A Systematic Conservation Plan for the Freshwater Biodiversity of the Crocodile (West) and Marico Water Management Area

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Executive Summary

1 INTRODUCTION

Riverine landscapes are a vital component of the environment that provide important ecosystem services such as clean water, energy, and transport. However, most of the world's large freshwater ecosystems are currently regarded as threatened, and many have undergone varying degrees of mild to severe alteration or deterioration because of anthropogenic impacts. As a result, the conservation status of freshwater ecosystems worldwide is poor and declining fast, with very few rivers retaining their original functional or ecological integrity (Revenga *et al*., 2000). In South Africa, the status of freshwater ecosystems matches worldwide trends, and the National Spatial Biodiversity Assessment that was undertaken during 2004 showed that about 44 % of South Africa's main rivers (excluding tributaries) are critically endangered (Nel *et al.,* in press).

The Millennium Ecosystem Assessment (MA) which was carried out between 2001 and 2005 assessed the consequences of ecosystem change for human well-being and identified the actions needed to enhance the conservation and sustainable use of ecosystems. The assessment revealed that over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any previous period of time in human history (MA, 2005). The discipline of *freshwater conservation planning* provides a means to halt and reverse the above trend by proactively and systematically identifying conservation priorities and options.

This study forms part of a broader project (DWAF project 2005-170) launched by the Department of Water Affairs and Forestry (DWAF), which aims to develop a planning capacity for freshwater conservation in South Africa. A planning exercise was conducted in the Crocodile (West) and Marico Water Management Area (WMA) to identify spatial conservation priorities for freshwater ecosystems. The study focussed on the following four objectives:

- Conserve and maintain a sample of the inland water biodiversity and associated ecosystem processes, with a focus on biodiversity of regional significance.
- Provide systematic and strategic guidance regarding the trade-offs between conservation and development.
- Direct future conservation and development opportunities.
- Provide strategic perspective to decision makers at the scale of a WMA.

The technical planning approach adopted for this study is based on systematic conservation planning principles and methods. This report presents the outcomes of the systematic planning approach that was followed and recommends generic management actions to promote the implementation of the suggested conservation plan.

2 SETTING EXPLICIT BIODIVERSITY TARGETS

According to Groves (2003) biodiversity targets set minimum, quantitative requirements for biodiversity conservation. These targets allow an evaluation of whether or not existing conservation efforts adequately represent the biodiversity of a region; provide guidance for planners who are balancing a number of competing demands for natural resources in a region; and provide water resource management and biodiversity conservation agencies with common quantitative measures for which to aim. The setting and adoption of biodiversity targets reflects scientific best judgement only and, hence, should be subject to review over time.

The biodiversity targets that were calculated for the Crocodile (West) and Marico WMA are provided below.

River types

The biodiversity target was calculated as 20 % of the total length of each stream-level river type (Appendix C). These targets should only be achieved within river reaches that have a present ecological integrity category of A or B - any river reach having an ecological integrity class that is lower than an A or B category, and included in the plan for maintaining longitudinal connectivity, did not contribute towards achieving this 20 % biodiversity target. There are 115 stream-level river types in the Crocodile (West) and Marico WMA – most of these river types are either unique or endemic to the study area. Forty-nine stream-level river types cannot achieve their biodiversity target in river reaches of A or B categories, i.e. the combined length of their A or B class segments has fallen below 20 % of the total length of that river type in the area.

Species

Biodiversity targets were set for the six fish species of special concern (Figure 9). These targets stipulated that at least one viable population of each species should be conserved in the WMA. River reaches chosen had to be in an A or B ecological integrity category and connected to rivers that are maintained in a category that supports connectivity.

Wetlands

A quantitative biodiversity target of 25 % of each wetland type was set for the Crocodile (West) and Marico conservation plan. The wetland biodiversity targets were based on species richness and diversity weighting, and only represent wetland pattern.

Special features

Twenty-seven features of special ecological significance were identified and included in the Crocodile (West) and Marico conservation plan (Figure 8). Hence, the biodiversity target for these special features was set as a 100 %.

Free-flowing rivers

For the purposes of this study, a biodiversity target of at least one free-flowing river of ≥ 100 km in length was set in the Crocodile (West) and Marico WMA. Furthermore, these rivers should also be in a high ecological category (ideally in an A or B integrity category) and incorporate the highest possible functional and structural diversity along their length.

3 REPRESENTING AN EXAMPLE OF EVERYTHING

Efforts designed to represent an example of the full spectrum of freshwater biodiversity occurring in the Crocodile (West) and Marico WMA require the systematic description and spatial mapping of this biodiversity. River and wetland types were used as primary surrogates of freshwater biodiversity. These biodiversity surrogates were then complemented with special biodiversity features, as well as data on fish species and invertebrate families.

Spatial scale and defining planning units

In order to select areas to achieve biodiversity targets, the units of selection, or planning units, need to be defined at the appropriate scale. Primary drainage areas and even the smaller quaternary catchments are at too large a spatial scale to provide information in sufficient detail for use at a broad sub-national scale (van Niewenhuizen and Day, 1999; Nel *et al*., 2006). In this study, 156 sub-quaternary catchments were modelled using ESRI's hydrological modelling tool set and used as planning units (Figure 3). These are nested within the 79 quaternary catchments in the study area.

River types

This assessment used the 1:500 000 rivers data layer (DWAF, 2004d) as well as seven extra streams from the 1:50 000 rivers data layer for the analyses of the river types. Sixteen level 2 ecoregions (Kleynhans *et al*., 2005) and seven hydrological index classes (Hannart and Hughes, 2003) were then used to derive 46 unique combinations of landscape-level river types. The landscape-level river types were further divided into 115 stream-level river types using longitudinal river zones (Rowntree and Wadeson, 1999). The stream-level river types were used as the final river types in the conservation plan (Figure 6).

Wetland types

A total of 8922 potential wetlands, (not actual wetlands), were identified in the study area. These potential wetlands were generated by the National Land Cover 2000 initiative and were enhanced through additional mapping and modelling techniques, as documented in Thompson *et al*. (2002). Wetland typing involved the use of physiographic settings which distinguish major wetland types (Bedford, 1996). These were then linked to the map of hydrogeological terrains of South Africa which were derived from a geological map. Hydrogeological terrains are classified into aquifers where the aquifer is indicated by the permeability of the lithological group (Colvin *et al.,* 2003). Six wetland types were identified (Figure 7).

Special features

River experts in the region identified 27 features in the landscape, or particular species, which had special value for biodiversity (Appendix D). These special features were mapped using on-screen digitising and are all represented in the final conservation plan.

Species data

Habitat modification has resulted in a decline in the abundance and overall distribution of several fish species in the study area. For the purposes of this conservation plan, six fish species of special concern (*Chetia flaviventris, Barbus motebensis, Aplocheilicthys johnstoni, Chiloglanis pretoriae, Clarias theodorae* and *Amphilius uranoscopus*) were identified and targeted for conservation. Only extant species were considered and were selected on the following basis: the presence of red listed species, the presence of isolated populations and type localities.

Due to the absence of species-level invertebrate data in the study area it was not possible to represent invertebrate species in the Crocodile (West) and Marico conservation plan. However, stream-level types could be used as surrogates to represent different invertebrate biotopes. The available family-level data - none of which can be regarded as indicating endemic or rare species - were used to delineate the special features and set SASS5 (South African Scoring System Version 5) thresholds to guide management of state of rivers in the Crocodile (West) and Marico WMA.

4 ENSURING PERSISTENT CONSERVATION

The conservation of species and habitats provides a snapshot of the biodiversity that currently exists in the WMA. In order for this biodiversity to persist and evolve naturally over time, it is also necessary to consider biodiversity processes.

Selecting rivers and wetlands of high ecological integrity

For the purposes of this project, only those rivers and wetlands with a present ecological integrity of "Natural" or "Good" (equivalent to A or B integrity categories) were selected. High integrity rivers and wetlands are more likely to incorporate many small-scale biodiversity processes such as localized nutrient cycling, sediment transport, inter- and intra-specific interactions.

The ecological integrity of rivers was assessed spatially according to the Ecostatus determination method, which provides an index of habitat integrity (Kleynhans *et al*., 2005). This method aims to provide a single, integrated index value that indicates the ecological state of a river system using the following categories that reflect varying degrees of integrity:

- Natural, unmodified (A category);
- Largely natural (B category);
- Moderately modified (C category);
- Largely modified (D category);
- Seriously to critically modified (D/E category); and
- Moderately to seriously modified tributaries (Z category).

Main rivers in the WMA are heavily utilized and regulated to provide water for social and economic development. This is reflected in the results obtained during this study. None of the main rivers in the study area have a portion of their river length in an A (natural) category, while only 13 % of the river length is in a B (largely natural) category (Figure 10). The majority of the river reaches (58 %) are in a C category (moderately modified), whilst 30 % are in D and E categories (largely to seriously modified). Thus, tributaries have a crucial role to play in meeting biodiversity targets (Nel *et al*., 2004; Nel *et al*., in press).

Percentage natural vegetation (Amis *et al*., in press) was used as a surrogate for mapping tributary river ecological integrity in this project. Any river reach where the % natural vegetation was ≥ 75 % was assumed to be in an A or B integrity category and able to contribute towards achieving river biodiversity targets. River reaches with natural vegetation < 75 % were assigned to a Z category, i.e. not intact. The assessment results were then reviewed by a river expert in the catchment. Compared to the main rivers, tributaries in the study area are in a relatively good condition with 58 % of the river length intact (A category) and 42 % in a Z category (moderately to seriously modified) (Figure 11).

Wetland integrity in the study area was calculated using the % natural vegetation within a 500 m wide buffer zone. This was then compared to the % natural vegetation within its sub-quaternary catchment and the mean % natural vegetation within the wetland itself. Any wetland with a minimum % natural vegetation ≥ 75 % was considered relatively intact and worthy of selection for conservation purposes. According to the results obtained in this study, 39 % of wetlands in the study area are intact (Table 6).

Incorporating connectivity

Longitudinal connectivity in the Crocodile (West) and Marico conservation plan was maintained by incorporating, wherever possible, whole river systems in the conservation plan. These selected rivers were in most cases connected to rivers that were moderately used or impacted. These connecting rivers should be maintained in a state that promotes longitudinal connectivity for its associated biodiversity.

Lateral connectivity refers to the interconnectedness that exists across an environmental gradient between aquatic, riparian and terrestrial ecosystems. Lateral connectivity was incorporated into the Crocodile (West) and Marico conservation plan by including entire sub-quaternary catchments (Figure 3). This implies that whole catchments need to be managed appropriately in order to conserve the freshwater ecosystems that drain them.

The connectivity between surface water and groundwater can be referred to as vertical connectivity. In this WMA, groundwater resources are available throughout the catchment and groundwater quality is usually good, although pollution is likely to pose an increasingly severe threat to groundwater quality in the future. Groundwater management guidelines must be followed to conserve vertical connectivity. In terms of connectivity, implementation of the conservation plan will depend on the ability of resource managers to achieve appropriate land management practices within sub-quaternary catchments.

5 DESIGNING A CONSERVATION PORTFOLIO

The aim of this process is to identify a set of sub-quaternary catchments that will achieve explicit biodiversity targets for rivers, wetlands, fish species and special features within the WMA.

Selection protocol

Six steps were followed sequentially, in the order listed below, to select rivers and sub-quaternary catchments for inclusion in the conservation plan:

(i) Use the 156 modelled sub-quaternary catchments (Figure 3) as the units of assessment and selection, or the planning units;

(ii) Use conservation planning decision support software to help with the derivation of an initial selection of sub-quaternary catchments, that takes into account the following multiple criteria:

- Complementarity and efficiency in achieving biodiversity targets for river types, wetlands and special features (fish species targets were included in Step IV);
- Building in longitudinal connectivity;
- Where there are choices between sub-quaternary catchments with similar biodiversity components, in order of appearance below:
  - Choose sub-quaternary catchments containing terrestrial protected areas; and
  - Choose sub-quaternary catchments whose river systems are the most intact.

(iii) Add in any additional sub-quaternary catchments that may be needed for rehabilitation;

(iv) Add in additional sub-quaternary catchments flagged as containing important, viable populations of the six fish species of special concern;

(v) Build in large-scale connectivity where it is still needed; and

(vi) Remove sub-quaternary catchments containing short stretches of river reach deemed to be too small to be viable, or where experts did not agree with the selection.

Selected rivers and sub-quaternary catchments

This analysis produced a conservation portfolio that contained both selected sub-quaternary catchments and rivers (Figure 13). In order to achieve the biodiversity targets for river types, wetlands, special features and fish species in the Crocodile (West) and Marico WMA, the conservation plan requires 38 (24 %) sub-quaternary catchments and 25 % of the total river length in the study area to be conserved. A further 25 sub-quaternary catchments are required for rehabilitation to attain an A or B ecological integrity class. An additional 14 (9 %) sub-quaternary catchments in the area (translating to 6 % of the total river length in the area) are required for maintaining longitudinal connectivity. These sub-quaternary catchments will need to be maintained in a state that permits connectivity, and should ideally not be in a lower integrity class than a D category. In each of the selected sub-quaternary catchments, generic management actions have been identified (Appendix G) - these provide firm recommendations based on the level of anthropogenic impact that should be allowed.

Rehabilitation assessment

The 49 stream-level river types that could not achieve their biodiversity targets in the Crocodile (West) and Marico study area were assessed in terms of their potential for rehabilitation. The assessment was guided by various data layers and expert opinion. The consequences of not meeting certain targets in the study area were also examined. For those stream-level river types that occurred elsewhere in the country, a qualitative assessment of landscape-level river types was undertaken to ascertain whether or not the biodiversity target for this study area could be adopted by another area in the country. The stream-level river types were assessed according to the following four categories (Figure 14 and Appendix F):

(i) *Rehabilitation for AB category is feasible*

- This category will contribute towards achieving the 20 % biodiversity target and requires 23 stream-level river types that represent 25 sub-quaternary catchments.
- The 25 sub-quaternary catchments that contain good examples of these stream-level river types have been flagged for rehabilitation in the Crocodile (West) and Marico conservation plan (Section 6.2).

(ii) *Rehabilitation for category C is feasible*

- This category represents 6 stream-level river types that can only be rehabilitated to a moderately modified condition.
- The nine sub-quaternary catchments containing these river types have been flagged for rehabilitation in the Crocodile (West) and Marico conservation plan (Section 6.2).

(iii) *Best conserved elsewhere*

- The 12 stream-level river types identified in this category will not be able to be rehabilitated in the study area because of their seriously to critically modified condition. However, these stream-level river types can be better conserved elsewhere in the country.
- Areas which could adopt the biodiversity targets for these 12 stream-level river types in the Crocodile (West) and Marico catchment have been identified and listed in Appendix F.

(iv) *Rehabilitation is not feasible and cannot be conserved elsewhere (unique to study area)*

- Rehabilitation is not feasible for eight unique stream-level river types.
- These stream-level river types are only present in the Crocodile (West) and Marico WMA and are now critically endangered in the country (i.e. have failed to meet the national target).

Assessment of targets achieved

Biodiversity targets were calculated and assessed for the 115 stream-level river types in the Crocodile (West) and Marico catchment. The biodiversity targets of 66 (57 %) stream-level river types in the study area would be achieved by the proposed river selections and their associated sub-quaternary catchments. Feasible rehabilitation would result in an additional 23 (20 %) stream-level river types meeting their biodiversity targets (Figure 14). The rehabilitation of 26 (23 %) stream-level river types is not feasible in the study area. Overall, 89 (77 %) of the stream-level river types can meet their targets in the study area with feasible rehabilitation.

Biodiversity targets were set for the six fish species of special concern (Figure 9a-f). The following four species achieved their targets within the conservation design: *A. uranoscopus* (Skeerpoort and Groot Marico rivers); *B. motebensis* (Sterkstroom River); *C. pretoriae* (Skeerpoort and Groot Marico rivers); and *C. flaviventris* (Skeerpoort and Groot Marico rivers). These four fish species are incorporated in the conservation plan through inclusion of four sub-quaternary catchments (numbers 80, 100, 104 and 110). The targets for the remaining two species, *C. theodorae* and *A. johnstoni,* could not be met in A or B category rivers and these species should be conserved elsewhere in the country.

Quantitative targets of 25 % of each of the six wetland types were achieved for all intact wetland types in the study area (Appendix G). The Crocodile (West) and Marico conservation plan requires 37 (24 %) sub-quaternary catchments for the wetland type biodiversity targets. Transformed wetland types did not contribute towards these biodiversity targets.

All special features were selected for inclusion in the conservation plan (Figure 15). However, entire catchments were not always selected and not all of the sub-quaternary catchments have their river reaches in ecological integrity categories A or B. Sub-quaternary catchments that are considered to be feasible for rehabilitation in a C category, and catchments that should be be maintained in a C or D category, were also selected to represent special features. Specific management actions for these special features are provided in Appendix G.

The target of conserving any stretch of river ≥ 100 km that is not yet dammed and also meets the criteria of having a high ecological category and a diverse number of longitudinal zones cannot be achieved within this study. This reflects the high utilization pressure and the discontinuous segments of rivers within this WMA.

6 COOPERATIVE CONSERVATION ACTION

Biodiversity issues span several different sectors of natural resource governance. Hence, to implement the conservation plan for freshwater biodiversity presented in this report, the overlapping sectoral roles and responsibilities of both water and biodiversity must be clearly understood and respected. Effective implementation requires the close cooperation of a number of organizations and agencies that have the internal capacity effectively to address this implementation challenge. One of the responsible organisations will have to play a leadership role in facilitating the coordination of their respective contributions. Several key parties (Table 9) have a mandate or responsibility that directly relates to the implementation of the conservation plan for the Crocodile and Marico rivers, or to the incorporation of this plan into their future planning, policy and strategy processes. These include organisations responsible for environmental monitoring, reporting and management, water resource monitoring, reporting and management, biodiversity conservation and land management.

7 RECOMMENDATIONS AND CONCLUSION

General findings

The southern part of the study area falls within the main economic hub of the country, and this is South Africa's most heavily populated WMA. Main rivers in the area are heavily regulated (only 13 % of main river length is currently intact) to cater for the high associated socio-economic needs. A higher proportion (58 %) of tributaries are currently intact, thus tributaries are likely to play a critical role in conserving the freshwater biodiversity of this WMA. In addition, many main rivers and tributaries will need to be managed to allow for sufficient connectivity, i.e. to be maintained in an appropriate desired state (C or D category).

The conservation plan requires almost all (71 %) of the rivers that are currently in an intact state. Thus, further degradation of any river that is currently intact (in an A or B category) should be avoided.

There are 82 stream-level river types in the study area that are either unique or endemic (i.e. ≥ 90 % of their national ranges fall within the study area), and located in the south-eastern portion of the WMA, which coincides with the Greater Johannesburg and Tshwane metropolitan areas. Rivers in this area are already very heavily impacted and it is therefore not surprising that targets cannot be met for 30 of these endemic river types. Thus, rehabilitation options for endemic river types that cannot meet their targets should be seriously considered since losing endemic river types that cannot be conserved elsewhere in the country implies that nationally important biodiversity will be lost.

The conservation of wetlands and groundwater to maintain functioning ecological systems is of key importance in this area. The proposed conservation plan, whilst giving consideration to representation of broadly defined wetland types, falls short of making explicit recommendations and selections for the roles that wetlands and groundwater play in maintain functioning ecological systems. Future studies should focus on wetlands and groundwater in this WMA.

Management actions

Appendix G provides specific management actions for the sub-quaternary catchments that were selected in the conservation plan. These generic management actions provide recommendations based on the level of human impact that should be allowed in the sub-quaternary catchments. Low impact activities such as grazing should be restricted to low impact zones. Impacts, such as agriculture should be restricted, or at the very least designated, to those portions of the catchment that are located furthest away from the freshwater ecosystem of concern. In general, flow modification due to artificial barriers such as weirs or to direct abstraction, should be avoided or minimised. Road crossings should be constructed in an environmentally sensitive manner that avoids constricting stream flows. Activities such as agriculture represent medium impact zones. However, the ecological functionality of the freshwater ecosystem as well as its immediate surroundings (e.g. riparian vegetation) should be protected in these zones. An important part of this functionality is maintaining the natural flow regime and longitudinal connectivity in rivers, to allow natural mobility of aquatic species.

Data limitations

The conservation planning exercise that was conducted for the freshwater ecosystems of the Crocodile (West) and Marico WMA relied on several data layers; all of these data layers have data limitations that must be corrected or improved in the future. The conservation plan should not be seen as a static product but rather as a departure point from which further refinement can and should take place. Verification (so-called “ground-truthing”) should be undertaken in selected sub-quaternary catchments to confirm that they contain the particular biodiversity features for which they were selected. This information should be fed back into the planning process so that the conservation plan can be revised whenever this is appropriate. An appropriate strategy should be developed for the implementation of the conservation plan, so that it caters for the dynamic interplay between management actions, ongoing monitoring and the formulation and testing of research questions.

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1. INTRODUCTION

The Millennium Ecosystem Assessment (MA) was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to identify actions needed to enhance the conservation and sustainable use of ecosystems. A major finding of the MA was that, over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any other period of time in human history. These changes are largely the result of human efforts to meet rapidly growing demands for food, fresh water, timber, fibre, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth and the degradation of ecosystem services. If not addressed, these issues will progressively diminish the benefits that future generations can obtain from ecosystems. Protecting and improving our future well-being requires wiser and less destructive use of natural assets. This in turn involves major changes in the ways that we make and implement decisions (MA, 2005).

