreholes. The direct dependency on the Gladdespruit for potable water and subsistence economic activities is negligible, as most people in the area are formally employed. There are some abandoned gold mines and associated buildings that would have historical value.
Teespruit - Resource Unit T: ***T1 - Teespruit***	
The EIS within the provincial reserve was considered *High* under natural and present conditions. The confidence for this assessment was high. The main determinants were the presence of endangered *C. emarginatus* and the presence of two flow-dependent fish species (*Chiloglanis* and *Amphilius uranoscopus*).	The area was considered of *Moderate* Socio-cultural Importance. Landuse is characterised by small-scale commercial and subsistence dryland farming and livestock grazing (mainly cattle). There are also small patches of irrigated agriculture. There are large areas of degraded, unimproved grasslands, with associated problems of soil erosion and exotic vegetation encroachment probably remnants of commercial agriculture. Direct dependence on river for water supply is likely to be fairly high, as houses are generally scattered. The river is important for washing of clothes, and it is likely that the river is also important for swimming. Moderate levels of natural resource harvesting are probable, including fuelwood, and river sand for building. There are almost certainly moderate to high levels of harvesting of medicinal herbs and tubers.
Seekoeispruit - Resource Unit S	
The EIS of RU S was considered *High* under natural conditions and Moderate present conditions. The confidence for this assessment was high. The main determinants was the presence of endangered *C. emarginatus*, the presence of two flow-dependent fish species (*Chiloglanis* and *Amphilius uranoscopus*), the presence of unique fauna such as the rare damselfly (*Pseudagrion inopinatum*) found around the Warmwater Springs in Badplaas, the loss of species (5 fish species) and the migration of eels.	The area was considered of *Moderate* Socio-cultural Importance. Landuse is RU S is characterised by small-scale commercial dryland farming and livestock grazing (mainly cattle). Population densities are low for most of the area, but moderate to high in the vicinity of Badplaas. Direct dependence on river for water supply is likely to be low, as most farmers and farm workers are likely to rely on boreholes for water supply, while residents in the vicinity of Badplaas are serviced with reticulated water. There are moderate levels of natural resource harvesting, including fuelwood, and river sand for building. There are almost certainly moderate to high levels of harvesting of medicinal herbs and tubers.

Ecological Importance and Sensitivity (EIS)	**Social-cultural Importance (SI)**
TRIBUTARIES	
	Badplaas is well-known for its hot springs, which have been developed into a major tourist attraction, and there is potential for further ecotourism development. The area contains a number of San archaeological sites.
Lomati River. Resource Unit L (upstream of Driekoppies Dam): No EWR site	
The EIS was considered *Very High* under natural and present conditions. The confidence for this assessment was high. The main determinants was the presence of the endangered *Chiloglanis bifurcus*, rare Little Bittern (*Ixobrychus minutes*), Laminate vlei rat and the vulnerable South African Python (*Python natalensis*), the endemic *B. brevipennis*, *Varicharinus*, *C. anoterus,* the presence of intolerant fish species such as *Chiloglanis, Amphilius, Varichanrinus* and the importance of the area for conservation as it fall into the Songimvelo - Barberton Mountain lands.	The area was considered of *High* Socio-cultural Importance. The upper reaches of the Lomati River, where the altitude exceeds 1000m, are used mainly for forestry. Population densities are low and social utilization of river resources are negligible. There are still large areas that are undeveloped and inaccessible. The area is outstandingly beautiful, so the potential for ecotourism development is high.
Lomati River. Resource Unit M (Lower reaches) ***: L1 – Kleindoringkop***	
The EIS within the provincial reserve were considered *Very High* under natural conditions and *High* under present conditions. The confidence for this assessment was high. The main determinants were the diversity of habitats (pools and riffles), the presence of the endangered crocodile (*Crocodylus niloticus)*, *Chetia brevis*, *Opsaridium*, hippopotamus (*Hippopotamus amphibious*), African finfoot (*Podica senegalensis*), Half-collared kingfisher (*Alcedo semitorquata*), the presence of flow-dependent fish species (*Barbus eutenia, Chiloglanis, Opsaridium*), the high number of fish species (15 fish species expected) and the importance of the area for conservation at a national scale.	The area was considered of *High* Socio-cultural Importance. The lower reaches of the Lomati River is used intensively for irrigated agriculture, sugarcane in particular. Direct dependence on the river by local communities is likely to be similar to RU D (ie, very important), but most villages are some distance from the river, and access to the river appears to have been restricted.

9.3.3 Recommended Ecological Categories and Alternatives

The PES, Importance, Recommended Ecological Category (REC) and alternatives for each Resource Unit are summarised in Table 9-4.

Table 9-4. Summary classification of the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS), Social Importance (SI), and Recommended Ecological Category (REC) for each Resource Unit in the Komati River Catchment.

R.U.	Site	PES	Importance		Ecological Category		
			EIS	SI	Alt (up)	Alt (down)	REC
Komati River							
A	-	B	M	L	N/A	N/A	B
B	K1	B/C	H	M	B	C/D	B/C
C	K2	C	H	H	B	D	C
Maguga	M1	C	H	V.H	B	D	C
D	K3	E	M	V.H	N/A	N/A	D
E	-	E	M	V.H	N/A	N/A	D
Tributaries							
G	G1	D	L	L	C	N/A	D
S	-	C	M	M	N/A	N/A	C
T	T1	C	H	M	B	D	C
L	-	B	V.H	H	N/A	N/A	B
M	L1	C/D	H	H	N/A	N/A	C/D

L = Low; M = Moderate; H = High; VH = Very High

K1: The EIS (present) was rated as *High*, indicating that a higher category should be recommended. However, due to the strategic importance and scarcity of water it was considered unrealistic to recommend a higher category. Maintaining the river as a Category B/C would be adequate from an ecological point of view and the PES was accepted as the REC. Two alternative Ecological Categories were considered: Category B and Category C/D.

K2: The EIS (present) and socio-cultural importance are *High*, indicating that a higher category should be recommended. There is potential for improvement of the local catchment conditions through changing land-use as a large portion of this Resource Unit has been bought for the Inkomazi Wilderness Area and it is likely that deleterious farming practices will be reduced. Erosion can be minimised through rehabilitation. As improvement can be achieved by non-flow measures, it was concluded that the PES Category C was recommended on account of the strategic importance of water in this catchment. Two alternative Ecological Categories were considered (Category B and D). Initial running of the model achieved a Category B/C (82%). However, vegetation achieved a high Category B (88%) so it was decided that the Alternative up falls in a Category B instead.

M1: The EIS (present) was rated as *High* and the socio-cultural importance was rated as *Very High.* Maintaining the river as a Category C would be adequate from an ecological point of view and the PES was accepted as the REC. Two alternative Ecological Categories were considered (Category B and D).

K3: The EIS (present) was moderate and the socio-cultural importance *Very High*. Considering that the PES is Seriously Modified (Category E) it was suggested that a higher Category (D) be recommended. Category D will help achieve a better level of sustainability. To improve the state of this Resource Unit to a Category D the following should be addressed:

- flow related issues (dam operation, weirs etc)
- importance of the river in delivering certain goods and services to the surrounding communities
- management of the entire catchment
- water quality

No alternative ecological categories were considered as establishing the REC Category D was regarded as a priority.

T1: The EIS (present) was *High* and the Socio-cultural Importance *Moderate*, indicating that a higher Category should be recommended. However, the PES was accepted as the REC, as maintaining the river as a Category C would be adequate from an ecological point of view. Two alternative Ecological Categories were considered (Category B and Category D)

G1: The Ecological Importance and Sensitivity (present) was low and the Socio-cultural Importance low, therefore the PES Category D was accepted as the REC. One alternative EC was considered (Category C) as it is not ecologically viable to go below a Category D.

L1: The EIS (present) and the Socio-cultural Importance were rated as *High*, indicating that a higher category should be recommended. Flows were not set for a higher than PES condition, because it is probably neither feasible nor possible to improve present conditions significantly. No alternative Ecological Categories were considered.

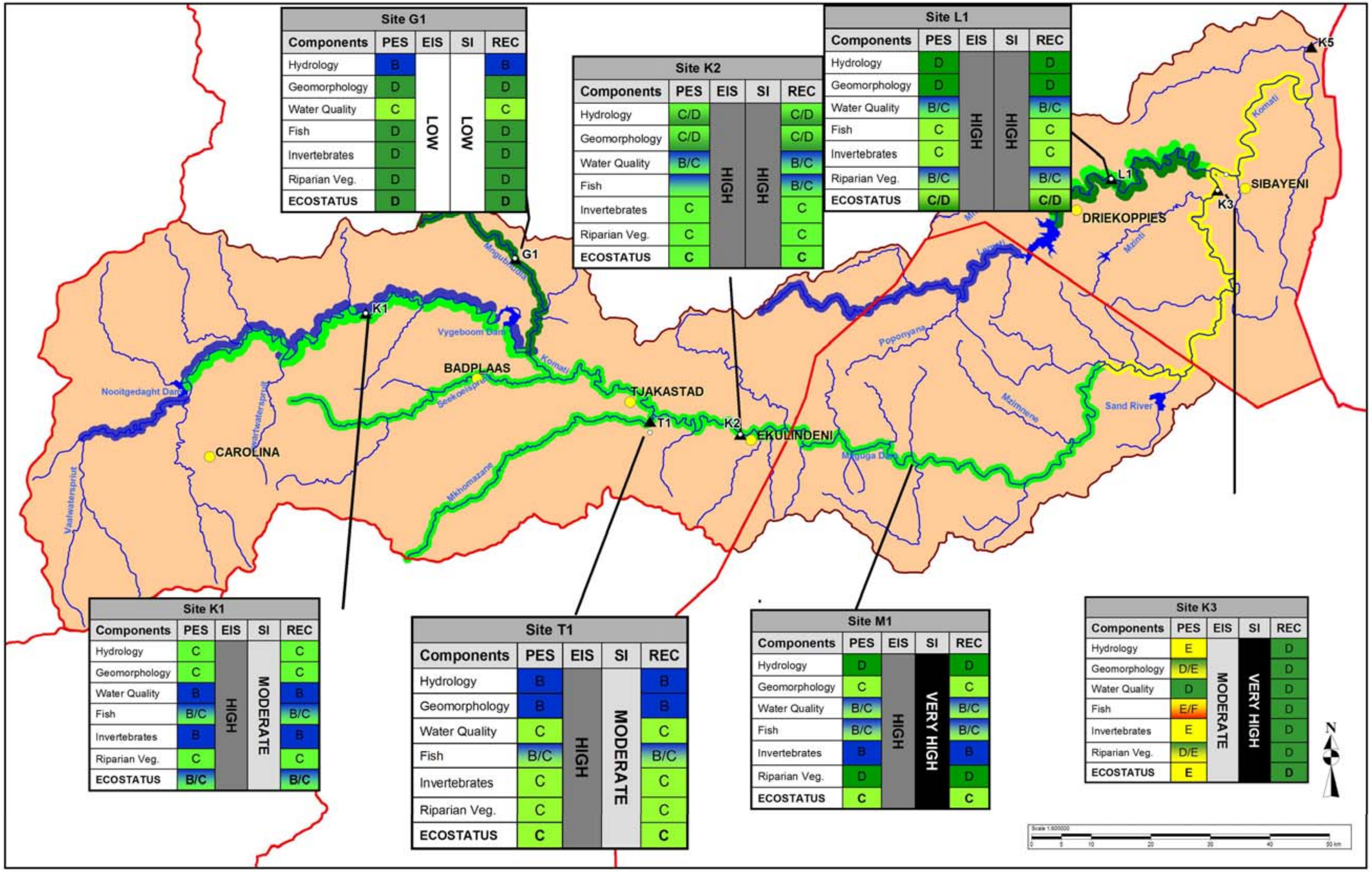
9.4 CONCLUSIONS

The REC was the same as the PES for all Resource Units except for the lower Komati (Resource Units D and E), in which an improvement from a Category E to Category D was recommended. The options for improving the PES in other Resource Units were tempered by the realities in the catchment, which include:

- **ESKOM:** The strategic demands by ESKOM in the upper catchment provide limited scope for improved flows.
- **Dams**: The ecological conditions downstream of large dams have changed irreversibly from historical reference conditions and it was considered unrealistic to recommend an improvement in current conditions.
- **Weirs:** The ecology of the lower Komati River has been severely impacted by a large number of weirs and associated irrigation development. These have had a major

impact on habitat availability and low flow conditions in particular.

- **Non-flow related impacts:** Many of the reasons for ecological degradation in the Komati River are unrelated to flow, so improved flows alone are not going to solve the problems. For example, the Nkomazi Wilderness Area, between Vygeboom Dam and the Swaziland border (Resource Unit C), is of high social and cultural value and is undergoing improved landuse practices due to the conversion of land from agriculture to conservation. However, improvements from a Category C to a B would be unlikely because the underlying causes of the PES were mainly catchment-related rather than flow-related.