The effects of pressures that arise from social and economic aspirations have been particularly severe on freshwater ecosystems. For example, the National Spatial Biodiversity Assessment that was undertaken for South Africa during 2004 found that the country's river ecosystems are in a much poorer overall state than its terrestrial ecosystems (Driver *et al*., 2005). A closer assessment of the status of the main rivers (excluding tributaries) of South Africa (Nel *et al*., in press) has revealed that:

- Less than one third of the total length of main rivers in South Africa are still of high ecological integrity and suitable for contributing towards achieving biodiversity targets for freshwater biodiversity.
- Of the 112 distinct main river types that were identified, only 16 % are currently not threatened in terms of their ability to support the biodiversity naturally associated with these river types; 54 % of these ecological river types are deemed to be critically endangered. The semi-arid interior of the country, characterised by rivers with highly variable flow, is the only area in South Africa that still contains a large proportion of main river types that are currently not threatened.
- Over 90 % of all main rivers in South Africa fall completely outside statutory Type 1 protected areas. While playing an important role in the conservation of biodiversity in general, it is clear that formally protected areas currently play a relatively small role in terms of conserving freshwater biodiversity.

The relatively young discipline of *freshwater conservation planning* provides a means to reverse the above trend by proactively and systematically identifying conservation priorities and options. Explicit conservation priorities and options provide guidance to natural resource planners and managers that enables them to make informed decisions regarding the trade-offs between the conservation and utilization of these resources. Finding the right balance between the protection and use of ecosystem is an important component of building a more sustainable future.

An important complicating factor is that the responsibility for conserving freshwater ecosystems is usually shared between several sectors of society and departments of government, with the result that there is often a considerable overlap of mandates. In South Africa, government departments that are responsible for water resource protection and management, biodiversity conservation, land use management, and integrated development planning, are all key role players - these authorities must co-operate closely if inland water ecosystems and their biodiversity are to be managed effectively. While most of these departments have developed legislation that relates to the protection or conservation of natural resources, the contexts, key concepts, terminology and enabling mechanisms of the respective statutes are often specific to a particular department.

In order to promote the development and adoption of coherent policies, compatible management instruments and complementary resource allocation priorities for freshwater conservation across all relevant departments, a set of five policy objectives and twenty implementation principles (see Information Box 1) have recently been developed as part of an inter-departmental initiative (Roux *et al*., 2006).

Drawing guidance from the above-mentioned objectives and principles, a planning exercise was conducted to identify spatial conservation priorities for the freshwater ecosystems of the Crocodile (West) and Marico Water Management Area (WMA). The purpose of the conservation plan is to:

- Conserve and maintain a sample of the inland water biodiversity and associated ecosystem processes, with a focus on biodiversity of regional significance.
- Provide systematic and strategic guidance regarding the trade-offs between conservation and development.
- Direct future conservations and development opportunities.
- Provide a strategic perspective to decision makers at the scale of a WMA.

This report presents the outcomes of the systematic planning process that was followed and recommends specific management actions to promote the implementation of the suggested conservation plan.

Information Box 1

National goal, cross-sector policy objectives and implementation principles for conserving freshwater biodiversity in South Africa (based on Roux *et al*., 2006):

The national goal is to conserve a sample of the full variety or diversity of inland water ecosystems that occur in South Africa, including all species as well as the habitats, landscapes, rivers and other water bodies in which they occur, together with the ecosystem processes responsible for generating and maintaining this diversity, for both present and future generations.

Five cross-sector policy objectives are imperative to achieving the national goal, namely:

Objective 1: Set and entrench quantitative biodiversity targets for inland water biodiversity.

To implement this objective:

- Target setting must be co-ordinated and directed at a national level and endorsed by sub-national implementation agencies. The national guideline is to conserve at least 20% of each inland water ecosystem type;
- The responsibility for target achievement should be shared by national and sub-national statutory structures; and
- The target should be reviewed every few years.

Objective 2: Plan for representation of inland water biodiversity. This objective aims to ensure adequate representation of the full spectrum of inland water biodiversity, based on the systematic description and depiction of this biodiversity within the region of concern. To implement this objective:

- Landscape or ecoregion-scale measures can be used as indictors to describe and classify inland water biodiversity;
- Fine-scale indicators of freshwater biodiversity should be used where they are available to supplement coarse-scale surrogates; and
- Local ecological knowledge should be used to supplement biodiversity data that are more readily available.

Objective 3: Plan for persistence of inland water biodiversity. This objective addresses the need to conserve the ecological and evolutionary processes that generate and maintain inland water biodiversity. To implement this objective:

- Ecosystems of high ecological integrity should be selected as conservation resources;
- Ecological connectivity along longitudinal, lateral and vertical gradients must be restored and maintained;
- Natural disturbance regimes should be allowed to operate within their natural ranges of variability; and
- Selected areas should be of sufficient size to ensure that the targeted biodiversity feature can be maintained.

Objective 4: Establishing a portfolio of inland water conservation areas (IWCAs). This objective addresses the incorporation of the first three objectives into a spatial design that will constitute the portfolio of inland water conservation areas (IWCA) of South Africa. The portfolio of IWCA should:

- Be legislated through existing statutory mechanisms;
- Be designed in a land-use efficient manner;
- Reflect the vulnerability and threat status of constituent ecosystems so that conservation action can be initiated timeously;
- Be treated as heritage resources for current and future generations rather than resources that can be used now and restored later; and

- Be subject to the development of management plans and performance monitoring programmes.

Objective 5: Enable effective implementation. This objective addresses the creation of an institutional environment that can ensure sustained conservation actions for all designated inland water conservation areas. To achieve this:

- Key stakeholders should be engaged in a way that would facilitate stakeholder adoption of both biodiversity targets and identified priority areas;
- Organisations or agencies with a mandated responsibility for conserving inland water biodiversity should reflect this responsibility as an explicit function in their institutional design;
- Responsible parties should plan and deploy their skills and resources in a coordinated and cooperative fashion to maximise the impact of their conservation actions;
- Conservation scientists, policy analysts/makers and decision-makers/practitioners should jointly debate what is feasible, desirable and acceptable and use knowledge from all three of these domains to adaptively improve their respective hypotheses, policies and management strategies; and
- The relevant authorities should actively promote basic discovery, inventory and improved understanding of inland water biodiversity.

2. STUDY AREA

2.1 Introduction

The Crocodile (West) and Marico WMA lies predominantly within the North West Province and also includes the northern part of Gauteng as well as the south-western corner of the Limpopo Province. Towards the north-west it borders on Botswana. The two main rivers in the WMA are the Crocodile and the Marico rivers which flow northwards to join the Limpopo River at their confluence. The Limpopo River is an international river basin shared between Botswana, Mozambique, South Africa and Zimbabwe, which flows into the Indian Ocean in Mozambique.

The Pilanesberg Nature Reserve, the Cradle of Humankind Heritage Site, the Bafokeng Tribal Area, the dolomitic wetland or eye systems and large dams such as Hartbeespoort, Vaalkop, Roodekopjes, Klipvoor and Roodeplaat are all very important features in the WMA. The Cradle of Humankind Heritage Site, the Pilanesberg Nature Reserve and Hartbeespoort Dam in particular, attract tourist from all over South Africa. The former comprises a strip of 13 dolomitic caves containing the fossilised remains of plants, animals and hominids (RHP, 2005).

2.2 Economic characteristics and demographics

The Crocodile (West) and Marico catchment is one of the most highly developed and economically active WMAs in South Africa. According to a recent report (DWAF, 2004a), economic activity in the WMA is dominated by the urban and industrial complexes of northern Johannesburg and Tshwane (previously known as Pretoria) (Plate 1) and platinum mining in the Rustenburg area. Two of the world's biggest platinum mines are located at Rustenburg, while new platinum mines are being developed on a large scale (RHP, 2005). These human activities have depleted and disturbed the natural vegetation to different degrees with the result that most drainage systems have been critically modified in these areas. For example, almost all of the streams flowing through the suburbs of Johannesburg have been canalized (Plate 2). Approximately 25 % of the country's Gross Domestic Product (GDP) originates in this WMA and is largely contributed by activities located in the Crocodile catchment (RHP, 2005).

The population of the Crocodile (West) and Marico WMA has been estimated to be approximately 6.7 million people (2001 data) which makes it the second most populous WMA in the country (DWAF, 2004b). About 85 % of the population live in the urban metropolitan area of Johannesburg and Tshwane. Unemployment is estimated to be between 30 % and 40 % which is higher that the national average (DWAF, 2004b). Recent studies suggest that these population estimates have been increased by high numbers of illegal immigrants in this area.

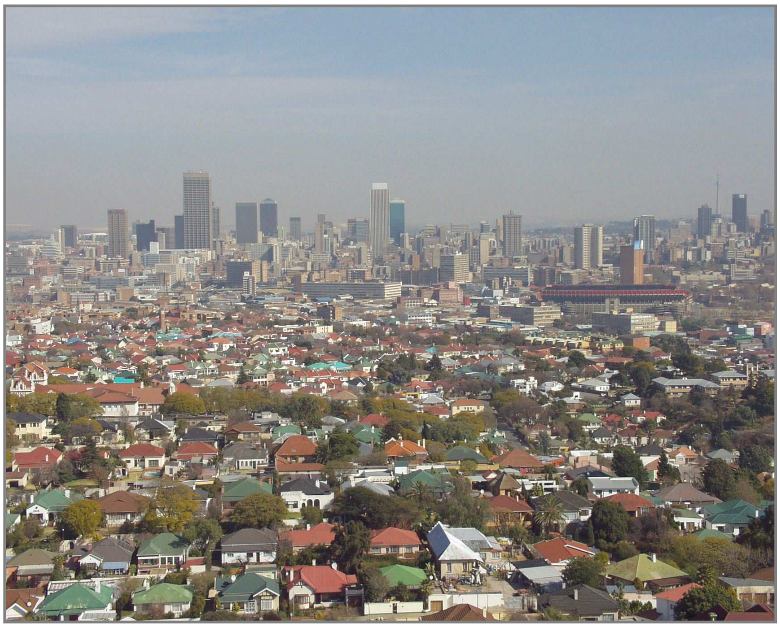

Plate 1: Low-level aerial photograph showing a portion of the mixed residential, industrial and urban developments in the northern Johannesburg area.

Plate 2: Example of a canalized stream flowing through a Johannesburg suburb

2.3 Sub-management areas

For water resources planning purposes, the Crocodile (West) and Marico WMA has been divided into six sub-management areas (Figure 1):

- Apies/Pienaars sub-management area, which comprises the catchment of the Moretele River down to its confluence with the Crocodile River.
- Upper Crocodile sub-management area, which corresponds to the catchment of the Crocodile River upstream of its confluence with the Elands River.
- Elands sub-management area, which corresponds to the catchment of the Elands River.
- Lower Crocodile sub-management area, representing the remainder of the Crocodile River catchment.
- Marico sub-management area, which corresponds to the catchment of the Marico River.
- Upper Molopo sub-management area, compromising the upper part of the Molopo River catchment.

Although it is of conservation importance, the Upper Molopo sub-management area was excluded from this study because the resolution of the data available for this area was significantly lower than that for the remainder of the WMA. A systematic planning process implies the use of relatively uniform data across the area of concern. This study made extensive use of data that were collected as part of a series of ecological river surveys that were conducted during 2004 (RHP, 2005). These river surveys focussed on the Crocodile and Marico river systems and excluded the Molopo River. Also, the latter represents a very different system that will be dealt with in the Northern Cape.

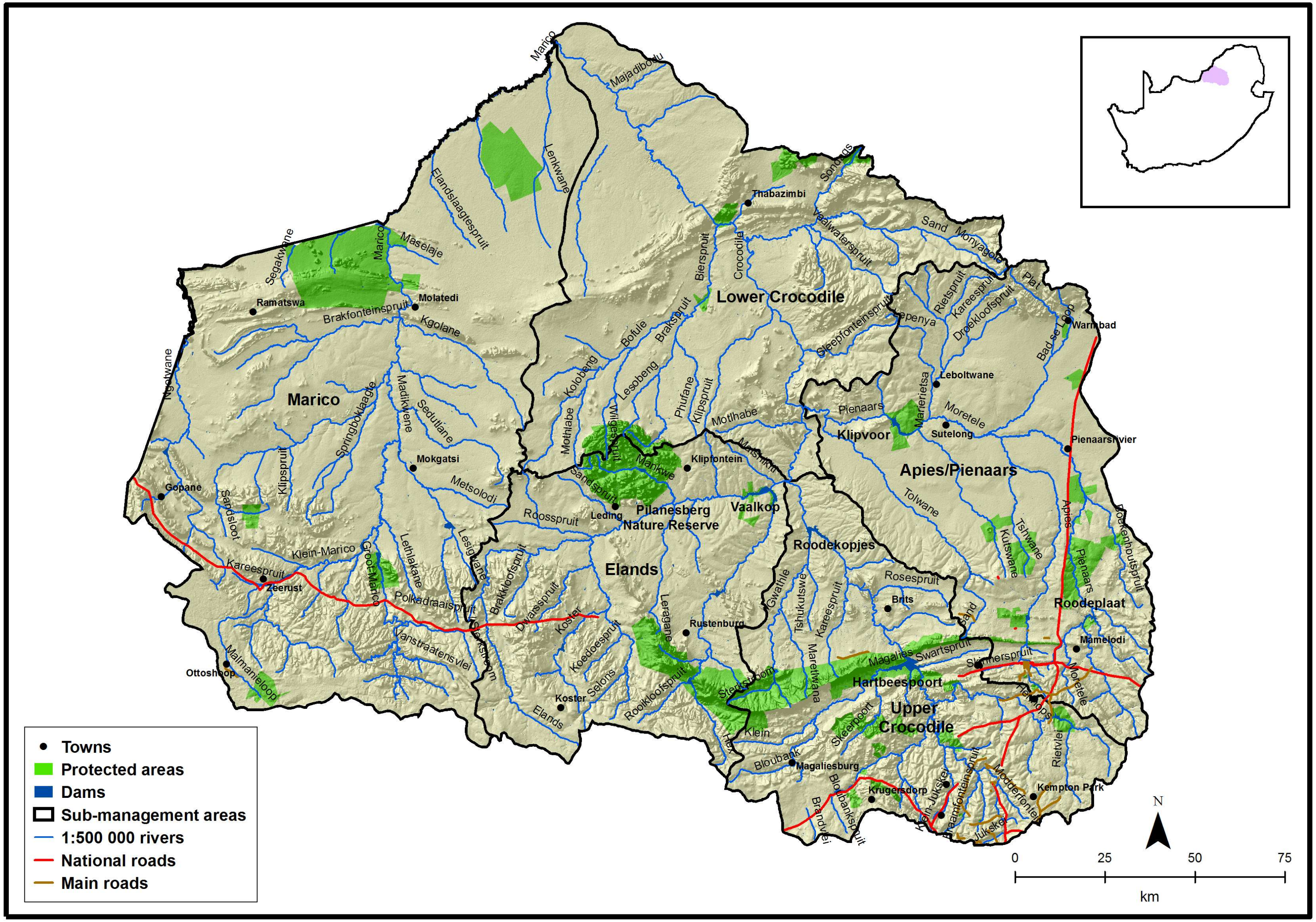

Figure 1: Map of the Crocodile (West) and Marico Water Management Area and study area.

2.4 Climate and rainfall

The climate of the Crocodile (West) and Marico WMA varies from temperate and semi-arid in the east to dry in the west. Rainfall ranges from 400 to 800 mm per annum, is strongly seasonal, and occurs mainly as thunderstorms during the summer months (DWAF, 2004b). The mean annual temperature ranges between 18 and 20 ˚C with relatively hot summers and mild to cold winters. Evaporation exceeds rainfall in most parts of the WMA (DWAF, 2004b; DACE, 2002).

2.5 Physical characteristics

The topography is generally uniform with gently undulating plains on the Highveld plateau located in the southern parts of the WMA (DWAF, 2004b). The altitude ranges from 1700 masl on the Witwatersrand to approximately 900 masl where the Crocodile River joins the Limpopo River (RHP, 2005). The main topographic features of the WMA include the Witwatersrand, Magaliesberg, Waterberg and Pilansberg.

The geology of the WMA is significant, particularly because of the Bushveld Igneous Complex which is located north of the Magaliesberg. Formations in this complex are extremely rich in minerals and include exploitable quantities of platinum, gold, uranium, iron, chrome, and manganese (DACE, 2002). Dolomitic rock is found in the Upper Crocodile, as well as the Marico and Apies/Pienaars sub-management areas. Dolomite tends to have a very high water storage capacity (DWAF, 2004b) and Tshwane abstracts a significant quantity of its water supply from these dolomitic compartments. The remainder of the catchment consists of sedimentary rock, of which the Magaliesberg Mountains are regarded as among the oldest in the world (DWAF, 2004b).

The natural vegetation in the Crocodile (West) and Marico WMA is dominated by the Mixed Bushveld vegetation type, which includes dense, short bushveld, and open tree savanna. The northern parts of the WMA are dominated by Mixed Bushveld, Sweet Bushveld and Mopane Bushveld. The central and western parts mainly comprise Mixed Bushveld, while the eastern parts are dominated by North-eastern Mountain Grassland and Mixed Bushveld vegetation. In the southernmost sections of the WMA, the Dry Sandy Highveld Grassland and Moist Cool Highveld Grassland vegetation types are more prominent (Mucina and Rutherford, 2004).

2.6 Land use

The discovery of gold in the Witwatersrand was the single most influential event that initiated the process of social and economic development of the region (DWAF, 2003). Land use (Figure 2) in the south-eastern part of the WMA is dominated by the urban areas of northern Johannesburg, Midrand and Tshwane Metropolitan Council. A strong industrial sector is also established in and around Johannesburg.

In the Marico and upper Molopo sub-management areas, the predominant land use characteristics comprise rural economic activities centred on subsistence dryland agriculture, cattle grazing and game farming, with some commercial irrigation in the upper catchment and along the Marico River downstream of the Marico Bosveld Dam and Molatedi Dam (DWAF, 2004b). Dryland crops (usually maize) are grown in the south and south-eastern parts of the WMA. North of the Magaliesberg, between Rustenburg and Brits, citrus farming is prominent, while irrigation occurs below Hartbeespoort Dam and along the main stem of the Crocodile River. Large-scale mining activities occur in the vicinity of the towns of Rustenburg, Brits, Cullinan and Thabazimbi. Various small open-cast stone, gravel and sand quarries are also found in the Upper Crocodile sub-management area (RHP, 2005).

2.7 Water resources and use

Mean annual runoff (MAR) for the WMA is 855 million m^3/annum, of which 75 % flows down the Crocodile River while the Marico sub-management area contributes 20 %. However, the total water requirements in the WMA exceed by far the resources available from the available sources. As a result, large quantities of water are transferred ('imported') into the Crocodile River sub-catchment from the Vaal River system to the south, to meet the current water demand (RHP, 2005).

Groundwater is also a very important resource in the WMA. The Marico River often has no visible surface water flows in the river segments downstream of the Marico Bosveld Dam due to abstraction for irrigation purposes (DWAF, 2004c). Significant volumes of water are abstracted from the large dolomitic aquifer compartments which stretch along the southern parts of the catchment from Tshwane to Mafikeng (DWAF, 2004b). A significant portion of the base flow of several tributaries originates from these aquifers (DWAF, 2003), while the sources of the Molemane and Marico rivers are of great conservation significance due to their uniqueness.

Water use in the WMA comprises mainly of urban, industrial and mining use (more than 50 %), while the agricultural sector uses approximately one third for irrigation and the remainder is used by rural communities and for power generation. The water abstracted from aquifers is mainly for urban, irrigation and rural use (RHP, 2005).

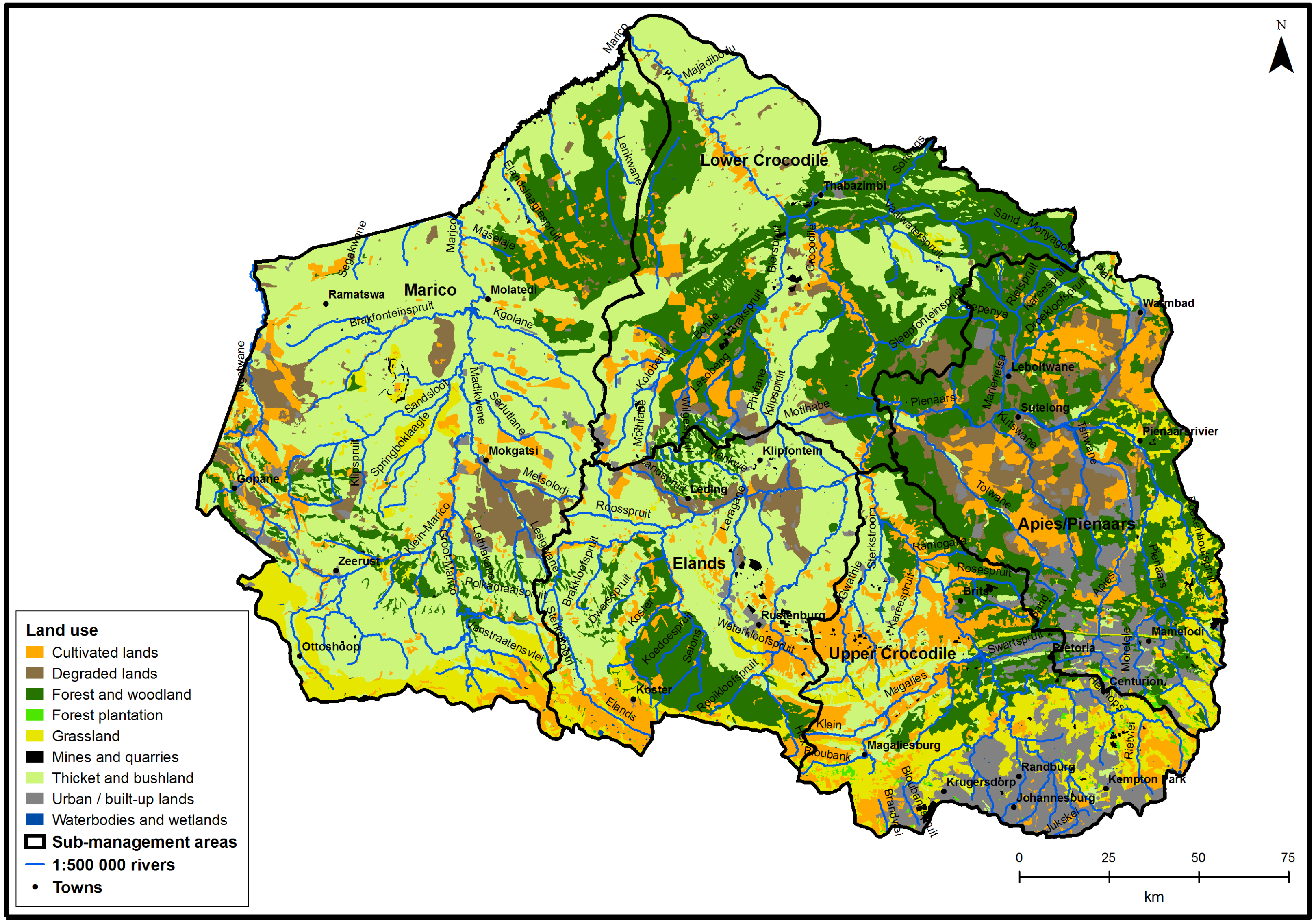

Figure 2: Land use in the study area (National Land Cover, 1996).

3. SETTING EXPLICIT BIODIVERSITY TARGETS

Biodiversity targets set minimum, quantitative requirements for biodiversity conservation in order to: allow an evaluation as to whether or not existing conservation efforts adequately represent the biodiversity of a region; provide guidance for planners who are balancing a number of competing demands for natural resources in a region; and provide water resource management and biodiversity conservation agencies with common quantitative measures for which to aim (Groves, 2003).

Targets reflect scientific best judgement, and the adoption and implementation of these targets is a reflection of societal norms and values. There is no correct way of setting targets because of the uncertainty around requirements of structural, compositional and functional elements of biodiversity. Therefore, the setting and adoption of targets should be informed through evolving understanding of the effect of anthropogenic activities on biodiversity. A set target should therefore always be subject to periodic review.

The recommendations emanating from the national cross-sectoral policy process (Roux *et al.*, 2006) were adopted in setting biodiversity targets for biodiversity in the Crocodile (West) and Marico WMA. This process has assembled recommended operational policy objectives and guiding principles to advance the practical conservation of inland water biodiversity across multiple sectors and spheres of government. These objectives and guidelines are a culmination of analysis, consultation and deliberation amongst the primary agencies responsible for conservation of inland water biodiversity in South Africa.

The recommendations emanating from the national cross-sector policy process (Roux *et al.*, 2006) were adopted in setting targets for conserving freshwater biodiversity in the area. In particular, the following guidelines were considered:

(i) At least 20 % of each inland water ecosystem type should be maintained in a Natural Class, where Natural Class refers to the highest level of protection afforded by the water resource classification system of the Department of Water Affairs and Forestry. The Natural Class roughly translates to the A and B ecological integrity categories of a six-category river assessment scheme commonly used in South Africa (see, for example, Kleynhans, 1996, 1999). This recommendation stems from the World Conservation Union's Caring for the Earth strategy (IUCN, 1989), which stipulates that a minimum of 20 % of a country's natural aquatic assets require protection - dropping below this threshold (i.e. failing to meet a minimum target of 20 %) implies that the ecosystem is inadequately represented in the country, and has become critically endangered.

(ii) In order to protect the functional elements of inland water ecosystems, whole river systems rather than isolated reaches should, wherever possible, be selected for contributing towards the national biodiversity target. Where this is not attainable, river ecosystems that are designated for conservation should, where relevant, be connected through river systems that are in a state that supports ecological connectivity - for example allowing migration of a key species. River systems that provide connectivity should be considered part of an overall design for inland water conservation, i.e. maintenance of their ecological state will be necessary for achievement of the overall biodiversity target. However, where such connecting rivers are in less than an A or B integrity category, they should not, in addition to their status as connectors, contribute towards satisfying the 20 % biodiversity target.

(iii) Where a particular inland water ecosystem has been identified as important for achieving targets, but because of past or current over-utilization has been modified to a state that does not conform to conservation objectives, restoration or rehabilitation should be undertaken subject to feasibility. Rehabilitation efforts should strive to return the chemical, physical and biological attributes of a water resource to levels that are associated with a defined (not necessarily pristine) ecological state.

Translating these recommendations to the Crocodile (West) and Marico, the following biodiversity targets were calculated:

River types

The biodiversity target was calculated as 20 % of the total length of each stream-level river type. These targets should only be achieved within river reaches that have a present ecological integrity category of A or B. Any river reach that has a lower classification than an A or B category, and has been included in the plan for maintaining longitudinal connectivity, should not contribute towards achieving this 20 % biodiversity target.

For those river types that cannot meet their biodiversity target, i.e. where the combined river length in A or B categories has dropped below 20 % of the total length of that river type, the feasibility of rehabilitating examples of these river types should be investigated. The biodiversity targets derived for each stream-level river type are shown in Appendix C, together with an assessment of the ability to achieve this target in the water management area. There are 115 river types in the WMA, of which 49 river types cannot achieve their biodiversity target in river reaches of A or B categories. A substantial number of these river types are unique, or endemic to the Crocodile (West) and Marico study area. Most of these unique river types are located around the urban and industrial metropolitan areas of Johannesburg and Tshwane. Consequently, all of these rivers and streams are heavily impacted and are therefore threatened. Options for rehabilitating examples of these river types within the study area were explored within the context of the potential opportunity for conserving these river types elsewhere in the country (Section 6.3).

Species

Biodiversity targets were set for the six fish species of special concern (Section 6.4.4). This stipulated that at least one viable population of each species should be conserved in the WMA. For the purposes of this study, viability was defined in a broad sense, as a self-maintaining, reproducing and naturally evolving population. The river reaches chosen had to be in an A or B state. To maintain longitudinal connectivity, selected river reaches should be connected to main rivers that are maintained in a state that supports connectivity (the actual state would depend on the sensitivity of each species to flow alteration and changes in water quality). In this scenario, selected tributaries can be viewed as refugia areas, replenishing each other from time to time through the connected main river.

Wetlands

Wetland targets were based on the findings of a conservation plan recently undertaken for the Mpumalanga Province, which used species richness and diversity weighting to set differential targets for wetland types ranging from 24-35 %. A quantitative biodiversity target of 25 % of each wetland type was set for the Crocodile (West) and Marico conservation plan. It should be noted that this 25 % is used to represent wetland pattern, and does not include the importance that wetlands play in maintaining functional freshwater ecosystems, and in disaster management (e.g. flood attenuation). Ideally, this functional component should be addressed in the future.

Special features

Twenty seven features of special ecological significance were identified. The biodiversity target for special features was set as 100% and all mapped special features were therefore included in the Crocodile (West) and Marico conservation plan (see Section 6.4.3). However, entire sub-quaternary catchments were not necessarily selected and conservation of these special features should be undertaken on-site.

Free-flowing rivers

Rivers are continuous ecological units, and conservation of their lower reaches is largely dependent on the conservation of reaches further upstream and vice versa. The length of a river is characterised by certain ecological gradients, e.g. temperature, nutrient and sediment/substrate gradients, along which biota are predictably structured. Anthropogenic disturbances such as excessive water abstraction or the construction of a dam create discontinuities, and discontinuous segments of a river cannot support the same ecological processes or provide the same services that are associated with free-flowing rivers. These services include the transportation of sediment that are essential for maintaining estuaries and coastal wetlands and controlling pollution through effectively transporting excess contaminants and nutrients.

A free-flowing river is a river that flows undisturbed from its source to its mouth, at either the confluence with a larger river or the sea (WWF, 2006). The size of a free-flowing river can be characterized in three important ways, based on total length from source to mouth, the size of the watershed drained by the stream or the average discharge at the mouth.

For current purposes, a biodiversity target of at least one free-flowing river of ≥ 100 km in length was set for the Crocodile (West) and Marico WMA. Further criteria in prioritisation of the conservation value of free-flowing rivers are that these rivers are in a high ecological category (an A or B integrity category) and incorporate the highest possible functional and structural diversity along their length. Any free-flowing river system identified in the study area should be incorporated, where possible, in the final conservation plan.

4. REPRESENTING AN EXAMPLE OF EVERYTHING

Representing an example of the full spectrum of freshwater biodiversity occurring in the study area requires the systematic description and spatial mapping of this biodiversity. River and wetland types were used as primary surrogates of freshwater biodiversity. These physically-defined surrogates are preferable because they provide an effective and relatively inexpensive method of describing biodiversity across the entire region in a consistent manner (Nel *et al*., 2006). These coarse-scale biodiversity surrogates were then complemented with special biodiversity features (derived from expert mapping), as well as data on fish species and macro invertebrate families.

4.1 Selecting appropriate scale and defining planning units

The primary purpose of this conservation plan is to inform future conservation and development opportunities at a water management area level. The spatial scale of mapping should therefore be detailed enough to provide a strategic perspective to sub-national decision makers on what should be done to conserve biodiversity of inland water systems. The outputs, however, will most likely not be fine enough to provide management guidelines at a local scale, e.g. detailed management objectives of a specific river reach habitat, or of a particular wetland.

In order to select suitable areas to achieve biodiversity targets, the units of selection, or planning units, need to be defined at the appropriate scale. Using catchments as planning units has the advantage of highlighting that conservation of inland water systems depends on appropriate management of both land and water systems in a drainage basin. However, primary drainage areas are too large to provide sufficient detail required at the water management area level. Indeed, it has been found in previous inland water conservation planning exercises (van Niewenhuizen and Day, 1999; Nel *et al*., 2006) that using even the smaller quaternary catchments is difficult since they are often at too large a spatial scale to provide information at a sufficient level of detail for use at a broad sub-national scale. For this reason, sub-quaternary catchments were modelled for use as planning units in this study. These also have the benefit of incorporating lateral connectivity (across aquatic-terrestrial gradients) and vertical connectivity (interactions with groundwater).

These sub-quaternary catchments were modelled using ESRI's hydrological modelling tool set, Arc Hydro, which incorporated digital elevation data and the 1:500 000 rivers (available from DWAF, http://www.dwaf.gov.za/iwqs/gis_data/river/All.html). The SRTM90 digital elevation data (http://www.personal.psu.edu/users/j/z/jzs169/Project3.htm) was used to create a flow direction grid. The Catchment Delineation function then uses the grid of flow directions to create a grid in which each cell carries a value corresponding to a stream segment that drains that area. This grid was converted to polygons that defined the sub-catchments. The size of these polygons can be varied by changing the threshold used to define stream segments or by creating a stream segment grid from a line coverage with the appropriate river data resolution. We opted for the first method with a threshold of 20 000 which gave satisfactory results in this study, but this may be improved upon using the later method for studies with larger more varied areas.

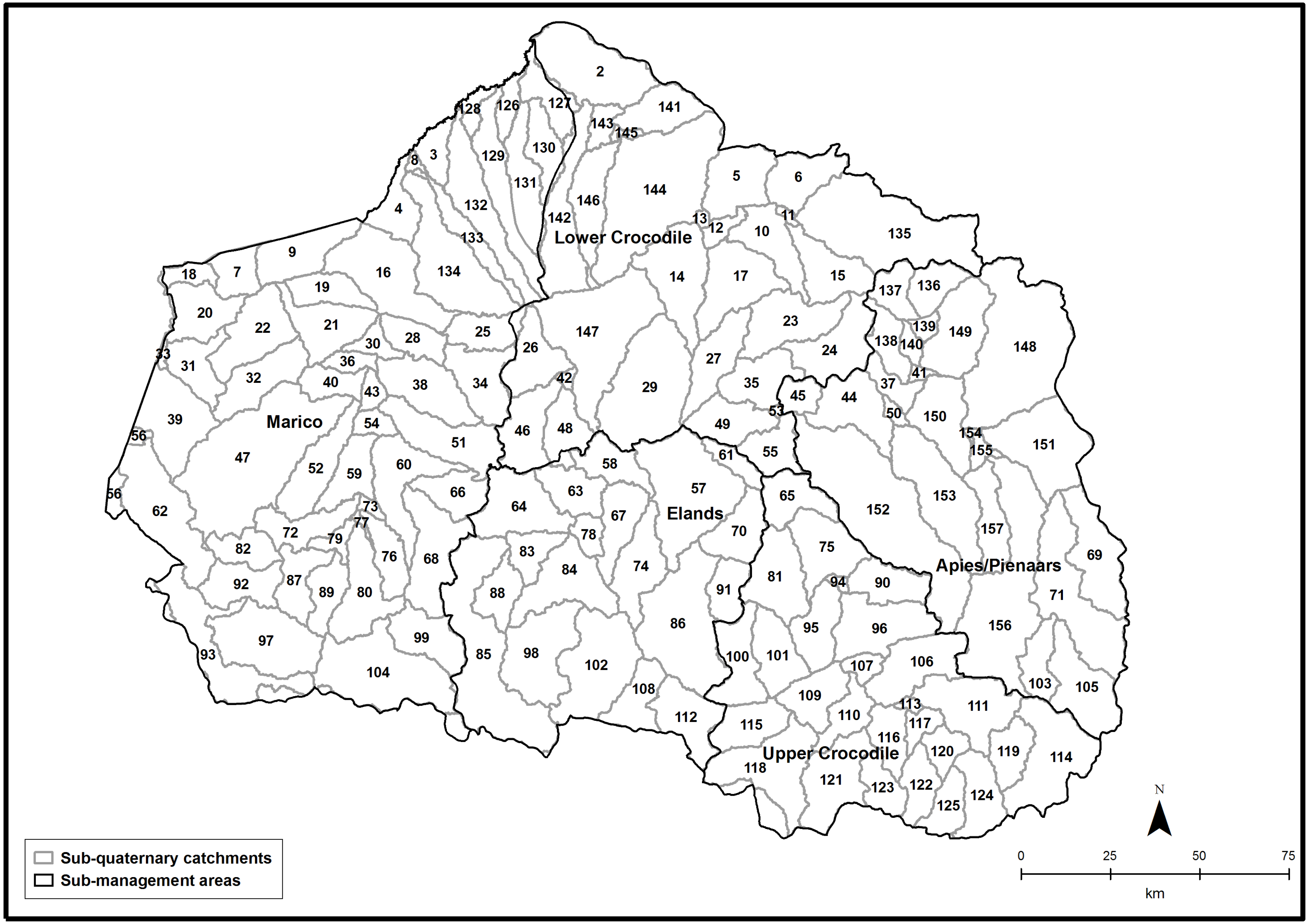

Figure 3: Map showing sub-quaternary catchment boundaries superimposed on sub-management areas.

This resulted in delineation of 156 sub-quaternary catchments (Figure 3), which are approximately nested within the 79 quaternary catchments; 17 of the smaller quaternary catchments were not sub-divided, while 15 of the largest quaternary catchments were split into four or more sub-quaternary catchments. The average size of a sub-quaternary catchment is 292 km^2, with sizes ranging from 9 km^2 to 1138 km^2.

4.2 River types

4.2.1 Selecting rivers and defining main rivers

The Crocodile (West) and Marico assessment used the 1:500 000 rivers data layer (DWAF, 2004d) for the analyses of the river types. This river data layer is based on the 1:500 000 topographical maps. However, it has been refined to include alignment of the rivers to within 50 m of the 1:50 000 topographical maps. River experts in the region facilitated the addition of seven extra rivers from the 1:50 000 rivers data layer to this dataset. These ‘additional’ rivers were mainly 1:50 000 streams that contained additional species or RHP data.

Main rivers were defined using the quaternary catchments derived by Midgely *et al*. (1994). Rivers that pass through a quaternary catchment into a neighbouring quaternary catchment are defined as main rivers. In situations where no river passed through the quaternary catchment, the longest river system was chosen as the main river. For example, this is the case in quaternary catchments containing only endorheic rivers or coastal quaternary catchments which often encompass relatively short, whole river systems. All rivers not considered main rivers are hereafter referred to as tributaries.

4.2.2 River typing

Level 2 ecoregions (Kleynhans *et al*., 2005) and the hydrological index (Hannart and Hughes, 2003) were used to derive broad landscape-level river types. These were further divided into stream-level river types using longitudinal river zones (Rowntree and Wadeson, 1999). The three physical descriptors comprising the river types in the study area are briefly described below.

Level 2 ecoregions

The river ecoregions system developed by Kleynhans *et al*. (2005), and based on the ecoregional typing approach from Omernik (1987), was used to characterise the land through which the river flows. The units represent regions within which there is relative similarity in the mosaic of ecosystems and ecosystem components (biotic and abiotic, aquatic and terrestrial). Hence, freshwater ecosystems grouped together in a particular ecoregion will be more similar to one another than to systems located in other ecoregions. The ecoregional typing approach is based on a top-down nested hierarchical procedure that involves the delineation of ecoregions with a progressive increase in detail at each higher level of the hierarchy. This implies that different ecoregions can be identified on the basis of various levels of detail (Kleynhans *et al*., 2005). Ecoregion boundaries in Kleynhans *et al*. (2005) were delineated with the knowledge of experts from various parts of the country. The Level 1 ecoregions, delineated at the first hierarchical level, involved evaluating maps of geographic phenomena such as climate, soils and geology, hydrology, natural vegetation and physiography. These ecoregions are broadly useful for identifying the main characteristics of major rivers. However, their primary purpose was to serve as a basis for the more detailed Level 2 delineations. Therefore, in identifying the level 2 ecoregions, the same delineators as for the level 1 typing was used, but in greater detail at the higher level of the hierarchy. For example, the following physiographic aspects formed part of the overall Level 2 ecoregion assessment: terrain morphology, relief, altitude and slope (Kleynhans *et al*. 2005). Level 2 typing produced regional or sub-catchment scale ecotypes, which means that they can be linked to stream classification and, hence, the river channel (Frissell *et al.*, 1986; Wadeson and Rowntree, 1999).

There are 31 Level 1 ecoregions in South Africa (Kleynhans *et al*., 2005), of which six occur in this study area. The characteristics of each of these six Level 1 ecoregions are summarized in Table 1. These are further divided into 16 Level 2 ecoregions which were used as a measure of landscape patterns (Figure 4). The Level 2 ecoregions have yet to be described formally.

Table 1: Summary of the characteristics of Level 1 ecoregions in the Crocodile (West) and Marico assessment (after Kleynhans et al., 2005).

Level 1 ecoregion	Description in study area
Limpopo Plain Ecoregion (No. 1)	This dry to arid ecoregion (mean annual temperature high to very high) located in the northern part of the study area is characterized by plains and lowlands with a low to moderate relief. The vegetation types consist mostly of Bushveld types and Mopane veld. Mean annual precipitation is low to arid (200-600 mm) and rainfall is received during the early to mid summer months. The Marico River, a perennial river, traverses this region. There are three Level 2 ecoregions within the Limpopo Plain ecoregion.
Waterberg (No. 6)	The Waterberg ecoregion is predominantly a tableland with moderate to high relief and consisting of sandstones that are important escarpment shapers. It contains one Level 2 ecoregion in the Crocodile (West) and Marico study. The Bushveld types such as Waterberg Moist Mountain Bushveld dominate the vegetation. The rainfall is seasonal, being received during the early to mid summer months, and the mean annual precipitation is generally moderate (300-600 mm).
Western Bankenveld (No. 7)	The Western Bankenveld ecoregion is located in the south-western and south-eastern part of the study area, containing five Level 2 ecoregions in the area. This ecoregion is characterized by a complex topography that varies from lowlands, hills and mountains to closed hills and mountains with the relief varying from moderate to high. Mixed Bushveld is the most definitive vegetation type of the region. Mean annual precipitation is low to moderate (400-700 mm), and rainfall occurs during the early to late summer months. The Crocodile (West), the Elands (West) and the Pienaars Rivers flow through this region.
Bushveld Basin (No. 8)	This ecoregion is extensive in the area (over 50 %) and consists of three Level 2 ecoregions in the WMA. This region consists predominantly of plains with a low relief, with Mixed Bushveld being the dominant vegetation type. Plains with a moderate relief and lowlands with a moderate relief occur in the eastern portion of this ecoregion. Perennial rivers traverse the region, e.g. the Marico, Elands (West), Crocodile (West) and Pienaars. Mean annual precipitation is 400-600 mm while rainfall is received during the early to mid summer months.
Eastern Bankenveld (No. 9)	Closed hills and mountains with moderate and high relief together with North-eastern Mountain Grassland and Mixed Bushveld are definitive of this region. It occupies less than 5 % of the study area and is located in the eastern part of the Crocodile (West) and Marico catchment. The Pienaars River and its tributaries flow through this region. Mean annual precipitation is moderate to moderately high (300 to 1000 mm), and rainfall is received during the early to mid summer months.
Highveld (No. 11)	The Highveld ecoregion is defined by plains with a moderate to low relief, as well as various grassland vegetation types (with moist types present towards the east and drier types towards the west and south). Mean annual precipitation varies from low to moderately high, increasing from west to east, and rainfall occurs during the early to late summer months. There are three Level 2 ecoregions in this ecoregion. The Hex and Elands rivers flow through the area.