Site G1

Components	PES	EIS	SI	REC
Hydrology	B	LOW	LOW	B
Geomorphology	D			D
Water Quality	C			C
Fish	D			D
Invertebrates	D			D
Riparian Veg.	D			D
ECOSTATUS	D			D

Site K2

Components	PES	EIS	SI	REC
Hydrology	C/D	HIGH	HIGH	C/D
Geomorphology	C/D			C/D
Water Quality	B/C			B/C
Fish				B/C
Invertebrates	C			C
Riparian Veg.	C			C
ECOSTATUS	C			C

Site L1

Components	PES	EIS	SI	REC
Hydrology	D	HIGH	HIGH	D
Geomorphology	D			D
Water Quality	B/C			B/C
Fish	C			C
Invertebrates	C			C
Riparian Veg.	B/C			B/C
ECOSTATUS	C/D			C/D

Site K1

Components	PES	EIS	SI	REC
Hydrology	C	HIGH	MODERATE	C
Geomorphology	C			C
Water Quality	B			B
Fish	B/C			B/C
Invertebrates	B			B
Riparian Veg.	C			C
ECOSTATUS	B/C			B/C

Site T1

Components	PES	EIS	SI	REC
Hydrology	B	HIGH	MODERATE	B
Geomorphology	B			B
Water Quality	C			C
Fish	B/C			B/C
Invertebrates	C			C
Riparian Veg.	C			C
ECOSTATUS	C			C

Site M1

Components	PES	EIS	SI	REC
Hydrology	D	HIGH	VERY HIGH	D
Geomorphology	C			C
Water Quality	B/C			B/C
Fish	B/C			B/C
Invertebrates	B			B
Riparian Veg.	D			D
ECOSTATUS	C			C

Site K3

Components	PES	EIS	SI	REC
Hydrology	E	MODERATE	VERY HIGH	D
Geomorphology	D/E			D
Water Quality	D			D
Fish	E/F			D
Invertebrates	E			D
Riparian Veg.	D/E			D
ECOSTATUS	E			D

Figure 9-2. Present Ecological State and Recommended Ecological Categories of the Komati River Catchment (2004).

10. ECOLOGICAL WATER REQUIREMENTS (QUANTITY)

10.1 OVERVIEW

Ecological Water Requirement (EWR) (quantity) refers to the flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. Data analysis focussed on the relationships between discharge and habitat availability and key ecosystem processes. This process did not consider whether these flows could be supplied or managed, and impacts on users were not considered.

10.2 OBJECTIVES

The objectives of this task were to recommend the magnitude, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic (e.g. geomorphology) and biotic components (plants and animals) of each Resource Unit in a particular condition, or Ecological Category (EC).

10.3 METHODS

10.3.1 Data Collection

Hydraulics

At each EWR site within South Africa one or more cross-sectional profiles were selected by the EWR team and surveyed by Mr Anthony Stephens in November 2003. Hydraulic data for EWR Site M1 in Swaziland was based on data collected as part of the Maguga Dam EWR study in 1997 (AfriDev *et al.* 1999). The profiles were used as the basis for hydraulic modelling and discharge and corresponding water levels were recorded on five separate occasions to calibrate the profiles. At EWR sites K1, K2 and L1 detailed spatial topographical data were collected and used to develop a two dimensional habitat model. The habitat modelling sites were surveyed by the Department of Water Affairs and Forestry: Directorate Geomatics in April 2004.

Geomorphology

Particle size distributions and other geomorphological data were collected at each EWR site within South Africa in August 2003. Geomorphological data for EWR Site M1 in Swaziland were based on data collected as part of the KOBWA EWR Monitoring Study in November 2003.

Riparian Vegetation

Vegetation profiles were surveyed and basic environmental data were recorded during the initial site-selection visit in August 2003. Many plants were dormant at the time so an additional survey to update the preliminary species checklists was undertaken in April 2004. Information for EWR Site M1 in Swaziland was based on data collected as part of the KOBWA EWR Monitoring Study in November 2003 and November 2004.

10.3.2 Specialist Meetings

Two Specialist Meetings were held as follows:

	Meeting 1:	Meeting 2:
Venue:	Bundu Lodge (Nelspruit)	CSIR (Pretoria)
Dates:	25-29 October 2004	31 January-1 February 2005
EWR sites:	K1, K2, K3, L1, G1, T1	EWR M1

10.3.3 Data Analysis

Low Flows

Recommendations for low flows were determined for each EWR site using the Habitat Flow Stressor Response (HFSR) method (Hughes and O'Keeffe 2004; IWR Source-to-Sea 2004). 4). The basis of the method is the application of a Stress Index that describes the responses of instream biota to changes in habitat conditions linked to flow. The stressors, flow hydraulics and associated habitat changes, are related to biotic responses in terms of abundance, life stages and persistence. Separate stress indices were determined for for invertebrates and selected target fish species, and an Integrated Stress Index was determined based on the most sensitive component. The stress indices were generated by examining the relationships between flows and habitat availability and fish and invertebrate survey results.

Stress requirements were then set for both fish and invertebrates and the recommended requirement consisted of the requirement which represented the lowest stress at any given duration. The Desktop Reserve Model estimates were then used as a basis and adjusted to fit the specialist requirements.

High Flows

Recommendations for high flows were determined for each EWR site using the Downstream Response to Imposed Flow Transformation (DRIFT) method (Brown and King 2000). The method involved the classification of floods, followed by an assessment of their ecological roles. Motivated recommendations regarding timing and frequencies were provided for the REC and alternative categories. Statistical analysis of the flood peaks was undertaken to determine a suitable relationship between flood peak discharge and catchment area for a range of return periods that could be used to estimate return period floods at each of the EWR sites under natural conditions. These values, in particular the 1:2 year return period flood, were used as a reference point for the floods at each of the sites. Where daily present-day hydrological data were available these were analysed using the flood analysis options in DRIFT-HYDRO (Flood analysis in DRIFT-HYDRO). This included EWR sites K1, K2 and K3 (partially). Where daily present-day hydrological data were not available, or were deemed to be unreliable, the present day flood daily averaged were estimated based on local knowledge about the water resource developments and the demands on those systems.

This included EWR sites K3 (partially), L1, G1 and T1. Four classes of intra-annual flood events calculated as:

Class IV = (1:2 annual peak –10%) to (1:2 annual peak –10%)/2;
Class III = (1:2 annual peak –10%)/2 to (1:2 annual peak –10%)/4
Class II = (1:2 annual peak –10%)/4 to (1:2 annual peak –10%)/8
Class I = (1:2 annual peak –10%)/8 to (1:2 annual peak –10%)/16.

10.4 RESULTS

The low flows and high flows were then incorporated into an integrated flow regime. The final output was EWR rules, presented as duration tables, were provided from the Desktop Model. The IFR assurance rules were documented in the report. Results were also provided as IFR tables (the .tab tables). The flows recommended for the recommended EC are summarised in Table 10-1, and constituted between 12 and 37% of the nMAR. These values represent the initial flow demands used in yield models. The values are generally lower than a previous estimate of the EWR of the Komati River, conducted in 1997.

Table 10-1. Summary Instream Flow Requirements for EWR sites in the Komati River Catchment, expressed as a percentage of the natural Mean Annual Runoff (nMAR) for the Recommended Ecological Categories (ECs).

EWR Site	REC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long-term mean of nMAR
K1	B/C	14.99	4.08	8.97	24.17
K2	C	8.53	2.8	8.22	14.63
M1	C	7.05	1.57	7.5	18.07
K3	D	19.78	8.6	6.18	28.79
G1	D	12.41	6.17	4.35	25.51
T1	C	18.89	8.22	15.46	36.54
L1	C/D	6.49	2.85	2.99	11.82

Confidence

A large amount of historical data were collected from the main Komati River, so confidence in the available biological data was generally high for the main river, and less so for the tributaries. The confidence in the low-flow hydraulics was generally high, but confidence in high flow hydraulics was low because the study was conducted during an extended dry period, which made it impossible to calibrate the hydraulics under high flow conditions. Confidence in the sites selected was high, with the notable exception of EWR Site K3 (Tonga), which had been historically inundated by backup from a weir, and was reinundated during the course of the study. Confidence in the hydrology was moderate for most sites, with the notable exception EWR Site G1 (Gladdespruit), where confidence was low.

11. OPERATIONAL SCENARIOS

11.1 OVERVIEW

Operational Scenarios refer to flow scenarios that are designed to incorporate the availability of water, operational constraints and user demands. The development of operational scenarios is the next logical step that follows the quantification of the EWR (Chapter 5). The development of operational scenarios is an iterative process in which the severity of impacts, complexity and budget constraints determined the number of iterations required. The EWR (quantity) scenarios for a range of ECs were used as the basis for developing an initial set of scenarios, and modified as required.

11.2 OBJECTIVES

The objectives of this task were to develop a range of operational scenarios that result in different impacts on different users. The impacts of incorporating the EWR on the ecology, system yield, goods and services and overall economic activities could then be assessed.

11.3 METHODS

The Water Resources Yield Model (WRYM) was set up for KOBWA by Ninham Shand. The basic operating policies were retained, but the model was modified to include EWR channels at the appropriate places and additional channels to facilitate analysis of supply to users. Analyses were done using the historic inflow time series from 1921 to 1999 to determine supply to users for each scenario.

Three meetings with regional water managers were held to develop appropriate operational scenarios. The model was set up in such a way that the first mechanism of curtailment was a rule curve based on the level of the dams, and EWRs were treated as a priority demand. The EWRs were first met by incremental tributary accruals and releases were made from the dams only when these accruals could not supply the EWR. In regulated Resource Units, the high flow component of EWRs was modified to account for the limited outlet capacities of upstream dams. High flow EWR requirements that could not be met because of outlet constraints were removed completely as a demand, and not capped at the maximum outlet capacity.

Unregulated tributaries were modelled the same for all scenarios, except for changes in the EC. Three scenarios with the EWR were assessed initially: the REC and the alternative categories “up” and “down”. These scenarios were further split into those that included full floods, and those excluding floods that could not be met because of system constraints. The following scenarios were considered:

11.4 RESULTS

A summary of the various scenarios considered is shown in Figure 11-1.

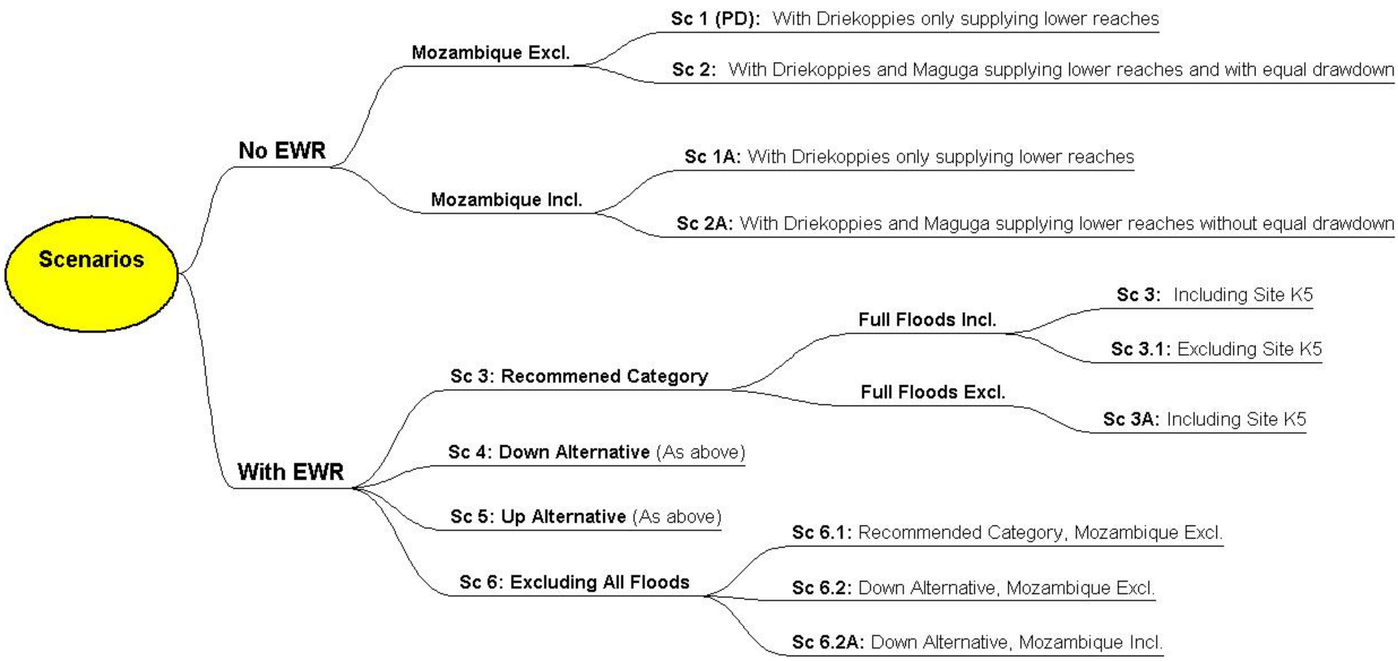


Figure 11-1. Operational Scenarios developed for the Komati River Catchment.