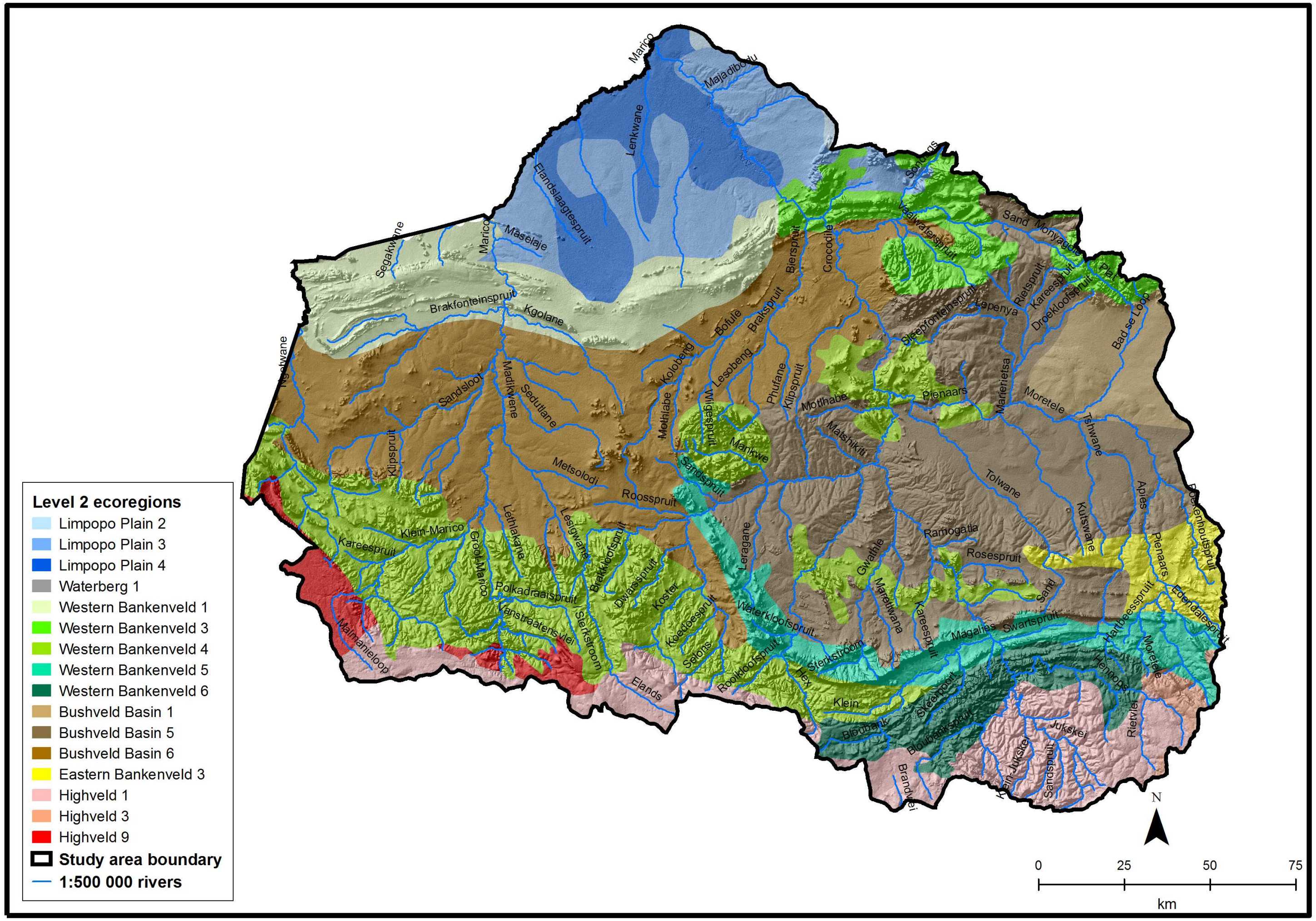

Figure 4: Level 2 ecoregions within the Crocodile (West) and Marico Water Management Area Delineated on the basis of Level 1 ecoregions by Kleynhans et al. (2005).

Hydrological index

The hydrological index derived by Hughes and Hannart (2003) was used to characterise the hydrological variability in this study. The index represents a ratio of flow variability to base flow in a river and is calculated from standard flow statistics. Hydrological index values were calculated for all 1986 quaternary catchments in South Africa, Lesotho and Swaziland using WR90 data (Hughes and Hannart, 2003). These values were grouped into nine statistical classes (ranked in ascending order) using an automated version of the Worsley Likelihood Ratio test (Worsley, 1979; Dollar *et al*., 2006). The most significant change in the average slope determined by the method of Worsley was taken as the break between classes. Table 2 depicts the hydrological index classes.

Table 2: Hydrological index classes after Worsley (1979) and Dollar et al. (2006).

Class	Hydrological index (HI) thresholds
1	HI ≤ 4.394
2	4.394 < HI ≤ 7.535
3	7.535 < HI ≤ 13.745
4	13.745 < HI ≤ 16.110
5	16.110 < HI ≤ 37.819
6	37.819 < HI ≤ 64.169
7	64.169 < HI ≤ 92.705
8	92.705 < HI ≤ 98.124
9	98.124 < HI

Rivers in South Africa with a hydrological index class of 1 indicate low variability that is associated with a more permanent-type (perennial) flow. Hydrological index classes of > 5 reflect rivers in semi-arid regions of high variability and periodic or ephemeral-type flow (Dollar *et al*., 2006). Expert evaluation of the nine classes in this study resulted in the assumption that any quaternary catchments with a hydrological index of 1-5 contain rivers that exhibit permanently flowing characteristics.

Seven out of the nine hydrological index classes occurred within the study (Figure 5). Classes 8 and 9 are absent. As expected, characteristically wetter Level 2 ecoregions such as the Eastern Bakenveld 3 and Western Bankenveld 6 reflect predominantly lower hydrological index classes, indicative of perennial-type rivers. In contrast, the drier Highveld 9 generally contains a higher proportion of periodic or ephemeral-type rivers (reflecting rivers with highly variable flows).

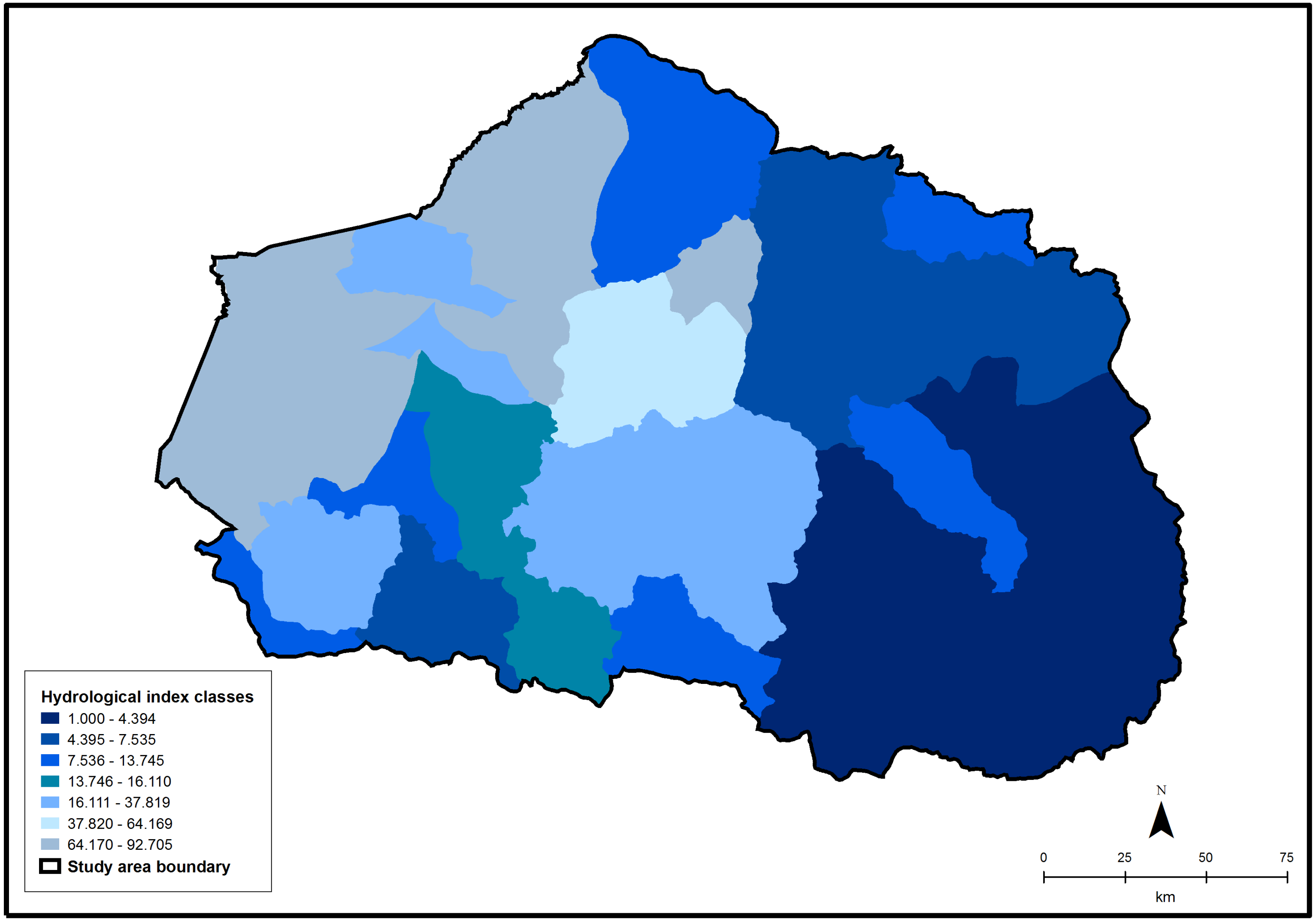

Figure 5: Hydrological index classes in the study based on indices from Hannart and Hughes (2003). Hydrological index classes ranges from class 1 (labelled 1.000-4.394 on legend) to 7 (labelled 64.169-92.705 on legend).

Longitudinal zones

River ecosystems are essentially a manifestation of prevailing climatic features and the landscapes that they drain. They are the result of the natural flow regime which drives the system, as well as the sediment that is transported or deposited in the system, and represent longitudinal or geomorphological zones. Generally, a longitudinal profile of a river shows a downstream decrease in the slope gradient which leads to a decrease in stream velocity. This, in turn, results in changes in the types of sediments found in the river channel. Larger and coarser sediments are typically associated with the steeper headwater rivers whereas increasingly finer particles and siltier sediments occur in progressively lower reaches of the lowland rivers (Rowntree and Wadeson 1999; Roux *et al.*, 2002). The combination of the longitudinal zones and landscape-level river types (Level 2 ecoregions and the hydrological index classes combined) can be used to describe the different physical habitat templates that are available for aquatic biota (Nel *et al*., 2006).

Longitudinal zones were derived for all rivers using techniques derived from Rowntree and Wadeson (1999) and a semi-automated procedure developed at the Directorate: Resource Quality Services, Department Water Affairs and Forestry. For the purposes of depicting biodiversity at a scale that is appropriate for conservation planning in the Crocodile (West) and Marico WMA, the resulting longitudinal zones were combined into six zones as follows:

1) Source zone kept separate;
2) Mountain headwater stream and mountain stream lumped together;
3) Transitional and upper foothill zones lumped together;
4) Lower foothill zones kept separate;
5) Lowland river zones kept separate; and
6) Rejuvenated zones in quaternary catchments with a hydrological index class of ≤ 5 (i.e. characteristic of perennial-type rivers) were kept as “Rejuvenated”; all other rejuvenated zones were subsumed into their associated non-rejuvenated longitudinal zone.[1]

Rivers were spatially overlayed with the hydrological index and Level 2 ecoregions, to classify rivers according to their flow variability and the ecoregion in which they occur. GIS data artefacts produced from the overlay process (i.e. they were considered “noise” created by polygon “slivers” or they were very marginal to the study area based on extent of range nationally) were cleaned. This produced 46 unique combinations of ecoregions and hydrological index values, which can be considered landscape-level river types. These landscape-level river types were then overlayed with the longitudinal zones defined at the level of individual streams, producing 115 unique combinations, which can be considered stream-level river types. These were used as the final river types in the conservation plan (Figure 6).

[1] Investigation revealed that there were no rejuvenated zones associated with rivers with a hydrological index of more than 5.

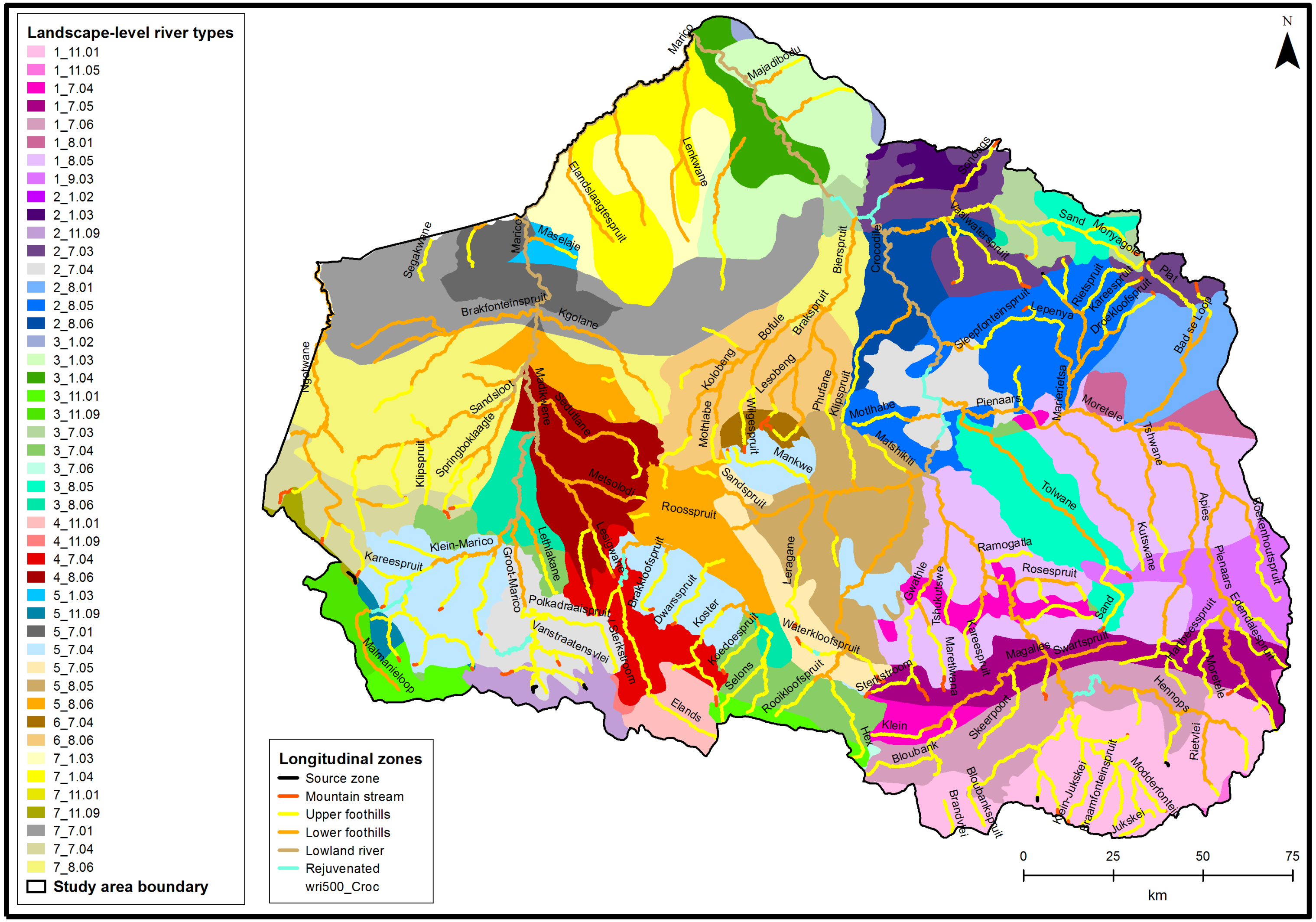

Figure 6: Landscape-level and stream-level river types for the Crocodile (West) and Marico assessment. Unique combinations of Level 2 ecoregions, hydrological index and longitudinal zones produced 115 final river types.

4.3 Wetland types

4.3.1 Mapping potential wetlands

The set of "potential wetlands" generated by the National Land cover 2000 initiative were used in this study and a total of 8922 potential wetlands were identified. In order to enhance the accuracy of the wetland data generated by the National Land Cover 2000 project, additional mapping and modelling techniques, as documented in Thompson *et al*. (2002), were applied to the basic wetland data to generate potential wetlands. Essentially, spectral data that indicate "greenness" and "wetness" are derived from two satellite overpasses taken at different times of the year (i.e. different seasons) and these are used, together with terrain-based hydrological modelling, to predict where wetlands are likely to occur within the five pre-selected land cover classes. The terrain-based hydrological modelling exercise uses information from a digital elevation model (DEM) (including elevation, flow accumulation, sinks and topographic position) to generate an index of "landscape wetness potential", which predicts, on a scale of 1 to 5, those areas in the landscape where water is most likely to accumulate (Ewart-Smith *et al*., 2006). It is important to note that the potential wetland layer represents potential wetlands and not actual wetlands. Future refinements should include verification (so-called "ground truthing") of the results as a minimum. The mapping of wetlands using detailed aerial photography should also be considered.

4.3.2 Wetland typing

There is general agreement that wetland typing systems based on geomorphic and hydrologic criteria are far more robust and consistent than those based on other criteria (Finlayson *et al*., 2002; Ewart-Smith *et al.,* 2006). A detailed hierarchical typing system has been developed for wetlands in South Africa (Ewart-Smith *et al.,* 2006). However, this method is still in its early phase and suitable data will not be available within the time span of this project.

In the absence of the data specified in the proposed classification, physiographic settings that can distinguish major wetland types (Bedford, 1996) were linked to the map of hydrogeological terrains of South Africa. The hydrogeological terrains were derived from a geological map of South Africa, Lesotho and Swaziland compiled for the Council of Geosciences by N. Keyser in 1997. The hydrogeological terrains describe how water moves through the aquifer. Impermeable layers limit percolation of water, while permeable layers store water. They were originally developed to identify and assess terrestrial ecosystem dependence on groundwater. Hydrogeological terrains are classified into aquifers where the aquifer is indicated by the permeability of the lithological group (Colvin *et al.,* 2003).

Aquifer types are:

- Surficial deposits (coastal and alluvial);
- Carbonate terrains (dolomite and limestone);
- Basement complex;
- Younger granites;

- Extrusives;
- Karoo dykes and sills;
- Fractured sedimentary terrains; and
- Unclassified areas (surface water, not included in the assessment).

These aquifer types can be associated with the three main wetland types that Bedford (1996) identified based on the basis of their physiographic setting:

(i) *Small depressional wetlands where surface drainage is poorly developed.*
Any topographic hollow may be associated with this type of wetland. Carbonate terrains, which are associated with sinkhole development, are a good example of an aquifer in this physiographic setting. Dolomite and limestone are highly soluble and jointed, producing extensive cavities, caves and underground drainage systems. Sinkholes develop when the cave roofs become unstable and collapse.

(ii) *Wetlands related to minimal land slope.*
Flatter land surfaces allow water to remain on the surface or within the soil for significant periods of time. These areas are commonly underlain by shallow water tables or an impermeable layer. Surficial deposits are horizontally layered deposits of fluvial and aeolian origin. The layers are complex and have differential permeabilities that cause extensive perched groundwater bodies. The water table is usually close to, above or at the surface of the deposit for at least part of the year. Extrusives and younger granite terrains are an example of the latter type as they are more resistant to erosion and act as impermeable layers that trap percolating water, creating perched water tables.

(iii) *Slope discontinuities that cause groundwater to discharge as seeps or springs, generally where steep slopes intersect flatter areas.*
Changes in the gradient of a slope are usually attributed to changes in the underlying lithology. Fractured sedimentary and basement complex terrains are examples of this type of physiographic setting, as the material is usually highly modified and capable of storing large amounts of water. The fractured sedimentary terrain consists of associated layers of extrusions and intrusions, sandstone and shales. The shales are the most permeable of the rock types and water moves easily through the shales, becoming trapped above the sandstones and dolerite intrusions. Groundwater recharge, as seeps and springs, occurs on the slope face at the contact between the highly weathered shale and the impermeable layers. The basement complex is highly weathered and modified and acts in the same way as the shales. In dolomitic areas, intruded dykes create impermeable boundaries that form compartments within the soluble rock. Springs and seeps occur in these zones where the groundwater is forced to the surface.

Aquifer types can be used to describe the physiographic setting of a wetland, as the aquifer is determined by the underlying lithology. Impermeable layers create flat surfaces on the landscape or changes in slope gradient where they protect underlying layers that weather and erode easily. Discharge occurs as springs and seeps along the boundary zones and provides water to surface drainage systems. Unconsolidated, surficial deposits are highly permeable and the water table can move freely through the layers; in these areas the wetlands may be partially connected to surface drainage. Perched water tables occur where material properties within the deposit differ and these occur as isolated patches. Although the physiographic types are generalizations of the different conditions under which wetlands can occur, this system allowed for the aquifer types to be categorized. This made the choice of management options easier where a variety of aquifer types occurred in a catchment. Low impact activities are allowed for carbonate terrains and surficial deposits, medium impact activities are allowed for fractured sedimentary terrains and basement complex, and high impact activities are allowed for the dolerite dykes, extrusives and younger granites.

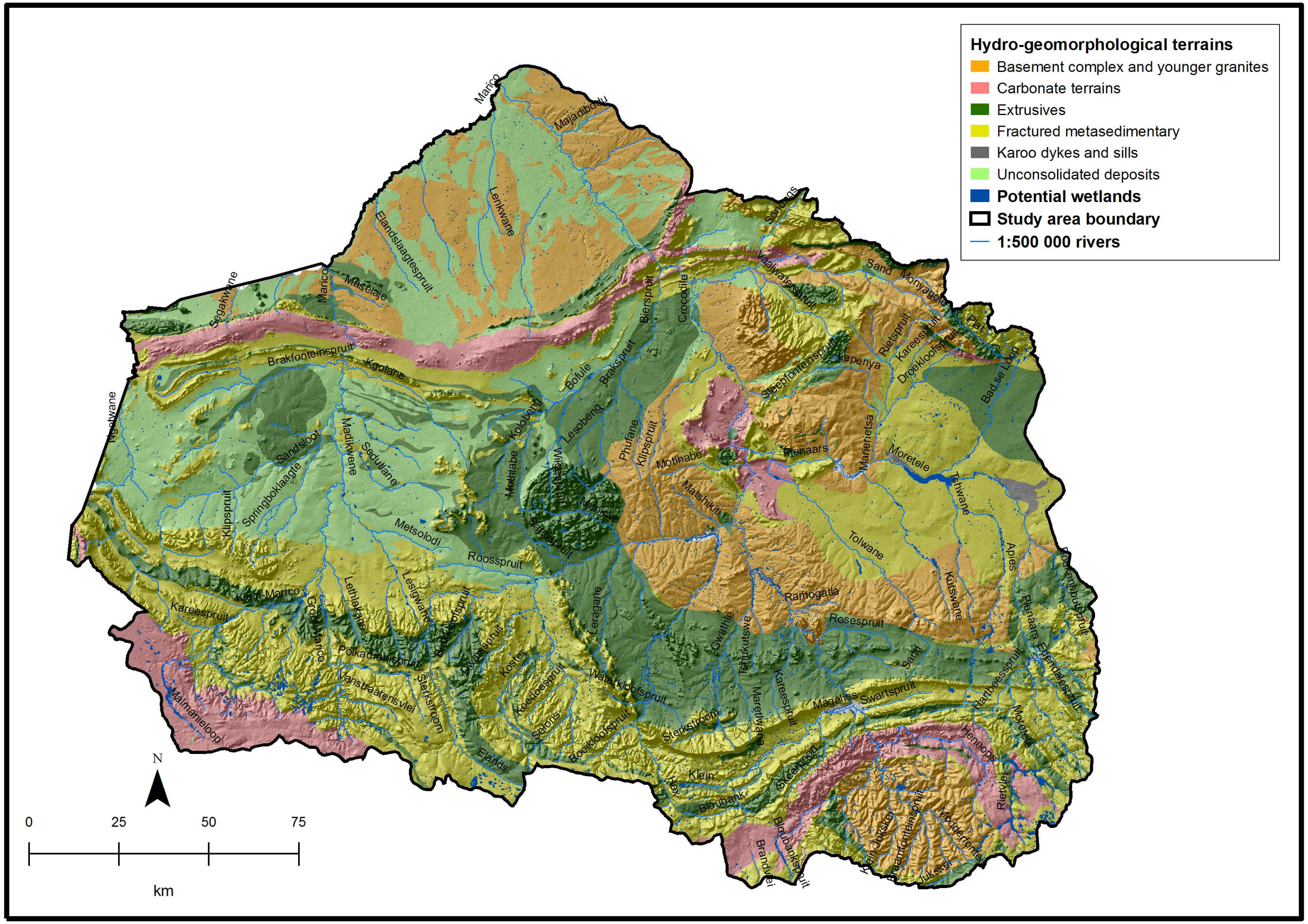

Figure 7: Map of wetland types in the study area.

Potential wetlands and hydro-geomorphological terrains are used for depicting wetland types.

4.4 Special features

During a workshop on 26 January 2006 a number of experts in the Crocodile (West) and Marico WMA helped to identify features in the landscape and species that had special value for biodiversity. To assist with identifying special features, seven categories were used:

- Refugia;
- Red data/rare species;
- Unique habitat;
- Unique species;
- Wetlands of particular conservation importance;
- Pristine area; and
- High habitat diversity.

In total, 27 special features were mapped using on-screen digitising during the workshop discussions (Figure 8). Appendix D lists these special features and the reasons for their identification. These features are all represented in the final conservation plan (See Section 6.4.3).

Due to the high levels of development and ecological transformation in the area, many of the special features represent the last remaining examples of those habitats in a relatively pristine condition. The sites also represent unique landscape features (e.g. the dolomitic eyes) that may not be found elsewhere. The dolomitic eyes are geological formations where groundwater from aquifers is forced through fractures to the surface (RHP, 2005). In these areas, the ecology is dependant on the surface water and groundwater. The Molopo, Molemane and Marico Rivers all have dolomitic eyes with unique biodiversity (Plate 3a-b). This is due to the relative isolation and evolutionary development of the species found in the surface water. A study completed in 1994 identified a number of new Insecta and Crustacea species and a possible new fish species (Skelton *et al.*, 1994). The unique biota included: three new species of mayfly (Ephemeroptera), one new dragonfly (Odonata), two new caddisflies (Tricoptera), four new seed shrimps (Ostracod), and one new Crustacean species.

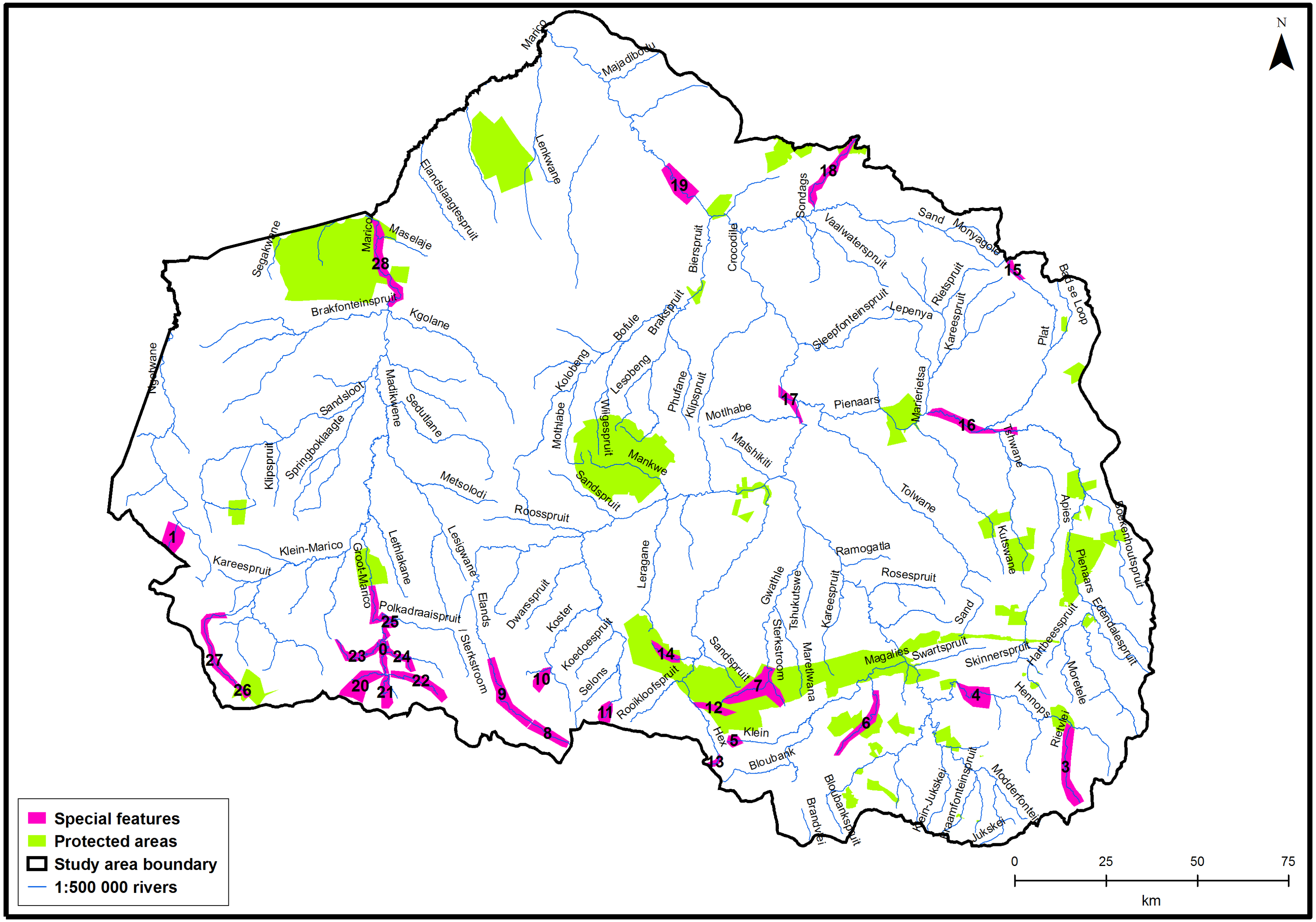

Figure 8: Map of special features in the study area.

(a)

(b)

Plate 3a-b: The Grootfontein eye at the origin of Kaaloog se Loop (a), and the Molemane dolomitic eye located at Molemane se loop (b).

4.5 Species data

4.5.1 Fish species

Species Richness

A total of 29 indigenous fish species are believed to have occurred in the Crocodile-Marico system under reference conditions. Most of these species tolerate adverse environmental conditions such as low flows, water quality modifications, general habitat alterations and fragmentation and are generalists in terms of their breeding requirements. However, even though these are generally hardy species, three of these species are now considered to be extinct in the Crocodile-Marico system

Habitat modification has resulted in a decline in the abundance and overall distribution of several species, while Southern barred minnow (*Opsaridium peringueyi*), Lowveld suckermouth or Rock catlet *(Chiloglanis swierstrai*) and Striped topminnow (*Aplocheilichtys katangae*) have disappeared from the study area. In contrast, several tolerant species are able to exploit modified habitats to their advantage, such as those created by impoundments. Although genetic studies may reveal some isolated taxa, present information indicates a low level of endemism with Canary kurper (*Chetia flaviventris*) and Marico barb (*Barbus motebensis*) being the only South African endemic species present both in the study area and elsewhere in South Africa. *Barbus motebensis* is considered to be a vulnerable species (www.iucnredlist.org).

Species of special concern

For the purposes of this conservation plan, only species of special concern were identified and targeted for conservation. Only extant (i.e. living, not extinct) species were considered and selected on the following basis:

- The presence of red listed species: *B. motebensis*.
- The presence of isolated populations: Johnston's topminnow (*Aplocheilicthys johnstoni*), Stargazer or Mountain catfish (*Amphilius uranoscopus*), *B. motebensis,* and Snake catfish (*Clarias theodorae*).
- Type localities (the location where the original species was discovered and described): Shortspine suckermouth or Rock catlet (*Chiloglanis Pretoriae*) (from the Crocodile River in the Pretoria district); *C. flaviventris* (from the Sterkstroom tributary of the Crocodile River), *and B. motebensis* (from the Motebe tributary of the Marico River).

Table 3 indicates the intolerance of these species to no flow conditions, while Table 4 shows the habitat preferences of these species according to flow velocity classes and their intolerance to water quality modifications.

Viable populations for species of special concern and management considerations

Viable population sizes for these species have not been determined in any way. However, the size of the fish, size and length of the streams (habitat volume), ability to move over artificial barriers, relative intolerance to anthropogenic habitat disturbances, presence of introduced species, and the presence of meta-populations, all influence the viability of a species. The concept that small isolated populations are at relatively high extinction risk are fundamental to assessing aspects that would influence the viability of fish. Aspects such as life-history strategies (e.g., r- and K-selected species) and distribution pattern within the riverine landscape are important in interpreting which species may be at a relatively high risk of extinction.

Table 3: The intolerance of the fish species of special concern to no-flow conditions in the study area.

Species	Intolerance or tolerance to no-flow conditions		
	Highly no-flow intolerant: Require flow during all life stages and a diversity of macro-invertebrates as food sources	Moderately no-flow intolerant: Require flow during the spawning season	Tolerant of no-flow: Not dependent on it for reproduction
A. uranoscopus	x		
B. motebensis		x	
A. johnstoni			x
C. theodorae			x
C. pretoriae	x		
C. flaviventris			x

Table 4: Habitat preferences of the fish species of special concern, relating specifically to velocity and their tolerance of water quality modifications.

Species	Habitat preferences according to velocity classes		Tolerance to water quality modifications		
	Fast (> 0.3 m/s): Rocky substrate cover	Slow (< 0.3 m/s): Marginal vegetation cover	Highly intolerant	Moderately tolerant	Tolerant
A. uranoscopus	x		x		
B. motebensis		x		x	
A. johnstoni		x		x	
C. theodorae		x			x
C. pretoriae	x		x		
C. flaviventris		x			x

Considerations such as the size of adult fish are important as this has a direct implication for the minimum habitat requirements. The maximum age a species can attain can also be important in terms of adult individuals being able to survive adverse conditions such as low or no-flow situations if the duration of such events does not exceed the maximum age. Similarly, the age and size of individuals when they attain sexual maturity is also important. Based on these considerations, the species listed were considered to be exposed to the following threats to their viability:

- *Amphilius uranoscopus* (Figure 9a) is a habitat specialist with a low fecundity and is not associated with any intensive form of development. It occurs in perennial streams in the Western Bankenveld. The Groot Marico River and its tributaries are very important for its conservation. It is also present in a limited number of source streams of the Crocodile River. Apart from a requirement for perennial flow and high water quality, these relatively small populations can be adversely effected by habitat modification such as weirs which will also contribute to population fragmentation and prevent recolonization. Connectivity between meta-populations is therefore essential for long-term survival as this species is not able to traverse obstructions. Population recovery potential is regarded as low.

- *Barbus motebensis* (Figure 9b) has a distribution that is very similar to that of *A. uranoscopus* in the Groot Marico River. Although it is less dependant on flowing water, it can be adversely impacted by low water quality and habitat fragmentation. Similar concerns and considerations as with *A. uranoscopus* are valid. It was historically also recorded in a number of upper tributaries of the Crocodile River but its continued survival there needs to be confirmed, as does its presence in the Plat River. Population recovery potential is regarded as low.

- *Aplocheilicthys johnstoni* (Figure 9c) has a strong preference for slow flowing water and in-stream and marginal vegetation. It feeds on small invertebrates, has a low fecundity and is considered to be relatively tolerant. Its limited distribution may be related to the use of insecticides. A number of isolated and apparently remnant populations occur in the east flowing rivers of South Africa and its population recovery potential appears to be moderate to low.

- *Clarias theodorae* (Figure 9d) has only been collected in the Buffelspruit, an upper tributary of the Plat River. Its ability to traverse obstructions is uncertain and the fragmentation of this small population may threaten its existence. Population recovery potential is regarded as low. Isolated populations of this species occur in a number of streams in the Waterberg ecoregion.

- *Chiloglanis pretoriae* (Figure 9e) is present in perennial streams, usually with clean, clear and fast flowing water. It has disappeared from streams draining urban areas and is found in substantial numbers in streams of high ecological integrity. However, it is still present in reasonable numbers downstream from the Hartebeespoort Dam and the Roodekoppies Dam. Although water in this section of the Crocodile River is nutrient enriched and contains a higher than normal salinity (mainly due to agricultural return-flows), flow releases from these dams provide clear water with suitable perennial habitat at cobble and bedrock areas for small numbers of *C. pretoriae* to survive. Population fragmentation is not a factor as it is able to easily traverse artificial obstructions. Given that meta-populations are able to survive, and the fact that flow and water quality is suitable, its recovery potential is regarded as moderate.

- *Chetia flaviventris* (Figure 9f) is present in several rivers in the Crocodile-Marico. It is well adapted for survival in standing water and consequently often occurs in very high numbers in impoundments and weirs. It is a mouth brooder and this contributes to its successful existence in several habitats. Population recovery potential is regarded as high.

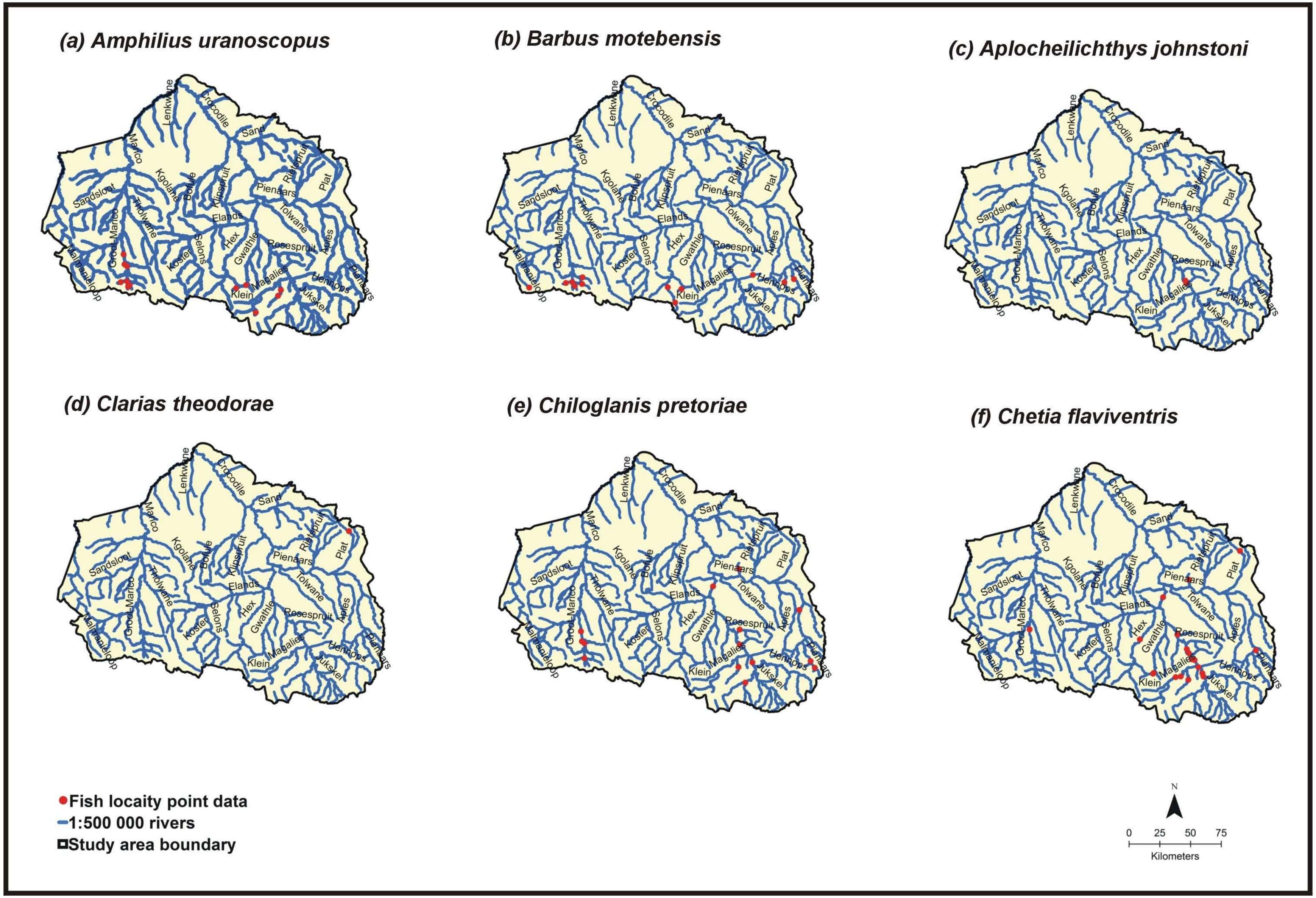

Figure 9a-f: *Distribution of the fish species of special concern for the Crocodile (West) and Marico catchment.*

4.5.2 Invertebrate families

During recent surveys, a total of 74 different invertebrate taxa were recorded in the Crocodile (West) and Marico WMA, though none of these taxa can be regarded as endemic or rare. The taxa found include very tolerant families such as Chironomidae, as well as those that are very sensitive such as Blepharoceridae. The actual distribution of the invertebrate taxa throughout the WMA depends on the environmental conditions such as available habitat, flow conditions as well as physical and chemical factors such as dissolved oxygen and water temperature. These features can be linked to the Level 2 ecoregions and longitudinal zones.