Four scenarios without EWR requirements were evaluated: two including Mozambique requirements and two excluding Mozambique requirements. The reason for various scenarios without the EWR requirements was that the operational management of the system is subject to phased implementation. The system is unlikely to be managed like this in future as once Maguga Dam has sufficient water it will be managed together with Driekoppies Dams, and international treaty requirements will need to be adhered to. Three scenarios with the EWR requirements were assessed initially: the Recommended EC and the alternative categories “up” and “down”. These scenarios were further split into those that included full floods, and those excluding floods that could not be met because of system constraints. The following scenarios were considered:

- **Scenario 1:** No EWR, excluding Mozambican requirements and with Driekoppies Dam only supplying the lower reaches. This is unlikely to be a future scenario but it was included because the baseline data collected for this study were collected under these conditions. This scenario therefore serves as an important reference and approximates present-day flows
- **Scenario 1A:** As above, but including Mozambican requirements.
- **Scenario 2:** No EWR, excluding Mozambican requirements, but including Driekoppies and Maguga Dam supplying the lower Komati River. This scenario was considered with and without equal drawdown of Maguga and Driekoppies Dams (Scenario 2 and 2A respectively);
- **Scenario 3**: With EWR at REC, and including full flood requirements. This scenario was considered with and without the hypothetical dummy site K5 as a demand on the system (Scenario 3 and 3.1 respectively);
- **Scenario 4**: As above, but with EWR in “down” alternative;

- **Scenario 5**: As above, but with EWR in "up" alternative. The "up" alternatives were included to determine sensitivity and the impact on the yield, but these were not evaluated ecologically because they are unlikely to be implemented. This scenario was subsequently removed from further analysis because it was considered unlikely to be implemented;
- **Scenario 6**: With EWR requirements but excluding floods that could not be met because of system constraints. This scenario was considered for the REC and the down alternative (Scenario 6.1 and 6.2 respectively). This scenario was based on discussions with operational managers who confirmed the need to consider a scenario that excluded all managed EWR flood requirements. An additional scenario (6.2.A) was the same as Scenario 6.2, but included Mozambique's requirements.

12. CONSEQUENCES FOR ECOLOGY AND WATER QUALITY

12.1 OVERVIEW

Having developed various operational scenarios in which the EWR may have been modified to account for system constraints and impacts on yield, the next step in the process was to assess the water quality and the resulting ecological consequences of the various operational scenarios.

12.2 OBJECTIVES

The aim of this component of the study was to describe the ecological and water quality consequences of various operational scenarios.

12.3 METHODS

The approach is summarised as follows:

- The output of each scenario was used to determine the water quality consequences using simple concentration modelling.
- The water quality consequences and other driver consequences were used to assess the response consequences for each different flow scenario.
- The assessment was made within the EcoClassification process and predicted the changes from the REC to the predicted Ecological Category (EC).
- Each driver and response component ECs were then integrated to determine the EcoStatus. This then comprised the ecological consequences.

12.4 RESULTS

The results of the ecological consequences assessment indicate that while some ecosystem components were detrimentally impacted by certain scenarios, the EcoStatus was unaffected by all scenarios that included EWR requirements (Table 12-1).

The EWR objectives in the upper reaches of the Komati River at K1 are met for all scenarios because of tributary accruals.

The flow scenarios that would improve water quality in the lower reaches are those scenarios that include improved (from present) baseflows (Scenario 6). The scenarios that would improve the water quality are 3, 6.1 and 6.2.

Table 12-1. Ecological consequences of various operational scenarios.

Site	PES	REC	EWR Excl.		EWR Incl.					
			SC 1	SC2A	SC 6.2	SC 6.1	SC 4A	SC 4	SC 3A	SC 3
K1	B/C	B/C	✓	✓	✓*	✓	✓	✓	✓	✓
K2	C	C	X (D)	X (D)	✓	✓	✓	✓	✓ (B/C)	✓ (B/C)
M1	C	C	✓	✓	✓	✓	✓	✓	✓	✓
K3	E	D	X (E/F)	X (E)	✓*	✓*	✓	✓	✓	✓
G1	D	D	✓	✓	✓	✓	✓	✓	✓	✓
T1	C	C	✓	✓	✓	✓	✓	✓	✓	✓
L1	C/D	C/D	✓	✓	✓*	✓	✓	✓	✓	✓
Number of EWR sites where ecological objectives are NOT achieved			2	2	0***	0*	0	0	0	0

* **Individual components not met**

12.5 CONCLUSIONS

The traffic light diagram in Figure 12-1 shows the approximate difference between scenarios, from an ecological point of view, along a continuum of impacts. The continuum illustrates how successfully the scenarios meet the EWR objectives.

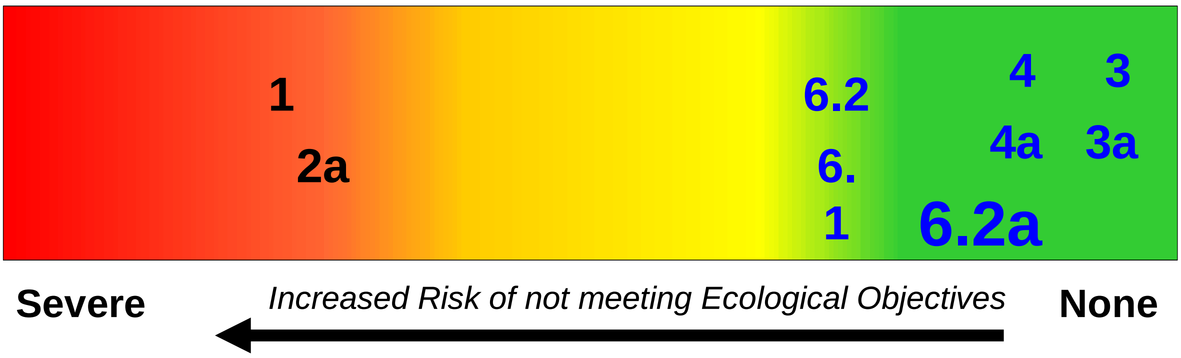


Figure 12-1. Ecological consequences for various operational scenarios in the Komati River.

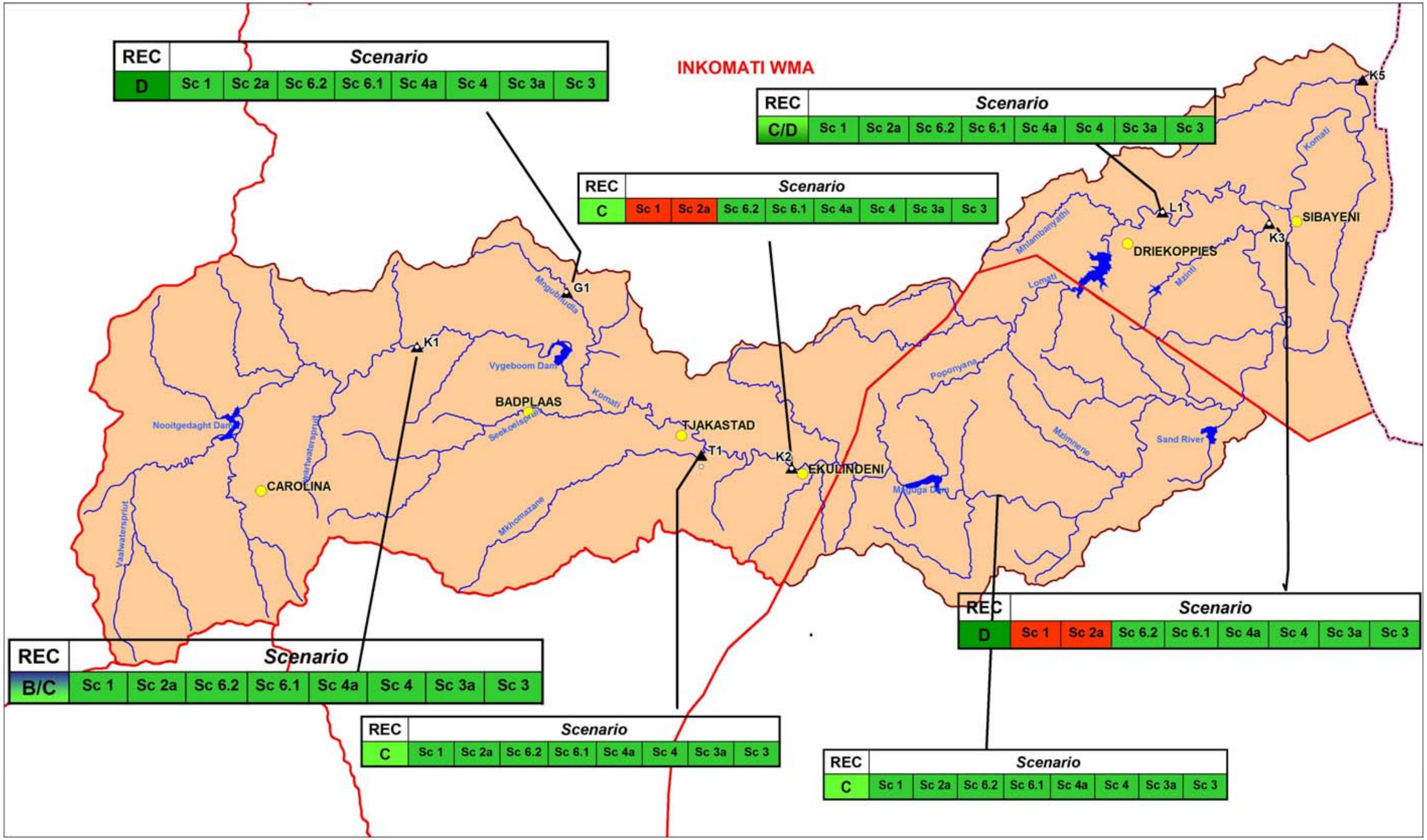


Figure 12-2. Ecological consequences of operations scenarios at each EWR site for the Komati River Catchment.

13. CONSEQUENCES FOR YIELD

13.1 OVERVIEW

Having assessed the ecological consequences of the various scenarios, the next step in the process was to assess the consequences for water availability within the catchment, or yield.

13.2 OBJECTIVES

The aim of this component of the study was to quantify the consequences of various operational scenarios for water yield.

13.3 METHODS

The Water Resources Yield Model (2000) was used to assess the impacts that the EWR Scenarios will have on the available yield of the system. User requirements were based on best available data and associated assurance of supplies. For example, 70% of the irrigation requirements were allocated at high assurance (98%), while the remainder was allocated at low assurance (80%). Curtailment rules were developed where the available water did not meet the requirements of the existing water users. The difference between the present day demands in the system model and the Piggs Peak Treaty demands is not significant, so the Treaty demands were used for all scenarios except Scenario 1. The user requirements that were included in the model are summarised in Figure 13-1.

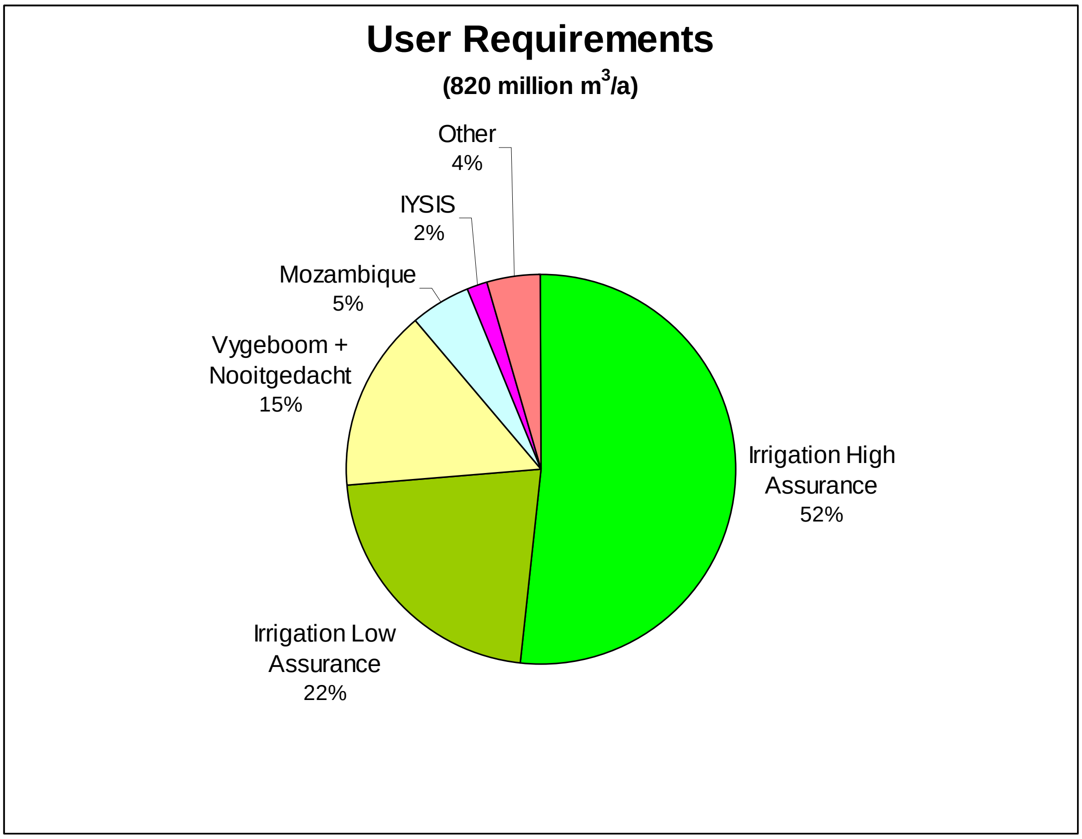


Figure 13-1. Water requirements for various user sectors in the Komati River Catchment.

13.4 RESULTS

The total supply to users for various scenarios is summarised in Figure 13-2. The results show that the full requirement cannot be supplied, even without the EWR. Scenario 2 provides the most water for users at 92% of the user requirement, but this scenario does not provide for the EWR, while Scenario 6.1 and 6.2 supply 90% of the requirement.

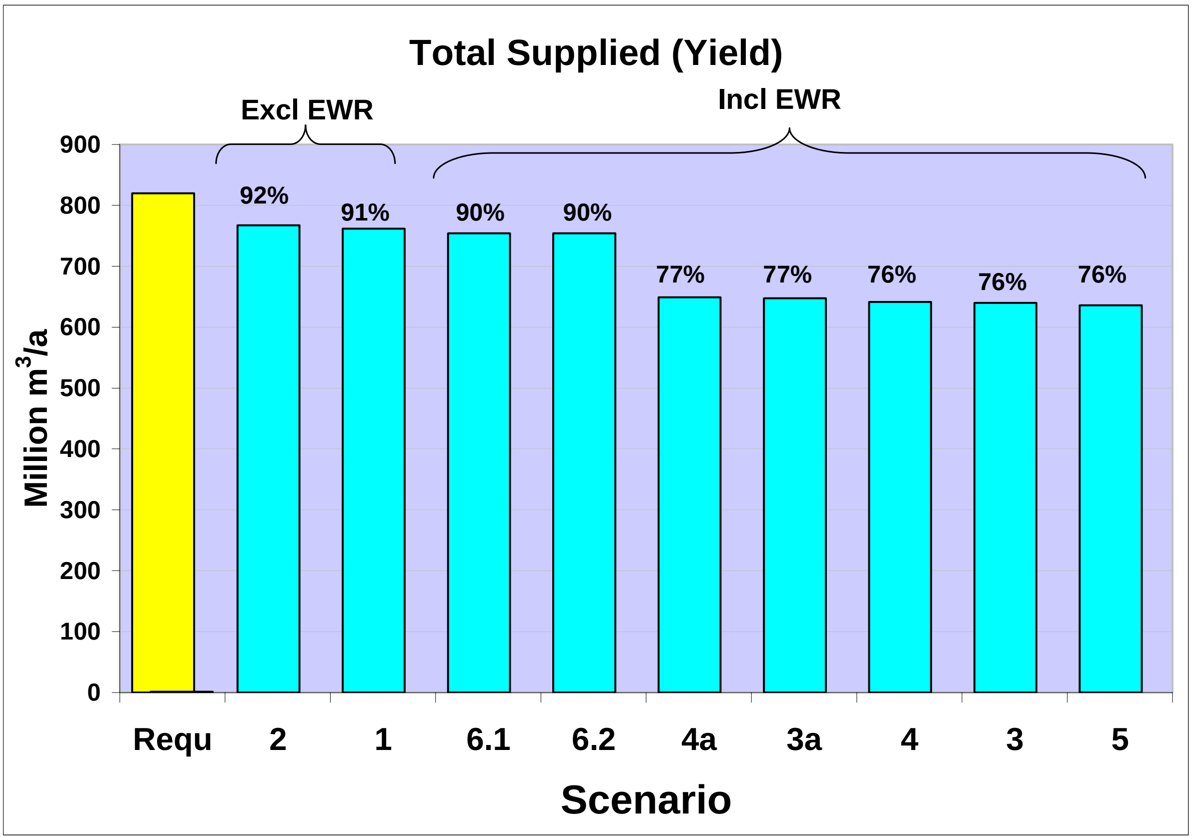


Figure 13-2. Total water supplied (in million m^3/a) to users for various flow scenarios in the Komati River Catchment. (Requ = User Requirement.)

13.5 CONCLUSIONS

Modelling results indicate that there is a 8% deficit in water availability without the implementation of the EWR (i.e. 92% supplied). Implementation of the recommended EWR results in an additional deficit of 16%, irrespective of the ecological category (i.e. 76% supplied). Modifying the EWR to exclude floods that cannot be met makes little difference to the yield (1%), but modifying the results to exclude *all* floods makes a significant difference to the yield (14%). The overall degree of curtailment on existing users for various operational scenarios mirrors the socioeconomic impacts (Chapter 9).

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14. CONSEQUENCES FOR THE GOODS AND SERVICES AND ECONOMY

14.1 OVERVIEW

Water resources provide important benefits to society, both as input capital for production and ecological goods and services. Due to the increasing scarcity of water for both production and environmental benefits and scarcity of resources to develop water infrastructure, it is necessary to make decisions about conservation and demand management and reallocation of the resource among competing uses that are compatible with government social objectives such as achieving equity, economic efficiency and sustainability. Economic valuation plays an increasingly important role in decision making between socioeconomic development and protection of the resource for long term sustainability. Therefore, development and management of water resources cannot be interpreted without some idea of the value of water to the socioeconomic activities taking place in a catchment, and the value of ecological goods and services provided by the catchment.

The water resources of the Komati River catchment which is a shared watercourse are now all allocated. In order to ensure the water resources of the Komati are managed in a sustainable manner, EWRs will be required. The Act provides that these flows have priority over all other water using sectors.

However allocation of flows to the ecology will mean reallocation of the available water in the Komati River catchment from existing water using sectors.

14.2 OBJECTIVES

The purpose of valuing the water for production and socioeconomic activities and ecological goods and services is to assess the preference of communities in the catchment for or against environmental change.

14.3 METHODS

14.3.1 Economic value of water for commodity use

The Komati River Catchment was divided into five economic zones or subsystems (Figure 14-1). For each zone, a customised Water Impact Model was developed to calculate the economic value of water. The model was based on a Social Accounting Matrix (SAM) that was developed separately for Swaziland and South Africa. The underlying principal of the model was that water is scarce, and so its allocation among competing users needs to be structured to ensure that positive socioeconomic impacts are maximised. The model distinguished four water user sectors as follows:

- Irrigated Agriculture
- Domestic including commercial and industrial

- Commercial Forestry
- Transfers for ESKOM Power Generation

Not all scenarios were investigated. The range of scenarios investigated was such that the worst case and base case for socio economy could be determined. The scenarios that were investigated therefore were Scenarios 2, 6.2 and 6.2a. These were compared with the base scenario (Scenario 1), which was the socioeconomic value of the present water available to the above water user sectors. The model was structured to provide a detailed description of the water availability in sub-catchments for various scenarios. Given the water availability for a new scenario, the model determined the economic and socioeconomic impacts emanating from the change in water availability.

The Water Impact Model determined the different impacts that the various scenarios will have on the economy. The marginal differences in economic and socioeconomic impacts were calculated by subtracting the impact of these situations from each other. This made it possible to quantify the impact that the various scenarios will have on the community, as well as the broader economy.

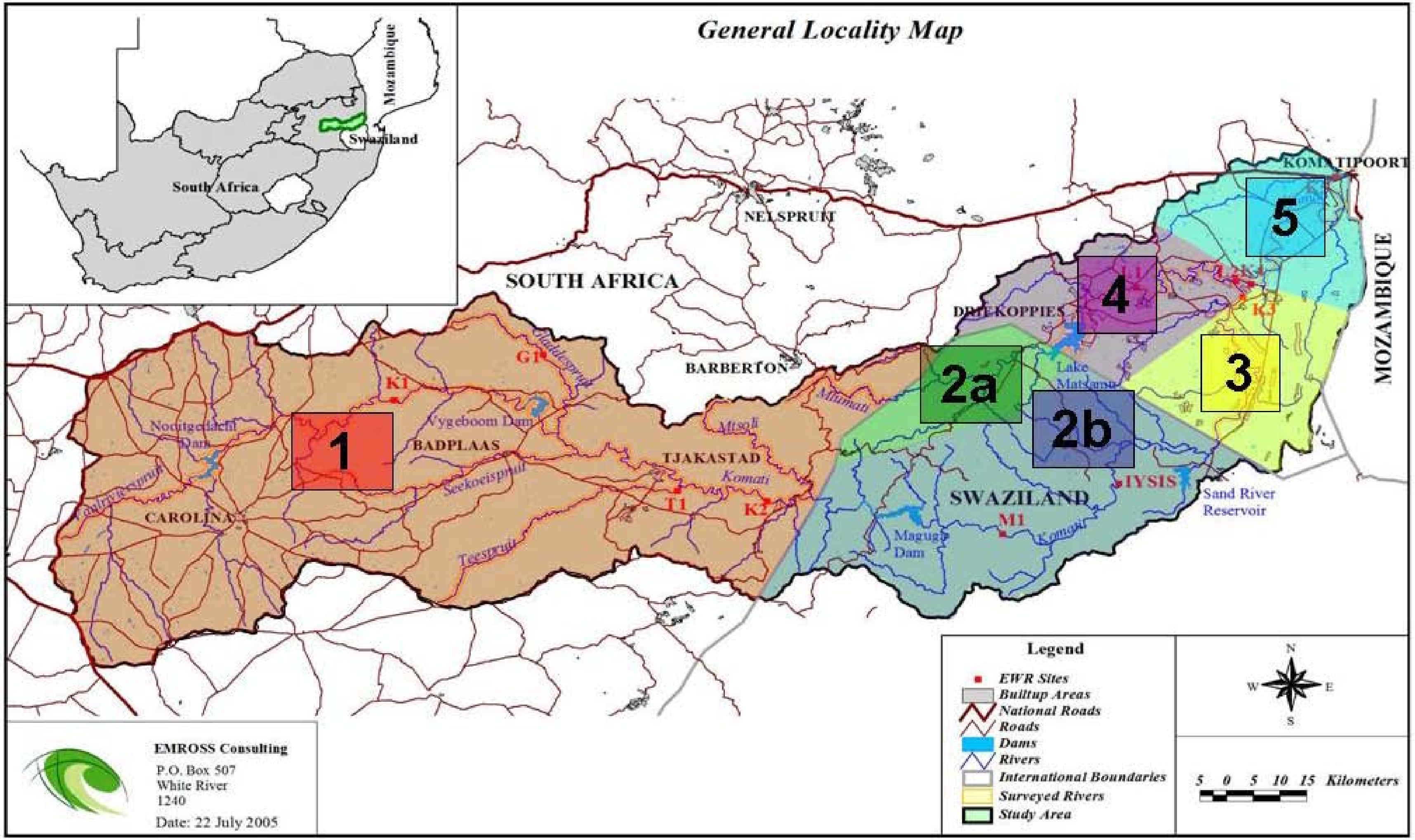

Figure 14-1. Map of the Komati River Catchment, showing the delineation of the catchment into five economic sub-systems.

The factors that were used to determine the implication of the EWR scenarios were the following:

- o The incremental change in the economic surplus or profit to the users in each sub-catchment and per water user sector
- o The incremental change in the Gross Domestic Product for each EWR scenario
- o The number of jobs that would be generated or lost for each EWR scenario.

14.3.2 Economic value of Goods and Service

A specialist workshop was held where the ecological goods and services in each sub-catchment were identified. The following ecological goods and services were identified:

- Fishing by community - Benefit
- Fish farming - Benefit
- Thatch grass
- Reed harvesting
- Wood gathering
- Recreational fishing
- Recreational boating
- Cultivated floodplains
- Sand mining
- Recreational swimming
- Medicinal plants

It should be noted that the above goods and services are from direct and indirect use of the river. The specialist workshop also identified the indirect use of the in stream water namely the following:

- Waste assimilation
- Waste dilution
- Black flies
- Livestock diseases
- Malaria
- Bilharzia
- Cultural activities
- Grinding stones

Various techniques were used to measure the economic value of direct and indirect goods and services provided by the Komati River because of the different volume of ecological water left in the river to protect the resource. These ranged from use of surrogate markets to contingency valuation methods.