Because species-level invertebrate data are currently not available for the study area, it was not possible to represent invertebrate species in the Crocodile (West) and Marico conservation plan. Rather, river types were used as surrogates to represent different invertebrate biotopes. This did not prevent the excellent family level data that are available for the planning domain from being applied in the study in two ways:

(i) Delineating the special features (Appendix D). Reference communities represented habitats of pristine conditions; and
(ii) Setting SASS5 (South African Scoring System Version 5) thresholds to guide management of state of rivers in the Crocodile (West) and Marico WMA.

The SASS technique provides a rapid bioassessment of the degree of impairment of water quality and the general health of rivers, based on the presence or absence of key invertebrate families (Dickens and Graham 2002). Details of the method, including its underlying theories and the sampling methods, are described in Chutter (1995), Dallas (1995) and Gerber and Gabriel (2002). Only those taxa that occurred in sufficient numbers frequently enough, and that are indicative of certain biotopes or environmental conditions, were used to set thresholds. This means that rivers can be managed according to different states of health using SASS indicators as applied in the River Health Programme (RHP) (http://www.csir.co.za/rhp**)**. The RHP uses in-stream and riparian integrity biological response monitoring to characterize the response of aquatic environments to multiple stressors (Roux *et al.*, 1999).

SASS thresholds are provided for rivers in each of the Level 1 and 2 ecoregions in Appendix E, based on an assessment of main rivers (recording also the river name on which the assessment was based). These thresholds also apply to any rivers falling into the same ecoregions. Applying these thresholds enables managers to determine what the SASS score needs to be to maintain the river in a particular condition or to improve its condition. Where the SASS5 score drops below these thresholds, it means that the condition of the river will slowly degrade. Managers are thus provided with an extra tool that can be applied to meet recommendations regarding rivers that are required to be: (i) in an AB integrity category for meeting biodiversity targets, and (ii) in a state for facilitating connectivity (preferably no lower than a C integrity category). An example of the above can be seen for the stones biotope in the Sterkstroom River, Ecoregion 7.04 Western Bankenveld (Table 5). The results in this table for example imply that for SASS scores of 24 to 174, the number of taxa should be 5 to 27 with the average score per taxon (ASPT) (total score/number of families) ranging between 3 to 7.25. River reaches should be maintained in an A integrity category for SASS scores of >120 while scores of >75 should accompany river reaches in integrity categories B or C. The benthic marco-intevertebrate families Heptageniidae and Elmidae in an A category river reach should be > 50% present while the number of taxa should be >20. Similarly, the ASPT scores in an A category river reach should be > 6.5.

Table 5:SASS thresholds for the stones biotope in the Sterkstroom River.

Ecoregion: Western Bankenveld 7.04; PES: B/C; Limiting factor: Poplar leaves			
SASS: (24 - 174)	*No of Taxa:* (5 - 27)		*ASPT:* (3 - 7.25)
BC > 75; A > 120	BC >15; A >20		BC >6; A >6.5
Families:	BC	A	
Heptageniidae	Present	>50%	
Elmidae	Present	>50%	
Chlorocyphidae	>10%	>50%	

5. ENSURING PERSISTENT CONSERVATION

Conserving species and habitats, as considered under biodiversity representation, provides a snapshot of the biodiversity that currently exists. If this biodiversity is to persist and evolve naturally over time, it is also necessary to consider biodiversity processes. Biodiversity processes take the form of ecological processes (those processes which maintain ecosystem structure and function) and evolutionary processes (those processes which maintain lineages and generate biodiversity over the long term). These processes include inter-specific interactions, short- and long-term dispersal, nutrient cycling, sediment transport, water recharge areas and flow regimes.

Biodiversity processes were included in this conservation plan during selection and design by:

(i) Selecting rivers and wetlands of high ecological integrity; and
(ii) Incorporating longitudinal, lateral and vertical connectivity.

5.1 Selecting rivers of high ecological integrity

Ideally, rivers and wetlands that are selected for the purpose of conserving biodiversity should be of high integrity, since these are the rivers and wetlands that accurately represent the biodiversity of the region, and in which ecological and evolutionary processes are more likely to operate within their natural ranges. Incorporating rivers and wetlands that are currently of high integrity will therefore incorporate many small-scale biodiversity processes such as localized nutrient cycling, sediment transport, inter- and intra-specific interactions. From a practical point of view, selecting rivers and wetlands that are currently of high integrity also: (i) facilitates operational management since rivers and wetlands operating close to natural conditions tend to be more self-sustaining, and require less conservation management; and (ii) improves the cost efficiency of conservation management as no rehabilitation is required. Mapping the ecological integrity of rivers and wetlands for the region is discussed below. For the purposes of this project, only those rivers with a present ecological integrity considered to be “Natural” or “Good” (equivalent to A or B integrity categories) were selected.

5.1.1 *River ecological integrity*

The condition of main rivers (at a landscape level) in the study area was assessed spatially according to the EcoStatus determination method (Kleynhans *et al*., 2005). The Index of Habitat Integrity (IHI), one of the tools applied in less detailed EcoStatus level assessments, was used, as well as RHP data available for the study area. The IHI assesses both the riparian zone and the in-stream channel by scoring certain physical and biotic attributes or criteria based on the impact of anthropogenic modification (Kleynhans, 1996). The EcoStatus determination method aims to provide a single, integrated index value that indicates the ecological state of a river system using the following categories, which reflect varying degrees of integrity:

- Natural, unmodified (A category);
- Largely natural (B category);
- Moderately modified (C category);
- Largely modified (D category);
- Seriously to critically modified (D/E category); and
- Moderately to seriously modified tributaries (Z category).

The main rivers in the study area are heavily impacted by large-scale mining activities, urbanization, water abstraction for irrigation, cattle grazing and dryland subsistence agriculture (Section 2.6). The south-eastern part of the WMA is dominated by populated urban areas such as northern Johannesburg, Midrand and the Tshwane Metropolitan Council which contain largely to seriously modified river reaches. This is reflected in the condition of main rivers in the study area, which have no river length in an A (natural) category and only 13 % of the river length in a B (largely natural) category (Figure 10). The majority of the river reaches (58 %) are in a C category (moderately modified), whilst 30 % are in D and E categories (largely to seriously modified). Main rivers are heavily utilized and regulated to provide water for social and economic development. Smaller tributaries are often less regulated and therefore are frequently in a better condition than main rivers. Therefore, tributaries play a crucial role in meeting biodiversity targets (Nel *et al*., 2004; Nel *et al*., in prep) in the Crocodile (West) and Marico WMA.

In this assessment, natural vegetation was used as a surrogate for mapping tributary ecological integrity. The method was based on a study conducted by Amis *et al*. (in press), which found that where no other data exist, the % natural vegetation serves as the best proxy for river condition. The mean % natural vegetation was calculated per sub-quaternary catchment and this value was then associated with rivers within the sub-quaternary catchments. In addition, the score for % natural vegetation within a 500 m buffer on either side of the river was calculated for rivers in each sub-quaternary catchment. The minimum of these two indices was then assigned to each river reach. Any river reach where the % natural vegetation was ≥ 75 % was assumed to be in an A or B integrity category and able to contribute towards achieving river biodiversity targets. River reaches with a natural vegetation score < 75 % were assigned to a Z category, i.e. not intact. The assessment results were then reviewed by a river expert in the catchment. During the review of the modelled results, the tributary integrity of sub-quaternary catchments 71, 81 and 94 was changed from an A to a Z category.

The resulting river ecological integrity map for main rivers and tributaries is shown in the Figure 10. Compared to main rivers, tributaries in the study area are in a relatively good condition with 58 % of their river length intact (A category) and 42 % in a Z category (moderately to seriously modified) (Figure 11). However, it is important to note that the tributary integrity data are preliminary and need to be refined to consider the cumulative upstream impacts of dams and water transfer schemes. Although cumulative upstream impacts of dams and water transfer schemes were integrated into the desktop present ecological status for main rivers, the tributaries do not take this into account (although tributaries are probably less subject to large upstream impacts than main rivers). The map should also be field verified.

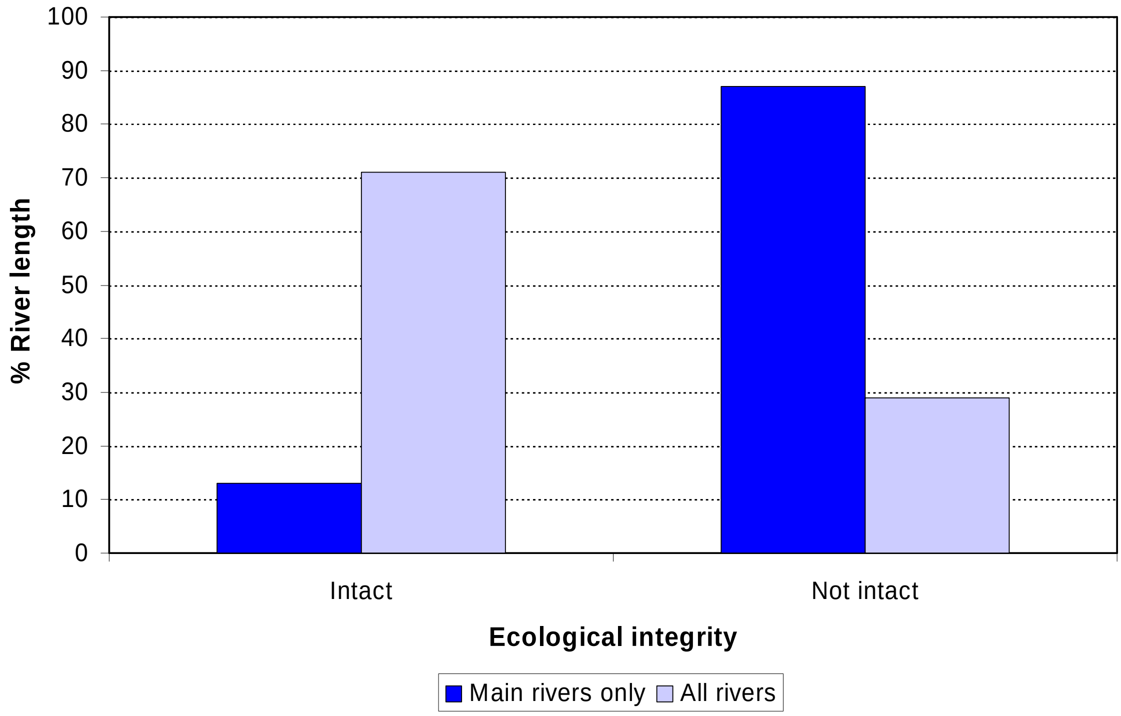

Figure 11: Assessment of ecological integrity for main rivers and tributaries showing the percentage river length for "intact" and "not intact" rivers.

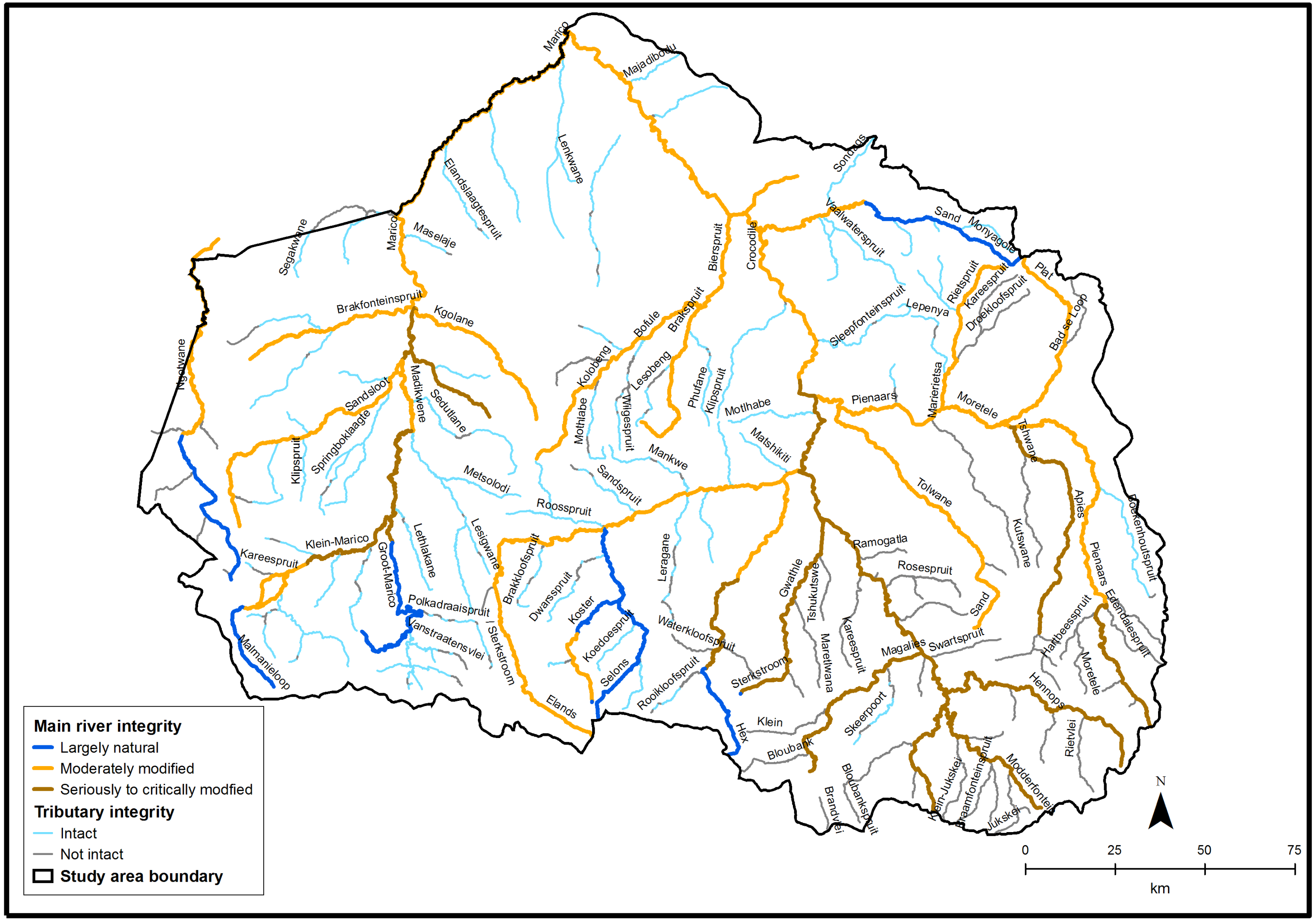

Figure 10: River ecological integrity map for main rivers and tributaries of the Crocodile (West) and Marico study area. Main rivers were assessed according to the Ecostatus method while natural vegetation was used as a surrogate for tributary integrity.

5.1.2 *Selecting wetlands of high ecological integrity*

Wetland integrity was calculated by using the % natural vegetation within a 500 m buffer zone. This was then compared to the score for % natural vegetation within its sub-quaternary catchment (see Section 5.1.1) and the mean % natural vegetation within the wetland itself. The minimum of the three scores for % natural vegetation was assigned to the respective wetland. Any wetland with a minimum % natural vegetation score ≥ 75 % was considered relatively intact and worthy of selection for conservation purposes. According to these calculations, 39 % of wetlands in the study area are intact. Wetlands on Extrusives are the most impacted, with only 28 % remaining intact. Wetlands on unconsolidated deposits and Karoo dykes and sills are the least impacted, with 70 % and 69 % remaining intact, respectively (Table 6 and Figure 12).

Table 6: Integrity of wetland types in the study area, based on % natural vegetation.

Wetland Type	Number of wetlands	Percentage of total	Percentage intact
Basement complex	2319	26.0	45
Carbonate terrains	356	4.0	37
Extrusives	2145	24.0	28
Fractured meta-sedimentary	3530	39.6	38
Karoo dykes and sills	16	0.2	69
Unconsolidated deposits	556	6.2	70

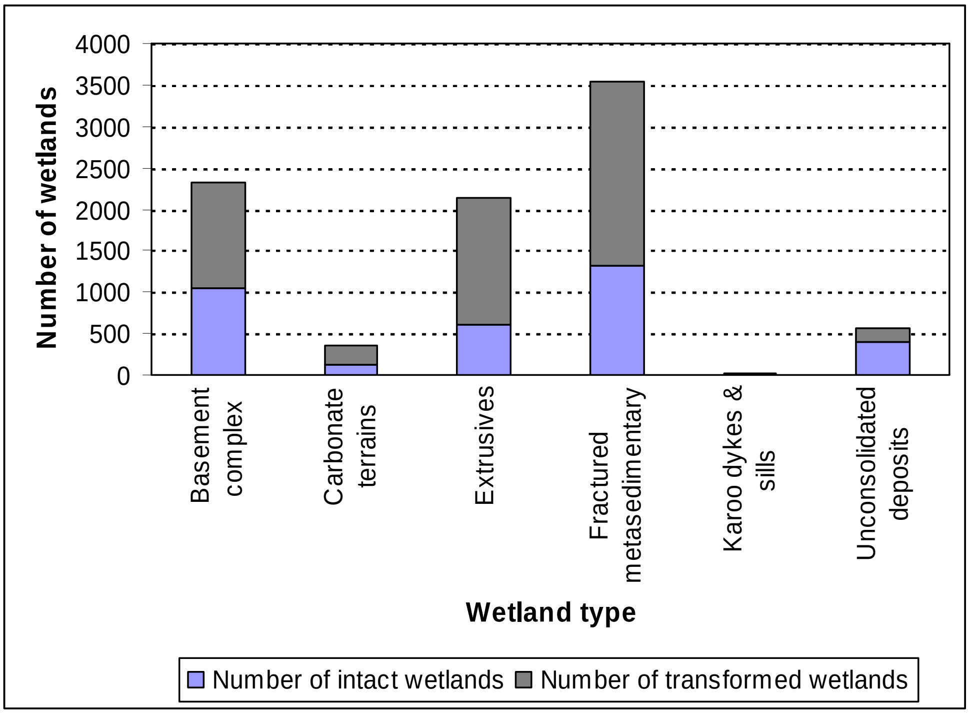

Figure 12: Assessment of wetland types showing the number of transformed and intact wetlands.

5.2 Incorporating connectivity

5.2.1 Longitudinal connectivity

In the case of rivers, most ecosystem functions are maintained directly or indirectly through connectivity. Rivers are continuous ecological units, and conservation of their lower reaches is largely dependent on the conservation of reaches that are located further upstream, and vice versa. Therefore, selecting discontinuous representative segments of a river is not an appropriate approach for the conservation of river ecosystems.

Longitudinal connectivity in the Crocodile (West) and Marico conservation plan was maintained by incorporating, where possible, whole river systems in the conservation plan. However, in this heavily utilised area, it was seldom possible to find whole river systems in a consistently high ecological category (where the river is in an A or B integrity category throughout its entire tertiary or primary length). Rivers that were selected for conservation (i.e., in an A or B category) were therefore connected through rivers that are only moderately used or impacted (ideally, not lower than a C category). Such connecting rivers were incorporated explicitly into the final conservation plan, with the recommendation that these should be maintained in a state that promotes longitudinal connectivity for its associated biodiversity.

5.2.2 Lateral connectivity

Lateral connectivity refers to the interconnectedness that exists across an environmental gradient between aquatic, riparian and terrestrial ecosystems. As a result, the ecological integrity of the whole catchment needs to be managed appropriately in order to conserve riverine and wetland biodiversity. The need for lateral connectivity was incorporated into the Crocodile (West) and Marico conservation plan by including entire sub-quaternary catchments (Section 4.1) within which selected river reaches occurred, highlighting that these sub-quaternary catchments will require appropriate land use practices in order to meet the level of protection awarded to the water resource.

5.2.3 Vertical connectivity

Vertical connectivity refers to the connectivity between surface water and groundwater. Groundwater resources are available throughout the catchment but their yield is dependent on the hydrogeological characteristics of the underlying aquifers. The natural groundwater quality is usually good, though continued pollution poses a growing threat to groundwater quality in this WMA. Pollution is caused by poor effluent disposal and waste management practices by municipalities, agricultural activities and mining. Of these, nitrates (from fertilizers and sewage) and acid mine drainage pose the biggest water quality threats.

Nitrate has a high potential for polluting groundwater as it is highly soluble and remains in the soil until it is consumed by plants or organisms, or denitrified to nitrogen gas and lost to the atmosphere. Inorganic salts containing nitrates are commonly introduced as fertilizers for agriculture whilst feedlots, poor sewage works maintenance, leachate from landfill sites, and runoff from rural and informal settlements, produce compounds that contain nitrate. Effluent from the Kempton Park sewage works is discharged into the surface waters that flow across the southern dolomites and into Rietvlei Dam; the likelihood of groundwater pollution is high should the sewage works not function properly (Hubert, 2003). Rural settlements are associated with a high density of pit latrines and these create conditions of increased salinity and elevated nitrate concentrations that are particularly evident around informal and formal settlements.