14.4 RESULTS

14.4.1 Overall economic valuation of changes in flows on market (rival) goods and services

In Table 14.1 the total impact of a specific scenario is compared to the other scenarios in the Komati Catchment. From Table 14.1 it is clear that Scenario 6.2a will have the most severe influence on the economy in the Komati River catchment if implemented and specifically on irrigated agriculture where a possible 95% of present cultivated lands will have to be curtailed. Scenario 6.2 is as far as economic impacts are concerned the least severe and if decided upon, only 1.6% of the irrigation area will have to be withdrawn when the water is reallocated for ecological flow requirements.

This does not take into account the potential for improving the current efficiency levels through improving the conveyance infrastructure for the irrigation system and reducing water losses in the domestic sector.

14.4.2 Overall economic valuation of changes in flow scenarios on ecological goods and services

The value of ecological goods and services were determined for the whole of the Komati River catchment for each flow scenario. The results are presented in Table 14.2. The outcomes of each scenario mirror the positive impact that each flow scenario has in each sub-catchment.

The overall incremental benefits are significant for scenario 6.2a but they tail of towards the base scenario. This indicates that any further optimisation will not realise significant benefits in the ecological flows which is the water regime provided within a river zone to maintain ecosystems and provide goods and services where there are competing water uses.

Scenario 6.2a therefore provides the optimised scenario for ecological goods and services in the Komati River catchment. Although this is not the scenario with the least impact on the socio-economic growth of the catchment, the overall impact is not as severe as only 1.62% of irrigation agriculture will be affected.

Table 14-1: Results of the value of macro-economic impacts for each flow scenario for the Komati River catchment.

Scenario	Total Surplus Rand million	GDP Rand million	Capital Formation Rand million	Low income households Rand million	All households Rand million	Employment Numbers	Change in irrigated area ha	% irrigation withdrawn
Baseline	3 796	15 597	41 033	10 606	19 031	113 538	53 323	
Scenario 2a	-3	-35	37	-24	-44	-1 000	-1 102	-2.07%
Scenario 6.2	-7	-9	122	-11	-11	-414	-864	-1.62%
Scenario 6.2a	-24	-128	-194	-89	-153	-1 584	-2 051	-3.85%

Table 14-2: Valuation of incremental benefits ecological flows in the whole of Komati River catchment.

Socio-economic variable	**Baseline (Current situation) R*1000**	**Scenario 2a**	**Scenario 6.2**	**Scenario 6.2a**
		Incremental benefit R *1000	**Incremental benefit R *1000**	**Incremental benefit R *1000**
Surplus value	48 130	3 400	4 731	5 434
GDP	54 810	4 020	4 880	5 470
Low income households	24 590	3 590	5 040	5 790
Employment generated	4 342	261	368	432
Percentage change from baseline of the surplus value		7.06%	9.83%	11.29%

14.4.3 Incremental and phased implementation of ecological flows

As explained in the conceptual framework of the water impact model, the model makes provision to measure the impacts if certain changes in management and technology are introduced in the irrigation-farming sector. It was therefore decided to apply some of these improvements to the farming sector over a 5-year period and to calculate whether the improvements are meaningful if compared to the results of the immediate introduction of water cutbacks.

In Table 14.3 the possible benefits of the phased option to the region is compared to the immediate applied option.

Table 14-3: Benefits derived from phased implementation of the flow scenarios.

Ecological flow scenario	**Benefits from the Phasing Options**			
	Employment Opportunities	*Percentage Improvement*	*Irrigation Hectares*	*Percentage Improvement*
Scenario 2a	971	97.1%	1 349	122.5%
Scenario 6.2	888	214.4%	1 303	150.9%
Scenario 6.2a	1 028	64.9%	1 509	73.6%

Phasing will have definite benefits to the farming community (Table 14.3). In the case of Scenario 6.2a the hectares to be withdrawn, decrease to approximately 579 ha if water use efficiency measures and improved management practices are put in place before the ecological flows are implemented. This is compared with the 1 584 hectares that will be lost under current water use efficiency levels and management practices.

Table 14-4: Overall impact of flow scenarios on the Komati River catchment with phased implementation of flows.

Scenario	Total Surplus Rand million	GDP Rand million	Capital Formation Rand million	Low income households Rand million	All households Rand million	Employment Numbers	Change in irrigated area ha	% irrigation withdrawn
Baseline	3 796	15 597	41 033	10 606	19 031	113 538	53 323	
Scenario 2a	13	24	151	16	29	-29	248	0.46%
Scenario 6.2	23	50	233	29	62	474	429	0.82%
Scenario 6.2a	-11	-73	-83	-53	-84	-579	-764	-1.4%

14.5 CONCLUSIONS

Besides the economic criterion, there are other criteria that need to be considered to assess the value of water. Ecological, social, cultural and broader environmental considerations which cannot be valued in monetary terms must equally be taken into consideration and incorporated into the policy decision of the level of resource protection of the Komati River Catchment.

In order to take consideration of these other scenarios, the overall implications of the various scenarios for ecology, goods and services and socioeconomics are summarised in a traffic light diagram (Figure 14.5). Scenarios that exclude the EWR have limited ecological impact on unregulated tributaries, but have a major impact on regulated rivers, particularly in the lower reaches. Scenarios that include the EWR generally meet the ecological objectives and enhance ecological goods and services.

The recommended flows for the lower Komati, which is in a very bad ecological condition, are designed to restore perenniality through improved baseflows. However, these actions alone will be inadequate. There is a need to reduce irrigation return flows and inundation from weirs. The Inkomati Catchment Management Agency could play a vital role in co-ordinating efforts to improve the riparian zone as a buffer, control deforestation, control cultivation and grazing in riparian zone, and reduce fragmentation caused by weirs.

The present water requirement for input into economic production is currently not being met without the EWR. This is because of over-allocation at the level of assurance of supply to the various user sectors. Any scenario with the EWR will further exacerbate the socioeconomic growth of the Komati Catchment.

The best practical scenario for the protection of the water resources of the Komati Catchment is Scenario 3. However, this scenario will have a significant impact on the economic contribution to Swaziland and South Africa and reduced employment. The scenario with the least impact on the economy and employment is Scenario 6.2 (EWR high flow requirements removed). However because of the requirements to meet the Interim Inco-Maputo Agreement, which requires a minimum flow of 2 m^3/s, Scenario 6.2a is considered the optimal option.

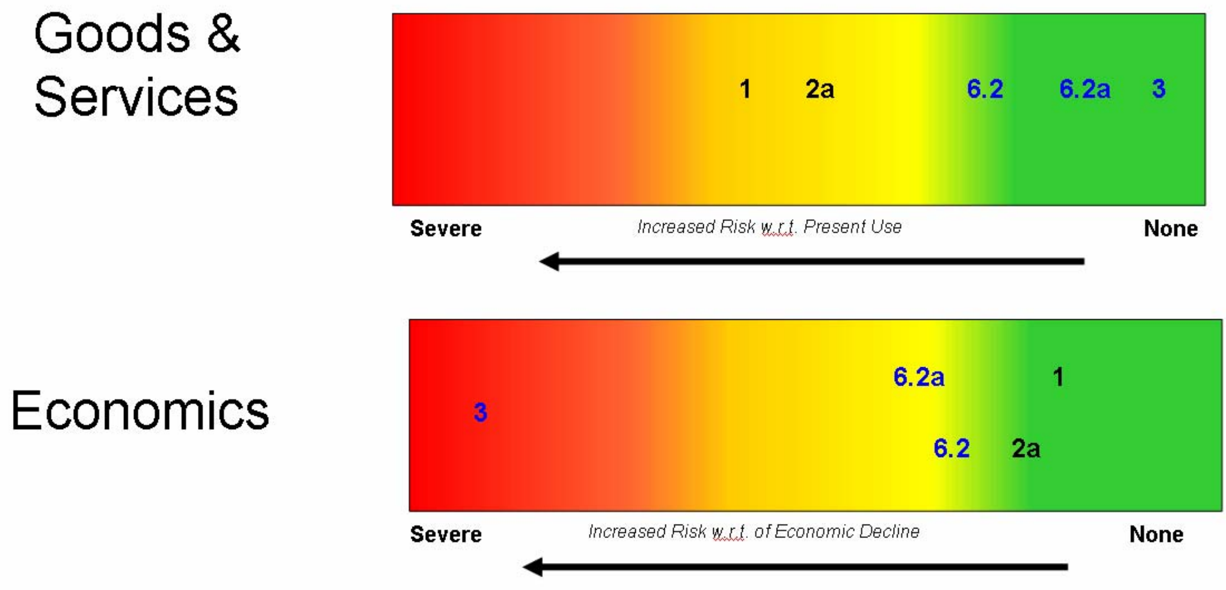

Figure 14-2. Comparison of consequences of various scenarios across major study components.

14.6 RECOMMENDATIONS

Although there are limitations in the valuation of the ecological goods and services because water is a classic non-marked resource, the valuation provides the implications of different flow scenarios on the social, economic and ecological welfare of the Komati River Catchment. This provides both stakeholders and decision makers with information to make informed decisions on the level of preference for protecting the resource, while balancing the need for social and economic development to achieve government objectives of poverty eradication in a sustainable manner.

The findings of the economic valuation indicate that the flow regime associated with Scenario 6.2 provides the best balance between ecological sustainability and social and economic development. It therefore recommended that the flow regime of Scenario 6.2a should be considered as the Ecological Reserve of the Komati River Catchment. This recommendation was accepted at a meeting with high level DWAF management that was held on the 27th September 2005 (Appendix A).

However it is important to test the implications of the ecological flows on the current cross-border flows. If the cross-border flows cannot be met with the ecological flows as provided for scenario 6.2, then additional releases will need to be made. This is in accordance with scenario 6.2a which will be the recommended scenario. It is also recommended that consideration be made in improving the water use efficiency levels in all the water using sectors in the Komati River catchment in order to reduce the negative socio-economic impact, implementation of the ecological Reserve will have on these sectors.

15. ECOLOGICAL RESERVE

15.1 INTRODUCTION

An assessment of the ecological and socioeconomic implications of the various operational scenarios concluded that the scenario with the least detrimental impacts on system yield, socioeconomics and ecology, is Scenario 6.2a. Although this scenario excludes all EWR floods as a demand, most of the EWR flood requirements were met by incidental runoff from unregulated tributaries. The only site at which this was no so was at Site K1, where unregulated runoff of high flows was compromised by Nooitgedacht Dam. All scenarios assumed present development conditions, and with increased development it is inevitable that unregulated flows will decrease. This means that if Scenario 6.2a were to be recommended as the Ecological Reserve, ecological flows would be compromised over time as the system becomes increasingly regulated. For this reason the recommended flows was revised to incorporate flows that were specified in the original EWR, provided they did not exceed the current predicted supplies (i.e., can be met under current demands). The final Ecological Reserve was therefore based on Scenario 6.2a plus those flows that were specified in the original EWR that could be supplied from unregulated runoff under current development conditions and demands.

15.2 METHODS

An annotated illustration of the process of generating the monthly time series for the EWR, operational scenarios, supplies under the recommended Scenario 6.2a, and final Ecological Reserve, are shown in Figure 7-1.