Mining adversely effects groundwater quality and quantity. Polluted mine drainage, caused by inadequate treatment and / or poor waste disposal from processing plants and waste heaps, is often very acidic (pH < 3) and can contain several heavy metals. Some areas of concern are the iron ore mines in the Thabazimbi region and the numerous platinum and chrome mines located between the towns of Brits and Rustenberg. The quantity of groundwater available may decline where mines pump large amounts of water from overlying dolomitic aquifers as part of their de-watering activities designed to ensure safe mining conditions. Over-abstraction and fluctuating groundwater levels can lead to subsidence and sinkhole development in dolomite compartments. Conversely, where mines have been closed and dewatering activities have stopped, rising groundwater levels can be polluted by chemicals that were previously used for ore treatment and processing. As a large proportion of the wetlands identified in the study area are dependent on groundwater, the impacts of groundwater contamination need to be properly identified and understood. Also, many human settlements rely heavily on groundwater from the central, western and northern parts of the WMA because surface water flows are so variable and unreliable.

Groundwater management guidelines must be followed to conserve vertical connectivity. In terms of lateral and vertical connectivity, implementation of the conservation plan will be fully dependent on the ability to achieve appropriate land management practices within these sub-quaternary catchments.

6. DESIGNING A CONSERVATION PORTFOLIO

The aim of this stage in the conservation planning process is to locate a set of catchments that will achieve explicit biodiversity targets for rivers, wetlands, fish species and special features. A selection protocol was developed with stakeholders, and used to select those sub-quaternary catchments and their associated river reaches that would best conserve the biodiversity of the region. This section outlines the selection protocol and the outputs of the conservation plan.

6.1 Selection protocol

The following sequential steps were used, in the order listed below, to select rivers and sub-quaternary catchments for inclusion in the Crocodile (West) and Marico conservation plan:

1) Use the 156 modelled sub-quaternary catchments (Figure 3) as the units of assessment and selection, or the planning units;

2) Use conservation planning decision support software to help with the derivation of an initial selection of sub-quaternary catchments, that takes into account the following multiple criteria:
   - o Complementarity and efficiency in achieving biodiversity targets for river types, wetlands and special features (fish species targets were included in Step 4);
   - o Building in longitudinal connectivity; and
   - o Where there are choices between sub-quaternary catchments with similar biodiversity components, in order of appearance below:
     - Choose sub-quaternary catchments containing terrestrial protected areas; and
     - Choose sub-quaternary catchments whose river systems are the most intact.
3) Add in additional sub-quaternary catchments needed for rehabilitation;
4) Add in additional sub-quaternary catchments flagged as containing important, viable populations of the six fish species of special concern;
5) Build in large-scale connectivity where it is still needed; and
6) Remove sub-quaternary catchments that containing short stretches of river reach which are considered too small to be viable, or where experts did not agree with the selection.

An outline of each of these steps is provided below.

Step 1: Defining the planning unit

See Section 4.1 and Figure 3 for a summary of why sub-quaternary catchments were used as planning units and how they were derived.

Step 2: Using decision support software for initial outputs

The process of using support software to aid decision-making on the most efficient way of meeting multiple criteria is frequently applied in conservation planning, since conservation plans attempt to achieve multiple biodiversity targets in an efficient manner, taking into account complementarity. However, to date, most conservation planning software has been developed for terrestrial ecosystems and has limited usefulness in assisting decision-making for inland water conservation plans. Recently, a marine conservation planning software system (MARXAN; Ball and Possingham, 2000) has been developed, which is more suited to inland water environments because it builds connectivity into its algorithm. This is now supported by a user-friendly front-face software, CLUZ (Smith, 2005), which interfaces with a geographic information system (ARCVIEW ver 3.2, ESRI, 1997). The MARXAN/CLUZ system was used to provide initial decision support in selecting catchments and rivers for inclusion into the conservation plan for this study.

MARXAN selects near-optimal solutions to achieving biodiversity targets by costing portfolios produced by simulated annealing algorithms, where effective portfolios have the lowest costs. The portfolio cost consists of three parts (see Information Box 2), which help to ensure that all the issues in Step 2 of the selection protocol are addressed, namely:

- Complementarity and efficiency in achieving biodiversity targets;
- Building in longitudinal connectivity; and

- Where there are choices between quaternary catchments with similar biodiversity components:
  - Choose sub-quaternary catchments containing terrestrial protected areas; and
  - Choose sub-quaternary catchments whose river systems are the most intact.

Using the cost parameters outlined in Information Box 2, MARXAN/CLUZ was run[2] to achieve targets for Level 3 river types, wetlands and special features.

Step 3: Adding additional quaternary catchments needed for rehabilitation

From the assessment of rehabilitation potential (Section 6.3), 25 sub-quaternary catchments were added to the plan. Specific rivers within these catchments (see Appendix F for details) need to be rehabilitated to an ecological integrity category of A or B in order to achieve the biodiversity targets for the Crocodile (West) and Marico conservation plan.

Step 4: Building in large-scale connectivity where it is still needed

Using MARXAN/CLUZ and the sub-quaternary catchments as planning units facilitated local connectivity within river systems. However, large-scale connectivity across the landscape is often not adequate, and needs to be accomplished manually. All the tributaries selected were checked to make sure that they connected to a main river. Eight additional sub-quaternary catchments were selected for maintaining upstream and downstream connectivity in the conservation design. Rivers playing a connecting role in these catchments are not necessarily required to be in an A or B ecological integrity category, instead they should rather be maintained in a condition that facilitates longitudinal connectivity.

Step 5: Investigating removal of marginal sub-quaternary catchments

Three sub-quaternary catchments were removed from the design:

- Sub-quaternary catchment 94 is very isolated from the rest of the conservation portfolio and it is not efficient to include this in terms of management effectiveness;
- Sub-quaternary catchment 71 was considered to be non-feasible since it was located in an urban centre; and
- Sub-quaternary catchment 81 was considered to be non-feasible since it is located in a platinum mining area.

2 Starting proportion 0.20, BLM 0.40, Clumping - default step function, Algorithm Used: Annealing and Iterative Improvement, No Heuristic used, Number of runs 1000, Number of iterations 5000000, Initial temperature set adaptively, Cooling factor set adaptively, Number of temperature decreases 10000

Information Box 2

MARXAN portfolio cost and system of costs applied for the Crocodile (West) and Marico conservation plan

The MARXAN portfolio cost consists of three parts, which are explained below in terms of the costs applied to the Crocodile (West) and Marico conservation plan.

1) The combined planning unit cost

Each planning unit is assigned a cost value. MARXAN calculates the combined cost of all the selected planning units (i.e. those in each portfolio). For example, the Crocodile (West) and Marico quaternary catchments were assigned a basic cost of 100, but those which had ≥ 10 % of their area under Type 1 protected areas[3] were discounted to 50. Where there are choices between two catchments with similar biodiversity components, this discounting encourages MARXAN to select those catchments where there is already some formal conservation activity.

2) The boundary cost

The boundary cost measures the amount of edge that selected planning units in a portfolio share with unselected units. This means that a portfolio containing one connected patch of units will have a lower boundary cost than a number of scattered, unconnected units. In the Crocodile (West) and Marico conservation plan, a boundary cost of 200 was assigned to boundaries between quaternary catchments that had rivers running through them into neighbouring catchments to encourage longitudinal connectivity. MARXAN then multiplies this value by the Boundary Length Modifier (BLM) constant, which is a user-defined number. Increasing this number increases the cost of having a fragmented portfolio. In the Crocodile (West) and Marico conservation plan, BLM=0.4.

3) Target penalty factor (or species penalty cost)

MARXAN calculates whether or not the target for each biodiversity feature can be met by a portfolio and includes a cost for any target that has not been met. In the conservation plan, the penalty cost was set at 100 000.

The total cost of a portfolio combines these three costs and is calculated as:

Combined planning unit cost + (boundary cost * BLM) + Combined species penalty factors

[3] Type 1 protected areas are statutory reserves as defined by Rouget *et al*. (2004), and include National Parks, Provincial Nature Reserves, Local Authority Nature Reserves and Forest Nature Reserves belonging to the Department of Water Affairs and Forestry.

6.2 Selected rivers and sub-quaternary catchments

This analysis produced a conservation portfolio (Figure 13), containing sub-quaternary catchments that are required for:

(i) Target achievement. Any river, wetland type or special feature selected should maintain its present ecological integrity category of A or B (Plate 4a-c);
(ii) Rehabilitation to an A or B ecological integrity category is required to help achieve biodiversity targets; and
(iii) Longitudinal connectivity of river reaches. Catchments need not be in an A or B ecological integrity category, but they need to be managed to facilitate connectivity, and should preferably not be in a lower class than a D category.

The conservation plan requires 38 (24 %) sub-quaternary catchments in the Crocodile (West) and Marico WMA to achieve the biodiversity targets for river types, wetlands, special features and fish species. This also translates to 25 % of the total river length in the water management area. A further 25 sub-quaternary catchments are required for rehabilitation to an A or B level of ecological integrity in order to achieve biodiversity targets. In order to maintain longitudinal connectivity, an additional 14 (9 %) sub-quaternary catchments in the area (translating to 6 % of the total river length in the area) are required. These catchments need not be in an A or B ecological integrity category, but will need to be maintained in a state that permits connectivity; ideally, these catchments should be no lower than a D category.

Generic management actions (Appendix G) which provide recommendations based on the level of anthropogenic impact that should be allowed in each of the selected sub-quaternary catchments have been identified. For example, sub-quaternary catchment 104 which consists of a number of special features, fish species such as Marico barb and mountain catfish, and diverse wetland types and stream-lever river types, should be managed for low impact activities such as grazing. Activities such as agriculture should be restricted or at the very least designated to those portions of the sub-quaternary catchment that are located furthest away from the biodiversity feature of concern while flow modifications should be avoided or minimised. Also, where road crossings are necessary, care must be taken to ensure that their impacts are minimized (e.g. bridges are better than causeways).

(a) Skeerpoort River, tributary to the lower Crocodile River.

(b) Koster River, tributary to the Elands River.

(c) Sundays River, tributary to the lower Crocodile River.

Plate 4a-c: Examples of rivers included in the Crocodile (West) and Marico conservation plan.

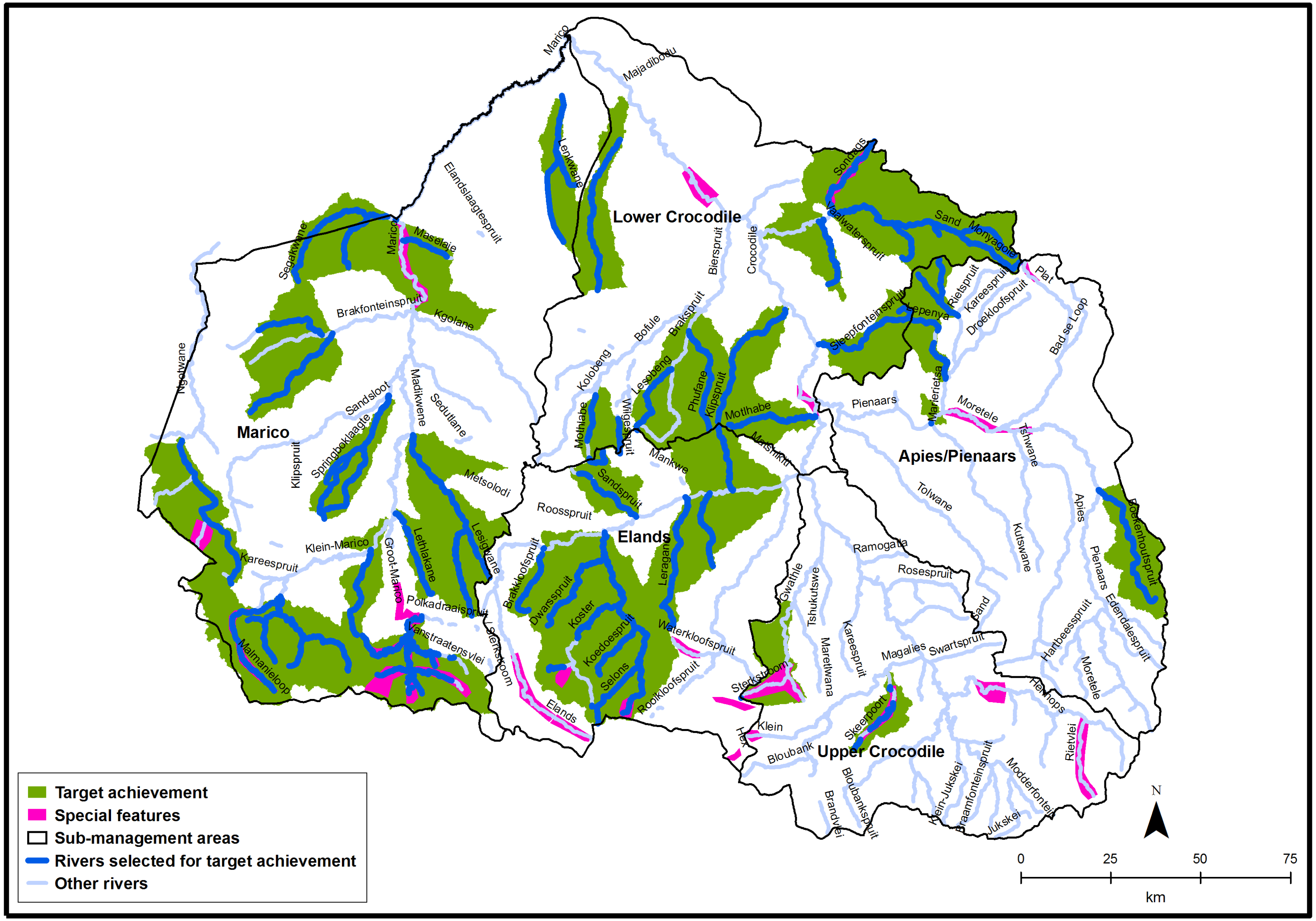

Figure 13: Rivers and their associated catchment segments selected for inclusion in the Crocodile (West) and Marico conservation plan.

6.3 Rehabilitation assessment

Stream-level river types that could not achieve their biodiversity targets in the Crocodile (West) and Marico study were assessed in terms of their potential for rehabilitation. The assessment was guided by various data layers and expert opinion. These data layers included, for example, special features, river integrity and the best attainable ecological management class (AEMC) compiled by Kleynhans (2000). However, the AEMC data are for main rivers only and are outdated. Hence, where the assessment results differed from the expert opinion, the expert opinion was preferred.

The consequences of not meeting certain targets in the study area were also examined. For example, not meeting conservation targets for a stream-level river type which is unique to the area (i.e. most of its national range is within the study area), implies that we have lost representation of this habitat in South Africa and possibly globally. Therefore, rehabilitation needs to be considered seriously. For those river types that occurred elsewhere in the country, a rapid (qualitative) assessment of landscape-level river types was undertaken to ascertain whether or not the target for this study area could be adopted by another area in the country. The assessment also included a preliminary analysis of river ecological integrity for the whole country using the updated Present Ecological Status (PES) data for main rivers (Nel *et al.*, in press) and the percentage natural vegetation as a proxy for tributary integrity.

There are 49 stream-level river types in the study that cannot achieve their targets. Most of these stream-level river types are unique to the study area (i.e. ≥ 90 % of their national ranges fall within the study area). The stream-level river types were assessed according to four categories (Figure 14 and Appendix F). The process of assessing rehabilitation feasibility in the study area also included C and D categories for maintaining longitudinal connectivity. This reflects the severely modified nature of certain parts of the catchment. The four categories that emerged are as follows:

(a) Rehabilitation for category AB is feasible

- This category will contribute towards achieving the 20 % biodiversity target and requires 23 stream-level river types that represent 25 sub-quaternary catchments.
- The 25 sub-quaternary catchments that contain good examples of these stream-level river types have been flagged for rehabilitation in the Crocodile (West) and Marico conservation plan (Section 6.2).

(b) Rehabilitation for category C is feasible

- This category represents 6 stream-level river types that can only be rehabilitated to a moderately modified condition.
- The nine sub-quaternary catchments containing these river types have been flagged for rehabilitation in the Crocodile (West) and Marico conservation plan (Section 6.2).

(c) Best conserved elsewhere

- The 12 stream-level river types identified in this category cannot be rehabilitated in the study area because of their seriously to critically modified condition. However, these stream-level river types can be better conserved elsewhere in the country.
- Areas which could adopt the biodiversity targets for these 12 stream-level river types in the Crocodile (West) and Marico catchment have been identified and are listed in Appendix F.

(d) Rehabilitation is not feasible and cannot be conserved elsewhere (unique to study area)

- Rehabilitation is not feasible for eight unique stream-level river types.
- These stream-level river types are only present in the Crocodile (West) and Marico WMA and are now critically endangered in the country (i.e. we have failed to meet the national conservation target).

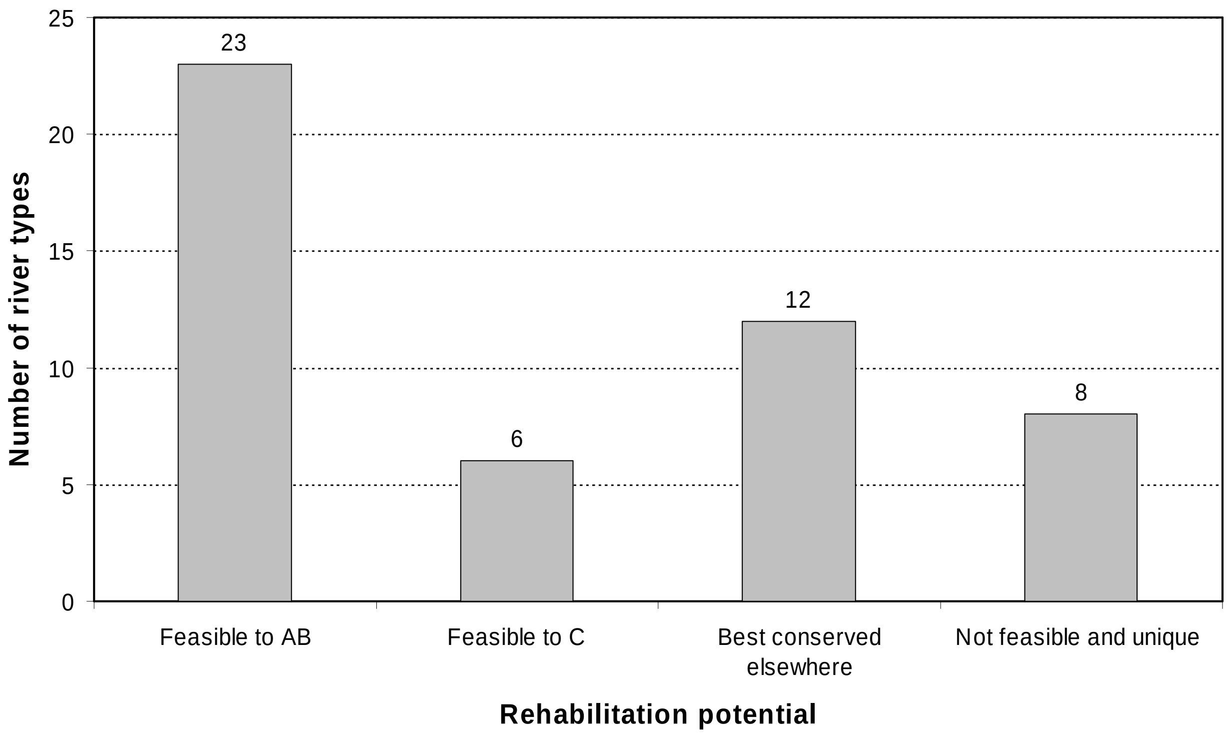

Figure 14: Rehabilitation assessment of stream-level river types that cannot meet their targets in the Crocodile (West) and Marico WMA.
Showing river types that (a) should be rehabilitated to an A or B ecological integrity; (b) should be rehabilitated to a C ecological integrity; (c) are best conserved elsewhere; and (d) are not feasible to rehabilitate in the catchment as they are unique to the study area. See text in Section 6.3 on the implications of each category.

6.4 Assessment of targets achieved

6.4.1 Stream-level river types

Biodiversity targets were calculated (20 % of the total length of each stream-level river type) and assessed for the 115 stream-level river types in the Crocodile (West) and Marico catchment. Overall, the proposed river selections and their associated sub-quaternary catchments would achieve the biodiversity targets of 66 (57 %) stream-level river types in the study area (Table 7). With feasible rehabilitation (Figure 15 and Appendix F), an additional 23 (or 20 %) stream-level river types will meet their biodiversity targets. Thus, with rehabilitation, 77 % of the stream-level river types can meet their targets in the Crocodile (West) and Marico WMA. The rehabilitation assessment results also indicated that biodiversity targets could not be met for the remaining 26 stream-level river types (23 % of the total), because rehabilitation of examples of these stream-level river types in the study area is not feasible.

Table 7: Achievement of biodiversity targets for stream-level river types in the planning domain. Numbers in brackets represent the % of total number of stream-level river types.