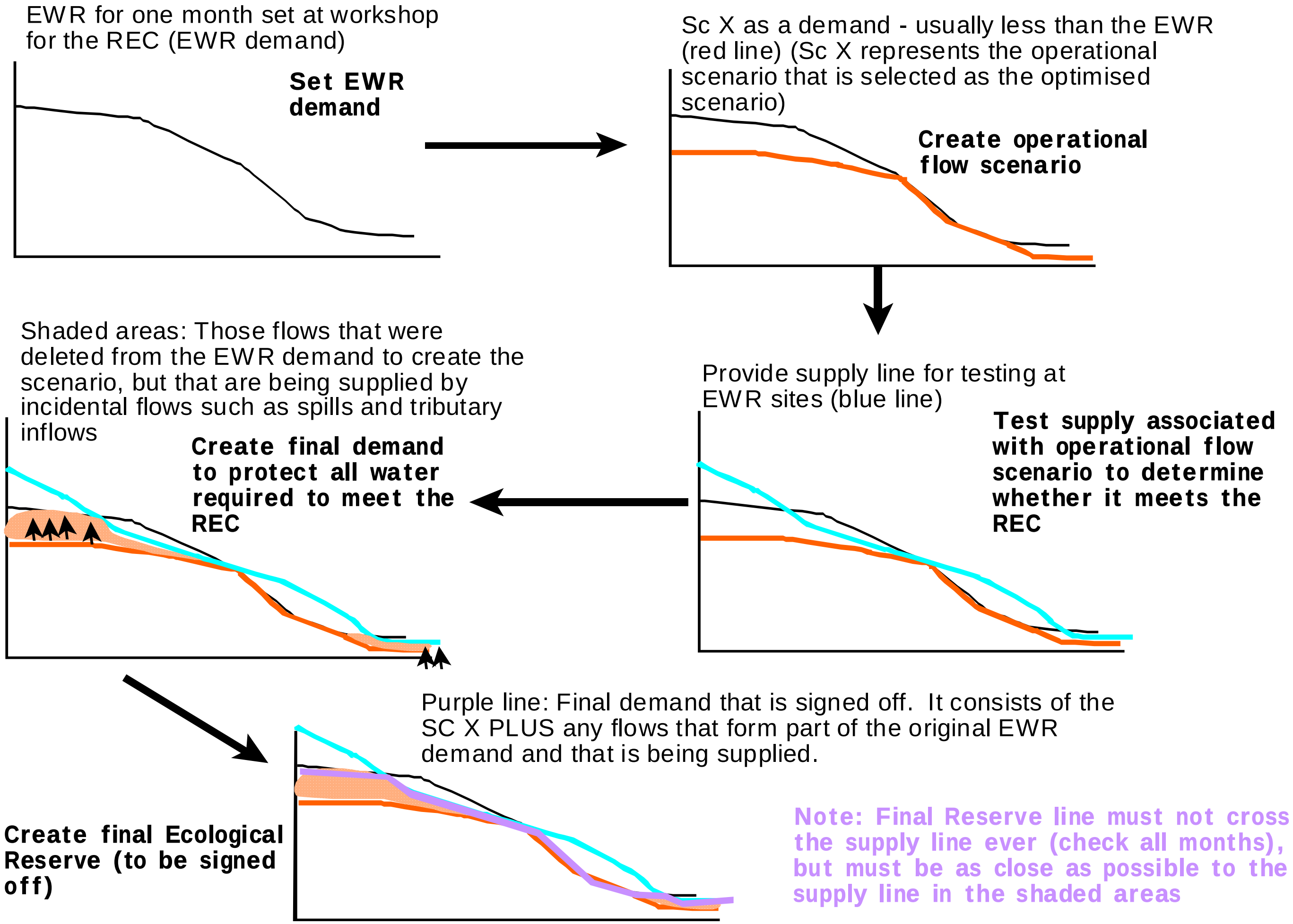

Figure 15-1. Illustration of the various EWR flow duration curves generated during the Reserve determination study, starting with the EWR demand for the REC, followed by various Scenarios (Sc) and associated supplies, and ending with a final ecological Reserve demand.

15.3 RESULTS

The final results of the Ecological Reserve are summarised in Table 7-1. The table shows the total annual EWR requirement and associated supply under Scenario 6.2a at each EWR site. The table also lists the full EWR for the REC, and the final total Ecological Reserve requirement at each EWR site. The Ecological Reserve constituted between 11.63 and 35.60% of the nMAR (Table 7-1). Detailed results of the Ecological Reserve are presented as monthly flow duration tables in Table 7-2. The evaluation of a Reserve for a water abstraction licence at any point in the Komati River System can now be determined by extrapolating the flow regime up or downstream from an existing EWR site.

Table 15-1. Mean Annual Flows at various sites for Ecological Water Requirement (EWR) under 1) Scenario 6.2a, 2) the supply under Scenario 6.2a 3) the full EWR, and 4) the recommended Ecological Reserve, expressed in million m3/a and as a percentage of the natural Mean Annual Runoff (nMAR).

		Mean Annual Flow (million m^3/a)				% nMAR	
Site	nMAR (MCM)	EWR Sc6.2.a Requirement	EWR Sc6.2.a Supply	Full EWR Requirement	Ecological Reserve	Full EWR	Ecological Reserve
K1	181.17	19.17	142.48	43.75	42.92	24.15%	23.69%
K2	527.16	34.37	310.50	94.40	92.71	17.91%	17.59%
K3	1016.48	110.61	289.53	192.52	141.42	18.94%	13.91%
M1	857.1	132.85	476.89	248.93	224.73	29.04%	26.22%
L1	321.65	27.99	221.76	37.94	37.42	11.80%	11.63%
G1	37.73	7.56	26.40	9.60	7.60	25.44%	20.14%
T1	60.59	8.69	48.65	21.54	21.57	35.55%	35.60%

Table 15-2. Monthly flow duration tables for the Ecological Reserve at selected sites in the Komati River Catchment.

K1

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.55	0.55	0.54	0.53	0.52	0.48	0.43	0.35	0.25	0.18
Nov	0.89	0.89	0.88	0.85	0.83	0.77	0.67	0.53	0.36	0.23
Dec	1.72	1.71	1.69	1.64	1.58	1.45	1.25	0.95	0.60	0.34
Jan	3.64	3.29	3.11	2.86	2.64	2.21	1.88	1.40	0.85	0.44
Feb	10.02	8.85	7.81	6.46	4.74	4.09	3.72	3.04	1.87	0.90
Mar	1.74	1.73	1.71	1.67	1.61	1.48	1.28	0.98	0.62	0.36
Apr	1.98	1.98	1.95	1.90	1.84	1.70	1.46	1.11	0.68	0.36
May	1.27	1.27	1.26	1.24	1.19	1.11	0.96	0.74	0.47	0.27
Jun	0.84	0.84	0.83	0.82	0.79	0.74	0.65	0.52	0.35	0.23
Jul	0.74	0.74	0.73	0.72	0.70	0.66	0.59	0.47	0.32	0.21
Aug	0.47	0.47	0.47	0.46	0.45	0.43	0.38	0.32	0.24	0.18
Sep	0.63	0.63	0.63	0.62	0.60	0.56	0.50	0.40	0.28	0.19

K2

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.99	1.98	1.96	1.75	1.51	1.38	0.96	0.75	0.51	0.28
Nov	3.13	3.12	3.06	3.00	2.88	2.64	2.25	1.67	1.02	0.37
Dec	3.36	3.35	3.31	3.18	3.10	2.85	2.44	1.86	1.17	0.66
Jan	6.45	5.93	5.46	4.94	4.55	3.78	3.24	2.48	1.60	0.95
Feb	14.65	13.36	11.68	10.18	9.52	7.54	6.44	4.87	3.01	1.63
Mar	11.19	10.26	9.16	7.82	6.96	5.70	5.05	3.88	2.41	1.32
Apr	2.63	2.63	2.61	2.53	2.47	2.29	2.01	1.58	1.07	0.69
May	2.09	2.09	2.07	2.03	1.97	1.84	1.61	1.27	0.86	0.54
Jun	1.95	1.95	1.93	1.89	1.84	1.71	1.49	1.16	0.75	0.44
Jul	1.81	1.81	1.79	1.77	1.71	1.58	1.36	1.00	0.68	0.39
Aug	1.67	1.67	1.63	1.46	1.27	1.00	0.95	0.81	0.58	0.34
Sep	1.85	1.84	1.74	1.62	1.21	0.99	0.90	0.80	0.63	0.28

M1

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.53	5.48	5.39	5.18	4.82	4.21	3.71	2.99	2.08	1.44
Nov	10.29	9.83	8.93	7.52	6.06	5.57	4.39	3.98	3.34	2.05
Dec	10.18	9.97	9.60	9.05	8.58	7.65	6.50	5.58	4.38	2.67
Jan	13.13	12.33	11.13	9.90	9.28	8.43	7.48	5.96	4.59	3.44
Feb	27.53	25.27	18.02	15.26	13.29	11.22	9.73	7.72	6.78	4.75
Mar	14.31	13.43	12.32	10.76	9.37	8.18	7.41	6.54	5.20	3.73
Apr	9.45	9.40	9.26	8.60	8.36	7.48	6.77	5.84	4.33	3.20
May	8.08	8.05	7.90	7.71	7.36	6.63	5.90	4.95	3.75	2.64
Jun	7.25	7.23	7.12	6.83	6.44	5.94	4.84	4.37	3.35	2.33
Jul	6.27	6.24	6.17	5.95	5.62	4.90	4.38	3.85	2.85	1.89
Aug	5.57	5.55	5.49	5.33	4.98	4.50	3.95	3.44	2.43	1.54
Sep	5.55	5.53	5.45	5.25	4.95	4.29	3.75	3.24	2.10	1.34

K3

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.84	3.69	3.62	3.59	3.54	3.41	2.81	2.14	1.18	0.50
Nov	4.92	3.77	3.74	3.64	3.53	3.20	2.87	2.34	1.42	0.53
Dec	6.43	5.29	4.77	4.18	4.15	4.06	3.55	2.55	1.44	0.74
Jan	12.02	7.24	6.14	5.31	5.14	5.07	4.43	2.98	2.01	0.71
Feb	13.84	12.65	6.06	5.84	5.60	5.08	4.83	3.35	2.28	1.34
Mar	34.99	27.78	5.76	5.68	5.41	5.22	4.84	4.07	3.02	1.33
Apr	6.18	5.37	5.33	5.24	5.04	4.68	4.12	2.55	1.79	0.82
May	4.87	4.85	4.78	4.69	4.51	3.84	3.32	2.34	1.47	0.65
Jun	4.38	4.37	4.30	4.20	4.04	3.55	2.92	2.03	1.37	0.59
Jul	3.88	3.87	3.82	3.72	3.56	3.36	2.79	1.73	1.22	0.50
Aug	3.72	3.71	3.65	3.56	3.40	3.10	2.44	1.99	1.07	0.45
Sep	3.64	3.64	3.60	3.54	3.43	3.20	2.77	2.33	1.18	0.43

G1

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.22	0.22	0.22	0.21	0.2	0.19	0.17	0.14	0.1	0.07
Nov	0.31	0.31	0.3	0.3	0.29	0.27	0.23	0.18	0.12	0.08
Dec	0.36	0.36	0.35	0.34	0.33	0.3	0.26	0.21	0.14	0.09
Jan	0.57	0.53	0.51	0.48	0.45	0.39	0.34	0.26	0.17	0.11
Feb	1.46	1.33	1.2	1.06	0.99	0.81	0.69	0.52	0.32	0.17
Mar	0.38	0.38	0.37	0.36	0.35	0.33	0.28	0.22	0.15	0.09
Apr	0.39	0.39	0.38	0.37	0.36	0.34	0.29	0.23	0.15	0.09
May	0.32	0.32	0.32	0.31	0.3	0.28	0.25	0.19	0.13	0.08
Jun	0.29	0.28	0.28	0.28	0.27	0.25	0.22	0.18	0.12	0.08
Jul	0.24	0.24	0.24	0.23	0.23	0.21	0.19	0.16	0.11	0.07
Aug	0.22	0.22	0.22	0.21	0.21	0.2	0.17	0.14	0.1	0.07
Sep	0.25	0.25	0.23	0.21	0.2	0.18	0.17	0.15	0.11	0.07

L1

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.54	0.54	0.54	0.53	0.51	0.48	0.44	0.36	0.27	0.21
Nov	1.05	1.05	1.03	1.01	0.97	0.89	0.80	0.63	0.43	0.28
Dec	1.29	1.28	1.27	1.23	1.20	1.11	0.97	0.76	0.53	0.35
Jan	2.34	2.20	2.03	1.91	1.78	1.53	1.32	1.00	0.67	0.41
Feb	3.12	2.97	2.73	2.59	2.32	2.08	1.82	1.42	0.90	0.52
Mar	5.08	4.76	4.15	3.55	3.04	2.75	2.36	1.95	1.20	0.63
Apr	1.56	1.56	1.54	1.51	1.46	1.36	1.18	0.93	0.62	0.39
May	1.31	1.31	1.30	1.28	1.24	1.15	1.01	0.80	0.54	0.34
Jun	1.12	1.11	1.11	1.09	1.06	0.99	0.87	0.70	0.48	0.31
Jul	0.82	0.82	0.82	0.81	0.78	0.74	0.66	0.54	0.38	0.27
Aug	0.60	0.60	0.59	0.59	0.57	0.54	0.49	0.41	0.31	0.23
Sep	0.68	0.67	0.67	0.66	0.64	0.60	0.54	0.44	0.32	0.23

T1

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.42	0.42	0.42	0.41	0.40	0.37	0.32	0.26	0.18	0.12
Nov	0.68	0.68	0.67	0.66	0.64	0.59	0.51	0.40	0.27	0.17
Dec	0.79	0.79	0.78	0.76	0.74	0.68	0.59	0.46	0.31	0.20
Jan	1.75	1.60	1.48	1.33	1.24	1.03	0.89	0.69	0.45	0.28
Feb	5.51	4.92	3.80	2.19	1.84	1.71	1.56	1.37	1.07	0.57
Mar	0.70	0.69	0.69	0.67	0.65	0.61	0.54	0.44	0.32	0.23
Apr	0.73	0.72	0.72	0.70	0.68	0.64	0.56	0.45	0.32	0.22
May	0.56	0.56	0.55	0.54	0.53	0.50	0.44	0.36	0.26	0.18
Jun	0.49	0.49	0.48	0.48	0.46	0.44	0.39	0.32	0.23	0.16
Jul	0.39	0.39	0.39	0.38	0.37	0.35	0.31	0.26	0.18	0.13
Aug	0.34	0.33	0.33	0.32	0.32	0.30	0.27	0.22	0.16	0.12
Sep	0.41	0.41	0.40	0.39	0.38	0.36	0.32	0.25	0.18	0.12

16. ECOSPECS AND ECOLOGICAL RESERVE MONITORING

16.1 INTRODUCTION

The National Water Act (Act No. 36 of 1998) (NWA) requires that Resource Quality Objectives (RQOs) must be defined for all significant water resources, based on their classification. The purpose of RQOs is to establish clear, auditable goals relating to the quality of the relevant water resources. The Classification and RQO are binding on all authorities and institutions when exercising any power under the NWA. The ecological component of RQOs are referred to as EcoSpecs. These are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity), that define the Ecological Category. The purpose of EcoSpecs is to establish clear goals relating to resource quality (Kleynhans *et al.* 2005).

The overall aims of Ecological Reserve monitoring are to measure and determine how the resource is changing over time, and to ensure that resource remains within acceptable limits of change, defined broadly as the Recommended Ecological Category (REC). If the ecological category deteriorates significantly compared to baseline conditions and the cause is known, management interventions are triggered. If the cause of deterioration is unknown, more intensive monitoring or research may be needed to identify the cause(s). Monitoring therefore provides the critical link between objectives and management interventions. The essential requirements of a monitoring programme are therefore clearly defined baseline conditions against which future changes may be compared, clearly defined objectives, and clearly defined Thresholds of Potential Concern (TPC). TPCs are end-points that describe the thresholds of a desired state in scientific detail and provide the basis for monitoring (Rogers and Bestbier 1997). The aims of this chapter were:

- **Baseline Conditions:** To assess the suitability of available data for defining baseline conditions for monitoring the Ecological Reserve in the Komati River Catchment, and to recommend additional baseline data requirements, if needed;

- **EcoSpecs:** To define the Ecological Specifications (EcoSpecs) for the Recommended Ecological Category (REC) at each Ecological Reserve Monitoring site, and;

- **Threshold of Potential Concern:** To define the associated Thresholds of Potential Concern (TPCs) for each monitoring site.

The report provides the basis for developing a monitoring plan, but does not address monitoring requirements or implementation as this requires the development of operational rules, negotiation with and commitment by all relevant management agencies, and a comprehensive Decision Support System that allocates responsibilities, and specifies the actions that should be taken in the event of non-compliance. These aspects fell beyond the scope of this study.

16.2 METHODS

Draft generic guidelines for ER Monitoring were used to provide guidance on ER monitoring (Kleynhans *et al.* 2005). The guidelines describe monitoring, assessment of data for adequacy of a baseline conditions and describe the methods to determine EcoSpecs and TPCs.

16.2.1 Recommended Scenario

This report defines EcoSpecs and TPCs for the recommended operational Scenario 6.2a. (see previous chapter).

16.2.2 Specialist Meeting

A two-day Specialist Meeting was held to discuss and define baseline information requirements, EcoSpecs and TPCs.

16.2.3 Baseline Data

The suitability of available data to serve as baseline information against which future changes may be compared was evaluated for each EWR site, and for each driver and response component. Suitability was evaluated in terms of the following key questions:

- Is there sufficient spatial data available?
- Is there sufficient temporal data available?
- How useful are available data for interpreting ecological preferences and environmental requirements?
- To what extent could changes in environmental conditions affect the reliability of baseline information?

The suitability of available data was rated from *Very Low* to *Very High*. This information was used to identify information gaps and recommend additional data that may be needed to provide a reliable baseline against future changes may be compared. Sampling techniques and assessment methods for surveys are described in the River Health Programme site characterization manual (Dallas 2005) and the EcoStatus Manual (Kleynhans *et al.* 2005).

16.2.4 EcoSpecs

The methods used for defining EcoSpecs for each ecological component are described in Kleynhans *et al.* (2005).

16.2.5 Thresholds of Potential Concern (TPCs)

Thresholds of Potential Concern are upper and lower levels along a continuum of change in selected environmental indicators (Rogers and Bestbier 1997). When a TPC is reached, or when modelling predicts that the threshold will be reached, an assessment of the causes of the change is triggered. The assessment provides the basis for deciding whether management action is needed, or if the TPC needs to be recalibrated. The TPCs provide specific targets and form the basis of an inductive approach to adaptive management, as they are hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are open to challenge and they must be adaptively modified as understanding and experience of the system increases (Rogers and Bestbier 1997).

Water quality TPCs were calculated as a percentile of the data record at the nearest reliable gauge for each water quality variable recommended for monitoring. The data assessment against the selected TPC was calculated using data from the monitoring point used for baseline monitoring, but always updated to the last three years of data or a minimum of 60 data points, or data collected during baseline monitoring. This was not possible at sites where there were no long-term water quality records (e.g., Gladdespruit), and here the limited data collected during this study was used.

16.3 RESULTS

An assessment of the ecological consequences of the recommended Scenario 6.2.A showed that the REC was almost always predicted to be met. The only exceptions were at L1, where the vegetation was predicted to decline, and at K1, where the water quality was predicted to decline. However, EcoSpecs for each ecological driver and response component were set for the REC, and no allowance was made for the two exceptions. The reason for this is that the EcoSpecs are essentially hypotheses that need testing, and should the predictions come true, the EcoSpecs would need to be modified accordingly.

16.4 RECOMMENDATIONS

16.4.1 Baseline Monitoring

The following recommendations for baseline monitoring were made:

Geomorphology: No additional geomorphology data are needed to describe baseline monitoring conditions, but the available data need to be converted to the Geomorphological Driver Assessment Index Level IV.

Water Quality*:* Monthly water quality monitoring is recommended at sites M1, L1 and T1 for at least one year.

Riparian Vegetation: The VEGRAI data needs to be converted to Level IV at all EWR sites. No further baseline data are needed at EWR sites, but monitoring at L1 is recommended because of the change in operation. Additional VEGRAI Level III data is recommended in Resource Unit B (K1) and Resource Unit D (K3).

Fish: Additional baseline monitoring for fish is recommended at Sites G1 and T1 once-off in autumn. No further baseline data are needed at EWR sites, but monitoring at L1 is recommended because of the change in operation.

Aquatic Invertebrates: Additional baseline monitoring is recommended once-off at K1 and T1 in autumn, and at G1 in spring and autumn. Additional monitoring sites are recommended 1) upstream of Nooitgedacht Dam, 2) downstream of Gemsbokhoek Weir and 3) at Komatipoort (K5).

16.4.2 Implementation

There is a need to define the natural triggers which are used to determine the Reserve requirements on a day-to-day (or month-to-month) basis. The natural trigger is used to determine the exceedence percentage point of the expected natural flow at any moment. This value is then used within the Reserve assurance rule table (specified as part of the gazetted Reserve) to fix the Reserve flow. Without this information it will be almost impossible to turn the gazetted Reserve determination into implementable information. The method that will eventually be implemented needs to be usable by a civil engineering technician. The output should be as close to real time as possible. Studies are underway to develop generic and prototype Reserve Implementation systems.

17. CAPACITY BUILDING AND TRAINING

17.1 OVERVIEW

The need for more trained Reserve determination specialists has been recognized by the Department: Water Affairs and Forestry (DWAF) and by Professional Service Providers who have been involved in developing Reserve determination methods. The Komati Reserve determination study provided the opportunity to conduct training and capacity building of identified trainees to extend the current skill base. Training was conducted through workshops, field trips informal discussions and a final 'wrap-up' training session.

17.2 OBJECTIVES

The aims of this report were to present the results of the Training and Capacity Building component of the Komati EWR study. This component of the study aimed to train Previously Disadvantaged Individuals in specific aspects of assessing EWRs, so that future studies of this nature may engage such individuals. The specific aims of the process were to ensure that each trainee acquired the following information and skills, as were relevant to their particular discipline:

- **Theory:** A theoretical understanding of the Reserve concept and process, and an understanding of the concepts related to their particular discipline;
- **Methods and Tools**: The ability to apply the methods and tools required by their discipline within the Reserve process (e.g. time-series analysis for hydrology, water quality modelling; application of riparian vegetation index etc);
- **Data Collection and Analysis:** The ability to collect and interpret information related to their discipline, particularly within the broader scope of the Reserve process.
- **Information Transfer:** The ability to communicate the information learnt to other specialists - both verbally and in a report format. It was recognized that this aim may be difficult to report on, so mentors were requested to include an assessment of the trainee's input to the process, and understanding thereof.
- **Teamwork:** The ability to work in a team of specialists from different disciplines, but with a common goal and with an understanding of the requirements of other specialists within the process.

17.3 MENTOR AND TRAINEE REPORTS

Five trainee-mentor partnerships were identified and each trainee was set specific training objectives and tasks at the outset of the project (Table 15-1). The tasks that were set were in line with the past experience and skills of each trainee. Training was conducted mainly through field trips, attendance of specialist meetings and a final 'wrap-up' training session. Training progress was monitored through periodic reporting by each mentor and trainee, and a final evaluation questionnaire was completed by both the mentor and trainee.

The following table summarises the main training achievements for various components of the study:

Component	Mentor	Trainee	Achievements
Geomorphology	*Prof K Rowntree*	*Mr Stanley Ntakumba*	*Mr Ntakumba leant most of the technical requirements for delineating Resource Units, identifying suitable EWR sites, and collecting, analysing and presenting geomorphological data. This was a highly successful outcome, but Mr Ntakumba is not readily available for future EWR studies because he has accepted full-time employment in a field unrelated to his training.*
Water Quality	*Dr Ralph Heath*	*Ms Jennifer Molwantwa*	*This was satisfactory outcome, but limited on account of Ms Molwantwa's withdrawal from the project to enroll as a full-time PhD student. She has, however, indicated an interest in participating in future studies of this nature.*
Riparian Vegetation	*Mr Graham Deall*	*Mr Victor Nkuna*	*Mr Nkuna learnt most of the technical requirements for assessing the present ecological state of the riparian vegetation.* *The training was successful, but he is not readily available for future EWR studies because he has accepted further training in another field.*
Hydraulics Engineering and General Assistant	*Dr Andrew Birkhead, Mr Robin Clanahan and Dr Rob Palmer*	*Mr Hendrik Ngwana*	*Mr Ngwana learnt most of the technical requirements for collecting hydraulic data, but the success of his training was limited, mainly because he was not always available when needed on the project. Mr Ngwana is not readily available for future EWR studies because of other commitments.*
General Assistant	*Dr Rob Palmer*	*Mrs Shaune Rogatschnig (formerly Spreckley)*	*Ms Rogatschnig learnt project management and reporting skills that could be applied to any similar project of this nature. This was a highly successful outcome, and she will be available for further studies of this nature.*

17.4 CONCLUSIONS

The training component of this project was active and successful during the data collection phase of this project. Trainees attended key meetings and all relevant site visits with their mentors and helped to collect data and prepare the specialist reports that formed part of workshop documentation. Some trainees also participated in the specialist workshops and gave input. A dedicated training workshop that was held towards the end of the project served to consolidate the lessons that were learnt. The aim of training Previously Disadvantaged Individuals was therefore met. However, the aim of providing a pool of Previously Disadvantaged Individuals that could be engaged in future studies of this nature was not met; Four out of the five trainees engaged in the study moved on to other work during the course of the study because of the need to find more permanent employment, and only two are likely to be readily available to participate in future studies of this nature. The main problem with the training programme was therefore the lack of continuity caused by the long duration of the study and the need for trainees to find alternative forms of income.

17.5 RECOMMENDATIONS

To address this short-coming, the following recommendations are made:

Register of Trainees: Trainees for EWR studies should be sourced from a pool of trainees that are permanently employed, preferably at state or semi-state organisations, and readily available to undertake such work. This means that when such studies go out for tender, each PSP team should not be responsible for identifying and appointing their own team of trainees. Instead, the RDM Office should be responsible for identifying and appointing the trainees from a register of EWR trainees, so that the same group of individuals are generally used, irrespective of which PSP wins the tender. This would enable follow-up training so that trainees would eventually reach a level that they would be able to undertake the work required without the need for additional training. For the Komati River it would be preferable to source trainees from relevant organizations, such as the regional DWAF office, the Komati Basin Water Authority, the Mpumalanga Parks Board, Water Resources Branch (Swaziland) and the Directorate National Aquas (Mozambique). It is recommended that the RDM Directorate develop and maintain a database of EWR trainees. The proposed database should include:

- names of personnel potentially available for EWR training;
- their qualifications;
- their specialist fields and level of understanding of EWR processes;
- contact details, plus;
- any other relevant details.

Training Budget: It is recommended that training budgets should be specified in the Terms of Reference for such projects, either as a sum of money to be allocated to training or as a percentage of the overall study budget. A training budget allowed for successful training in the Thukela Reserve study, but a similar process was not followed for the EWR studies initiated in 2003.

Dedicated Training: A dedicated EWR training programme is recommended. Although the mentor-trainee partnerships are important, they cannot be expected to provide the full range of training that can be provided by a dedicated training programme. The training should include not only a detailed description of the principles and processes of EWR determination, but should also include a comprehensive introduction to hydrology and scenario analysis.

18. REFERENCES

Africon. 2004. Inkomati Water Management Area. Water Resources situation assessment. Appendices: Volume 3 of 3. Report prepared by Africon for the Department of Water Affairs and Forestry as part of the National Water Resource Strategy. Report No P WMA 05/000/00/0101.

AfriDev, Knight Piésold Joint Venture and JTK Associates. 1999. Environmental Impact Assessment and Instream Flow Requirement CMP Supporting Report E: Instream Flow Requirements. Report prepared for the Komati Basin Water Authority Contract MDC-6. October 1999.

AfriDev. 2004. Aquatic monitoring in the lower Lomati and Komati Rivers. Internal report prepared by AfriDev for the Komati Basin water Authority.

BKS. 2003. Inkomati Water Management Area. Overview of Water Resources Availability and Utilisation. Report prepared by BKS for the Department of Water Affairs and Forestry as part of the National Water Resource Strategy. Report No P WMA 05/000/00/0203.

Brown C. and King J., 2000. Environmental flow assessment for rivers. A summary of the DRIFT process. Southern Waters information Report No 01/00.

Bruwer, C. A. 1993. Environmental Water Requirements at different nodes in the Inkomati System. Report to the Driekoppies Environmental Task Group. Department of Water Affairs and Forestry.

Dallas, H. F. 2005. Site characterization field-manual and field-data sheets. Report prepared for the Department of Water Affairs and Forestry Directorate: Resource Quality Services.

Department of Water Affairs and Forestry (DWAF). 2002. Methods for Assessing Water Quality in Ecological Reserve Determinations for Rivers. Pretoria.

Department of Water Affairs and Forestry. 2003. Proceedings of Ecological Reserve (Quantity) Workshop. 8&9th April 2003, Delectus Manor, Pretoria. Compiled by D Louw, IWR – Source-to-Sea.

Huggins, G. 2003. Social Importance. Appendix G In: Department of Water Affairs and Forestry. Thukela System Reserve Determination Study. Prepared by IWR Source-to-Sea as part of the Thukela Water Project Decision Support Phase. DWAF Report No. PBV000-00-10303.

Hughes, A. and O'Keeffe, J. H. 2004. Flow-stressor response approach to Ecological Water Requirement Assessment. Extract from WRC Project No K5/1160/0/1 presented In: IWR Source-to-Sea, Department of Water Affairs and Forestry:

IWE Environmental 2001. Gladdespruit Ecological Reserve. Internal report prepared by IWR Environmental for the Department of Water Affairs and Forestry Directorate Resource Directed measures.

IWR Source-to-Sea (eds). 2004. A Comprehensive EcoClassification and Habitat Flow Stressor Response Manual. Prepared for IWQS: DWAF, Project no. 2002-148.

Jooste, S. AND Rossouw, J. N. 2002. *Hazard-Based Water Quality EcoSpecs For The Ecological Reserve In Fresh Surface Water Resources.* Report No. N/0000/REQ0000. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

King, J. 1998. Social dependence on the river ecosystem. Annexure A. Maguga Dam Contract MDC-6 – Environmental Impact Assessment and Instream Flow Requirement CMP Supporting Report E. Report prepared for the Komati Basin Water Authority by AfriDev/Knight Piesold joint Venture and JTK Associates.

King, J. M. and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

King, J.M. Tharme, R.E. and de Villiers, M.S. eds. 2000. Manual for the Building Block Methodology, 339pp. WRC Report No. TT131/00. Water Research Commission, Pretoria, South Africa.

Kleynhans, CJ, Louw, MD, Thirion, C, Rossouw, NJ, and Rowntree, K. 2005. River EcoClassification: Manual for EcoStatus determination (Version 1). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05.

Ninham Shand, 1994. Driekoppies Dam EWR worksession. Proceedings of the worksession that took place 13-14 September 1994. Driekoppies Environmental Task Group IEM Consultants to the Komati Basin Water Authority.

Rogers, K. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental Affairs and Tourism, Pretoria.

Singh, A. *et. al.* 2003. Draft Report: Rapid determination of the Reserve at level III (Rapid III Ecological Reserve Methodology (RERM III)). for the Pongola River downstream of the Grootdraai weir in quaternary catchment W44A; the Lomati River in quaternary catchment X14G and H; and the Lusushwana River in W56A. Internal report prepared by IWR Source-to-Sea for the Department of Water Affairs and Forestry Directorate: Resource Directed Measures.

Tennant, D. L. 1976. Instream flow regimes for fish, wildlife, recreation and related environmental resources. Fisheries 1(4): 6-10.

Tlou & Matji. 2004. Inkomati Water Management Area. Internal Strategic Perspectives. Report prepared by Tlou & Matji Engineering Services, in association with Charles Sellick and Associates, for the Department of Water Affairs and Forestry as part of the National Water Resource Strategy. Report No P WMA 05/000/00/0303.

TPTC Inco-Maputo Interim Agreement. 2002. Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Swaziland for the co-operation on the protection and sustainable utilisation of the water resources of the Incomati and Maputo Watercourses. 62pp.

APPENDIX A: MINUTES OF DWAF DECISION MEETING, HELD ON 27 SEPTEMBER 2005.

COMPREHENSIVE ECOLOGICAL WATER REQUIREMENT STUDIES FOR THE KOMATI AND LETABA CATCHMENTS

PRESENTATION TO DWAF MANAGEMENT

SUMMARISED NOTES OF KEY ISSUES

DWAF, PRETORIA, 27 SEPTEMBER 2005

Chair: Mr Harrison Pienaar

1. PRESENT

Balekoa, Wendy (DWAF, RDM)
Bapela, Lerato (DWAF, NWRP)
Comrie, Werner (DWAF, Mpumalanga Region)
Espey, Quentin (DWAF, RQS)
Hadebe, Xolani (DWAF, RDM)
Heath, Ralph (Pulles, Howard and de Lange)
Herbst, Paul (DWAF, RP+W)
Hinsch, Manda (DWAF, WA)
Jeleoti, Albert (DWAF)
Kadiata, Mamogala (DWAF, RDM, WRC)
Louw, Delana (Water for Africa)
Matlala, Moloko (DWAF, Limpopo Region)
Moseki, Chris (DWAF, WRPS)
Mtnembu, Dumisani (DWAF, Nelspruit)
Palmer, Rob (Nepid)
Pienaar, Harrison (DWAF, RDM)
Pretorius, Piet (DWAF, WQ)
Tlou, Toriso (Water for Africa)
Tunha, Washingon (DWAF, Limpopo Region)
Van Niekerk, Peter (DWAF, IWRP)
Van Rooyen, Johan (DWAF, NWRP)
Van Wyk, Niel (DWAF, NWRP)

2. PURPOSE AND OUTCOME OF THE MEETING

The purpose of this meeting was to present the results to date of the comprehensive Ecological Water Requirement Assessments for the Komati and Letaba River Catchments to DWAF senior management, and to recommend an operational scenario for each river system.

3. APPROACH AND METHODS

D Louw and T Tlou presented the generic methods followed to comply with the 8step Reserve process as well as the economic assessment method followed. The following key issues were raised:

- A range of questions (Van Niekerk, Van Wyk, Van Rooyen) focussed around the timing of these studies compared to the detail hydrological studies that will be undertaken. It was pointed out that once the revised hydrology is available, the EWRs will have to be reviewed. It was also indicated that in future it would be more effective if these studies ran parallel especially if in preparation for compulsory licensing. Ms Louw indicated that the ecological knowledge was of a reasonably high confidence, especially around the instream biota. Therefore, the EcoClassification process might not require revision, however, the EWR process which is dependant on an understanding of the present hydrology, will be required. Monitoring initiated as soon as possible would limit the amount of work required during the revision process.
- Linked to the above questions, the lack of a detail stakeholder process was also raised. It was pointed out by NWRP that such a process should in any case form part of the stakeholder process required for compulsory licensing.
- The methods of dealing with water quality during scenario evaluation were queried (Espey). The response was that concentration modelling was undertaken, however this tool requires specific detail of hydrological information and water quality data. In cases where this data was absent, the consequences were derived.
- The reference to importance was questioned with regards to who decides and what methods are used to assess this (Van Niekerk). The Importance in the presentation refers specifically to the Ecological Importance and Sensitivity approach as well as the Socio-Cultural Importance. The tools consist of a rule based model with specific metrics that are each individually evaluated using a score (0 – no importance to 4 – high importance).
- The link between the socio-economic assessment and health was questioned (Espey) and how one attaches a monetary value to this.
- It was pointed out that both systems are stressed. Water demand management and conservation will not address the existing problems and implementation of the Reserve will be a problem (Comrie)

4. LETABA RESULTS

The Letaba results were presented by Dr Heath and Mr Tlou. The following issues were raised.

- The results were queried – specifically why more flows are required than present flows if one is only maintaining the present state (Van Rooyen). The reasons could be any of the following (Louw and Tlou):
  - Improvement of flows could be required if a negative trend is present; i.e. to maintain the present state, one will have to address the negative trend (if flow related)
  - The present hydrology has not been verified and could be inaccurate. Therefore, there is uncertainty whether more flows than present was actually requested.
- A description of Scenarios 7 was requested (Van Wyk and Van Niekerk):. It was indicated that Sc 7 is a modified scenario where the EWR demand is decreased to determine whether spillage and incremental flows will supply the flows. The objective is to design an optimised scenario. It did became clear

that the description of scenarios are confusing and misleading and that an alternative way of describing these will be required.

- Dr Espey pointed out that increases or maintenance of the Ecological Category could happen through improvement in the catchment and not necessarily just improvement in flows.

4. KOMATI RESULTS

The Komati results were presented by Dr Palmer and Mr Tlou. The following issues were raised.

- Under the present conditions, only EWR 3 in the Lower Komati requires significant improvement. EWR 2requires some improvement. All other areas are being maintained by present flows (Van Niekerk).
- It was again emphasised that another way of describing scenarios is required (Van Niekerk, Louw, Tlou).
- The Goods and Services presentation could be misleading – i.e. the swimming issue and the way this information is presented must be refined. (Van Niekerk).
- EWR 3: The lower Komati problems are a combination of the no flow situation as well as catchment issues. It was queried why Scenario 2A did not address the problems at EWR 3 as it did include the requirements for Mozambique (Van Niekerk). Based on this observation, it became apparent that the column in the comparison table was incorrectly labelled and this will be corrected.

5. RECOMMENDATION

The study team recommended Scenario 7 for the Letaba River and Scenario 6.2A for the Komati River. The following was decided upon:

- The recommendation to the DG will be to sign these recommendations off as preliminary for use in any licenses in unstressed parts in the catchment as well as to use for a basis to be able to respond to license requests negatively in the stressed parts of the catchment. As the results have indicated that the preliminary Reserve is not presently available in the main sections of the system, sufficient grounds should be available to respond to licenses negatively.
- A final decision on the scenarios can only be made after the hydrology has been upgraded and compulsory licensing has taken place.
- On the basis of this signed off Reserve, one cannot make decision regarding a decrease in irrigation until compulsory licensing has been implemented.

Mr Pienaar concluded that he would submit these two scenarios to the DG based on the above

Some general comments were made:

- Mr Van Niekerk indicated that the Provincial Government is a key stakeholder that should have been involved. Mr Van Rooyen added that the Departments of Agriculture and Environmental Affairs should also be involved.

- Dr Espey stated that a stakeholder process versus a community participatory process is very different and that a community participation process can require more detail and be more expensive.
- Mr Comrie reported that a CMS workshop was held for the Komati. The Reserve was raised as a key issue as well as how one will address the Reserve. He said that a strategy must be determined in the mean time and that it is important to Mr Rowlston must be brought into this process.
- Mr Van Wyk stated that a very detailed Thukela public participation process was held. Although this process did not in change the results generated, such a process does have the advantage of building confidence and partnerships.

6. CLOSURE

The meeting was closed at 13:15