Targets met without rehabilitation	Targets achievable with rehabilitation	Cannot meet targets
66 (57)	23 (20)	26 (23)

6.4.2 Fish species

Six fish species of special concern were identified and biodiversity targets were set for these species (Section 3 and Figure 9a-f). Four species achieved their targets within the conservation design, namely:

- *Amphilius uranoscopus* (Skeerpoort and Groot Marico rivers);
- *Barbus motebensis* (Sterkstroom River);
- *Chiloglanis pretoriae* (Skeerpoort and Groot Marico rivers); and
- *Chetia flaviventris* (Skeerpoort and Groot Marico rivers).

All species, with the exception of *B. motebensis* which only occurs in the Lower Crocodile sub-management area, achieved their biodiversity targets in the Marico and Lower Crocodile sub-management areas). These four fish species are incorporated in the conservation plan through inclusion of four sub-quaternary catchments (numbers 80, 100, 104 and 110). However, these species are threatened by human activities that cause habitat loss and degradation, presence of in-stream dams (preventing migration of species), and over-abstraction of water. Two species could not meet their targets in A or B category rivers: *Clarias theodorae* and *Aplocheilicthys johnstoni. The f*easibility of conserving these species elsewhere in the country should be investigated, as both of these species are hardy and widespread.

6.4.3 Wetland types

Quantitative targets of 25 % of each of the six wetland types were set for the Crocodile (West) and Marico conservation plan (Section 5.3). These targets were achieved for all intact wetland types in the study area (Table 8 and Appendix G). Transformed wetland types did not contribute towards achieving the 25 % biodiversity targets. The conservation plan requires 37 (24 %) sub-quaternary catchments in the study area to achieve the biodiversity targets for wetland types.

Table 8: Achievement of biodiversity targets for wetland types.
"Area percentages" are calculated as the proportion required to the total number of intact wetlands. "Target" refers to wetlands required to meet biodiversity targets (i.e. that need to be maintained in an A or B ecological integrity category) and is calculated as 20 % of the total number of wetlands; and "Percentage of target achieved" refers to the number of wetlands that can meet their targets (100 % means achieved wetland target).

Wetland type	Number of intact wetlands	Percentage area for intact wetlands	Target for intact wetlands (number of wetlands)	Percentage of target achieved
Basement complex	1053	10	263	400
Carbonate terrains	131	16	33	397
Extrusives	605	8	151	401
Fractured meta-sedimentary rocks	1328	55	332	400
Karoo dykes and sills	11	<1	3	367
Unconsolidated deposits	389	10	97	401

6.4.4 Special features

All special features were included for in situ conservation; however, entire catchments were not all selected (Figure 15). This is because not all of these sub-quaternary catchments have their river reaches in ecological integrity categories A or B. These sub-quaternary catchments also represent catchments that are feasible for rehabilitation to a C category and catchments that should be maintained in a C or D category. The selected special feature sites represent habitat remnants of the once pristine conditions found in the Crocodile (West) and Marico catchment. Management options for these special features are given in Appendix G.

6.4.5 Free-flowing rivers

The target of conserving any stretch of river ≥ 100 km that is not yet dammed and meets the criteria set out in Section 3 cannot be achieved within this study. This is a reflection of the high utilization pressure and the discontinuous segments of rivers within this WMA. Connectivity is important for species drift or migration, as well as for habitats and refugia, and for the flux of nutrients, energy and organic matter (Gomi *et al*., 2002). Connectivity loss undoubtedly alters the productivity of river systems through disruptions in nutrient cycling, food webs, water quality and ecological processes (Wydoski and Wick, 2000).

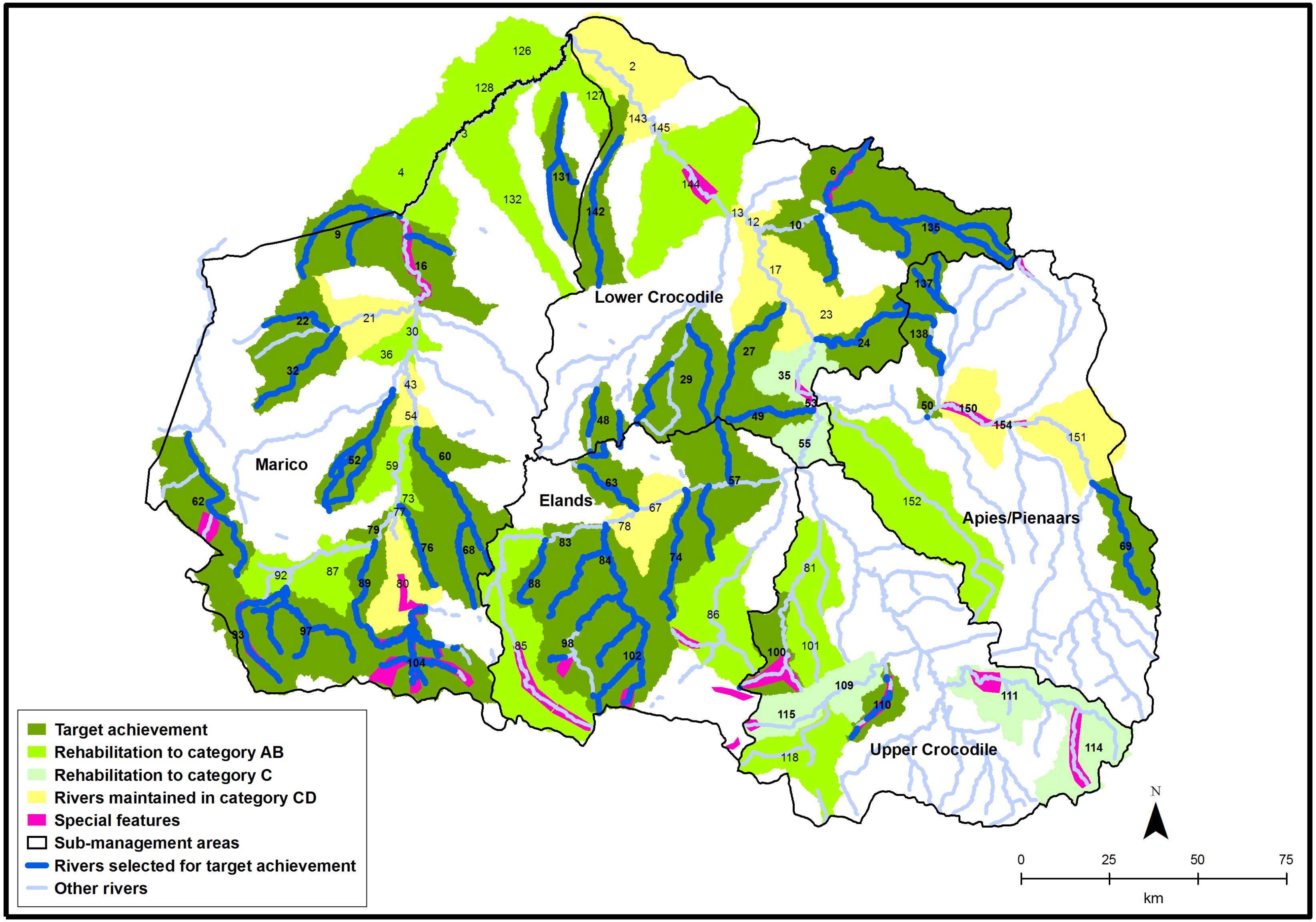

Figure 15: Selected sub-quaternary catchments for inclusion in the Crocodile (West) and Marico conservation plan.

7. COOPERATIVE CONSERVATION ACTION

Water affects every activity of human society and every level of life on Earth. In a similar way, biodiversity issues span several different sectors of natural resource governance and have a fundamental affect on the quality and sustainability of life on our planet. To implement a conservation plan for freshwater biodiversity, as presented in this report, the overlapping sectoral roles and responsibilities of both water and biodiversity must be understood and respected. Effective implementation requires that a number of organizations and agencies have the internal capacity to effectively contribute to this implementation challenge. A further condition for success is that their respective contributions must be properly coordinated and reflect a co-operative spirit in order to achieve optimal returns from the limited financial and human resources that are available for conservation actions.

Several organisations have a mandate or responsibility that directly relates to the implementation of the conservation plan for the Crocodile and Marico River Systems. These include organisations responsible for water resource management; environmental monitoring, reporting and management; biodiversity conservation; and land management. The following table presents the key responsible parties that should be involved in implementing this conservation plan, or that should at least incorporate this plan into their future planning, policy and strategy processes.

Table 9: Organisations with responsibility for implementing the conservation plan for freshwater ecosystems in the Crocodile (West) and Marico WMA, together with their mandates and main management instruments related to this responsibility. A glossary is provided below this table for the terms used.

Organisation	Mandate / responsibility	Management instrument(s)
National sphere of government		
Department of Water Affairs and Forestry (DWAF), and in particular its: • Policy and Regulations Branch, • Directorate: Resource Directed Measures, and • Crocodile (West) and Marico Catchment Management Agency (in the interim this operational responsibility is shared by the North West, Gauteng and Limpopo Regional Offices of DWAF)	Policy development and effective management of water resources, including to conserve, manage and develop the nation's water resources in a scientific and environmentally sustainable manner in order to meet the social and economic needs of South Africa, both now and in the future.	• National Water Act (Act No. 36 of 1998) • National Water Resource Strategy (2004) • Water Resource Classification System • Internal Strategic Perspectives (ISPs) • Catchment Management Strategy
Department of Environmental Affairs and Tourism (DEAT), and in particular its: • Biodiversity and Conservation Branch, and • South African National Biodiversity Institute (Directorate for Biodiversity Programmes, Policy and Planning).	Central policy-formulation and coordinating body for taking care of the environment, including the management and conservation of South Africa's biodiversity.	• National Environmental Management Act (Act No. 107 of 1998) • National Environmental Management: Protected Areas Act (Act No. 57 of 2003) • Mountain Catchment Areas Act (Act No. 63 of 1970) • National Environmental Management: Biodiversity Act (Act No. 10 of 2004) • National Biodiversity Strategy and Action Plan (2005) • National Biodiversity Framework • Bioregional plans
Department of Agriculture (DoA)	To lead and support sustainable agriculture and promote rural development.	• Conservation of Agricultural Resources Act (Act No. 43 of 1983)
South African National Parks (SANParks)	To manage a system of parks which represents the indigenous fauna, flora, landscapes and associated cultural heritage of the country.	• The Protected Areas Act (Act No. 57 of 2003)

Organisation	Mandate / responsibility	Management instrument(s)
Department of Minerals and Energy Affairs (DME)	To formulate and implement minerals and energy policy to ensure optimal use of these resources.	• Minerals and Petroleum Resources Development Act (Act No. 28 of 2002)
Provincial sphere of government		
North West Department of Agriculture, Conservation and Environment Gauteng Department of Agriculture, Conservation and Environment Limpopo Department of Economic Development, Environment and Tourism North West Parks and Tourism Board Limpopo Tourism and Parks	Creating a conducive climate for sustainable development in agriculture, environment and tourism development	• Bioregions and bioregional plans: Publish a plan for the management of biodiversity (for freshwater, terrestrial, marine and estuaries) within a bioregion.
Local sphere of government		
Central District Municipality (DC38) Bojanala District Municipality (DC37) Waterberg District Municipality (DC36) West Rand District Municipality (CBDC8) Metsweding District Municipality (CBDC2) City of Tshwane Metropolitan Municipality City of Johannesburg Metropolitan Municipality Ekurhuleni Metropolitan Municipality	The objectives of these local government municipalities are to: (a) provide democratic (both representative and participatory) and accountable government; (b) ensure the provision of services to communities in a sustainable manner (including a safe and healthy environment); and (c) promote social and economic development.	• Municipal Structures Act (Act No. 117 of 1998) • Municipal Systems Act (Act No. 32 of 2000) • Integrated Development Plans (IDP)

Glossary related to above table

- The **internal strategic perspective (ISP)** presents DWAF's strategic perspective on how it wishes to protect, allocate, use, develop, conserve, manage and control the water resources within a water management area until the Catchment Management Agency (CMA) has been established and is in a position to take over all or most of these functions.
- The Biodiversity Act provides for the development of **a National Biodiversity Framework** to guide all strategic development planning processes regarding the integration of biodiversity planning and monitoring in South Africa. Such a Framework will provide an integrated, coordinated and uniform approach to biodiversity management, identify priority areas for conservation and establish norms and standards to guide provincial and municipal environmental conservation plans.
- **National Spatial Biodiversity Assessment (NSBA)** provides a national context – and statutory biodiversity management plans for threatened ecosystems or species.
- **Bioregional Plans** involve systematic conservation planning and implementation of these plans, and must be based on systematic biodiversity/conservation plans. In the development of Bioregional Plans, provincial parks and tourism boards are responsible for formal conservation areas whereas provincial environmental affairs departments are responsible for areas outside these formal conservation areas. In the absence of a provincial parks and tourism board, the provincial environmental affairs department is responsible for conservation and non-conservation areas.
- Under the Municipal Systems Act, 2000 district municipalities are required to prepare five year **Integrated Development Plans (IDPs)** to guide and inform all aspects of planning, implementing and managing service provision in their areas. The plans must be compatible with national policy and legislation and be aligned with provincial strategies and plans (NWRS, 2004). In effect, IDPs are planning and strategic frameworks to help municipalities fulfil their developmental mandate.

Each of the organisations mentioned in the above table must have the internal capacity to understand, direct and incorporate freshwater biodiversity issues within their respective operational contexts. Freshwater biodiversity assessment and conservation planning represents a highly trans-disciplinary field of work, involving the combination and integration of a diverse and specialised cluster of skills. However, every participating organisation does not have to be self-sufficient in every one of these skills, but should be in a position to effectively cooperate within a larger network of stakeholders within which all the necessary skills are represented.

Cooperation, however, does not happen by itself. The management or governance processes related to freshwater biodiversity take place in a complex environment where decision-making is typically associated with low levels of certainty and potentially high levels of disagreement among stakeholders. In this environment, active and respectful negotiations are required to ensure that organisations, departments and agencies with different professional identities and mandates can successfully agree to, and achieve, shared objectives. This level of cooperation requires new mindsets and new practice models that necessitate change in how and where decisions are made as well as who is accountable for both the decisions and the outcomes of those decisions (Kinnaman and Bleich, 2004). One of the organisations listed in Table 9 will have to play a leadership role in facilitating the establishment and maintenance of a network of role players that share a passion and commitment for conserving a representative and functional sample of the freshwater biodiversity of this Water Management Area. If this level of leadership does not emerge naturally, a “river conservation steward” could be appointed to fulfil this cross-cutting function.

8. RECOMMENDATIONS AND CONCLUSIONS

The main objective of this report is to present a systematic conservation plan for the freshwater ecosystems of the Crocodile (West) and Marico WMA. The planning exercise was also conducted to direct future conservation and development opportunities; provide systematic and strategic guidance regarding the trade-offs between conservation and development, and provide a strategic perspective to decision makers at the scale of a WMA.

8.1 General findings

A significant part of this WMA falls within the main economic hub of the country, and the WMA as a whole has the largest population of any WMA in South Africa. Main rivers in this area are heavily regulated to cater for the high associated socio-economic needs for water. This is evidenced by the current ecological integrity of the rivers within the WMA, which show that only 13 % of main river length is currently intact (in a B ecological integrity category). A higher proportion (58 %) of the tributaries is currently intact, and thus these tributaries are likely to play a critical role in conserving the freshwater biodiversity of this area. However, many of the main rivers will still need to be managed to allow for sufficient connectivity between tributary and main river habitat.

Because of the poor condition of rivers in this area, the conservation plan requires almost all (71 %) of the rivers that are currently in an intact state to be conserved. Thus, a key management message is to prevent further degradation of any river that is currently intact (in an A or B category). A further priority would be to manage the rivers identified for the purposes of connectivity. Management plans at the level of quaternary catchments, should therefore be developed as a priority for:

- All rivers that are currently intact – to prevent further degradation; and
- All rivers identified as important for maintaining connectivity – to ascertain an appropriate desired state (C or D category), ecological reserve requirements and mitigation measures.

There are 115 river types in the Crocodile (West) and Marico study area. From these, 82 are unique or endemic river types (i.e. ≥ 90 % of their national ranges fall within the study area). However, the majority of these endemic river types are located in the south-eastern portion of the WMA, which coincides with the Greater Johannesburg and Tshwane metropolitan areas. Rivers in this area are already heavily impacted and it is therefore not surprising that targets cannot be met for a large proportion of these endemic river types. Since river types represent different biotopes for aquatic fauna and flora, losing endemic river types that cannot be conserved elsewhere in the country implies that nationally important biodiversity will be lost. Thus, rehabilitation options for endemic river types that cannot meet their targets should be seriously considered. There are 49 river types (30 of these river types are endemic) in the study that cannot achieve their targets. Therefore, this study included a rehabilitation assessment, and has shown that only 16 of the 30 endemic river types can be feasibly rehabilitated. This means that 14 endemic river types will not achieve their national targets. Given the present ecological condition of the rivers in the WMA, the conservation plan can achieve biodiversity targets for 66 (57 %) river types. Fifty-two of these river types are endemic or unique. With feasible rehabilitation, 68 endemic river types could meet their biodiversity targets. Overall, the proposed river selections and their associated sub-quaternary catchments and feasible rehabilitation would achieve the biodiversity targets for 89 (77 %) river types in the study area.

Conserving wetlands and groundwater to maintain functioning ecological systems is of key importance in this area. The proposed conservation plan, whilst giving consideration to representation of broadly defined wetland types, falls short of making explicit recommendations and selections for the role wetlands and groundwater play in maintain functioning ecological systems. Future studies should focus on wetlands and groundwater in this area.

8.2 Management actions

Specific management actions for each sub-quaternary catchment selected in the conservation plan have been provided in Appendix G. These are generic management actions, which provide recommendations based on the level of anthropogenic impact that should be allowed in the catchments. Low impact zones are areas where land use should be restricted to low impact activities such as grazing. The more deleterious impacts, such as cultivation, should be restricted or at the very least designated to portions of the catchment furthest away from the freshwater ecosystem of concern. Flow modification due to abstraction and artificial barriers such as weirs should be avoided or minimised wherever possible. Road crossings should be constructed in an environmentally sensitive manner. Medium impact zones are areas in which activities such as cultivation are acceptable. However, the ecological functionality of the freshwater ecosystem as well as its immediate surroundings (e.g. riparian zones) should be protected. An important part of this functionality is the flow regime and longitudinal connectivity in rivers, which should be in a state to allow natural mobility of aquatic species.

8.3 Data limitations

The development of the conservation plan relied on several data layers. Each of these data layers had its own limitations, and all of them can be improved given time and resources. The conservation plan should therefore not be seen as a static product but rather as a departure point from which further refinement can and should take place. Verification (so-called “ground truthing”) should be undertaken in selected catchments to confirm that they contain the biodiversity features for which they were selected; this information should be fed back into the planning process so that plans can be revised wherever appropriate. In fact, a strategy for the implementation of the conservation plan should cater for the dynamic interplay between ongoing monitoring, management actions and the formulation and testing of research questions.

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Appendix A:
Participants of stakeholder workshop

1st Stakeholder Workshop – Attendants Register

Date:	Tuesday 23 August 2005
Time:	09h00 – 15h30
Venue:	Kosmos Library, Hartbeespoort Dam
Objectives:	To formulate and discuss achievement of a freshwater conservation goal for this Water Management Area, and in particular: • How to describe or spatially depict the ecological variety (biodiversity) associated with aquatic ecosystems of this area; • How to rank ecosystems for conservation preference; • How to configure selected ecosystems into a Freshwater Conservation Design, to best achieve conservation persistence and social-ecological resilience; and • The setting of a quantitative target.

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Appendix B:
Participants of stakeholder workshop

2nd Stakeholder Workshop – Attendants Register

Date:	Thursday 30 March 2006
Time:	10h00 – 15h30
Venue:	Kosmos Library, Hartbeespoort Dam
Objectives:	To present various spatial data layers that were developed and the resulting options for conservation of freshwater biodiversity in the study area; • To decide on the best format for presenting, and means of diffusing, a freshwater conservation plan for the area of concern; and • To deliberate how the plan will be implemented, including issues of institutional roles and responsibilities.

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Appendix C: Stream-level river types in the study area

Stream-level river type comprises a number from 1 to 9 representing the hydrological Index class, followed by the name of the Level 2 ecoregion, and lastly a letter corresponding to the longitudinal zone (S = source zone, B = mountain headwaters/mountain streams, D = transitional zones/upper foothills, E = lower foothills, F = lowland rivers and R = rejuvenated zones). "Length" is the total length of each river type in the Crocodile (West) and Marico catchment; "Length AB" is the length of the river type in ecological integrity category A or B; "Target" is calculated as 20 % of "Length". River types where Rehabilitation = 1 cannot achieve the target in rivers with an ecological integrity category A or B, and need to be investigated for rehabilitation (see Appendix F for a detailed assessment of the rehabilitation potential for these river types).

Stream-level river type	Length (m)	Length AB (m)	Target (m)	Rehabilitation
1_11.01_B	4750.0	0.0	950.0	1
1_11.01_D	266741.5	0.0	53348.3	1
1_11.01_E	36417.5	0.0	7283.5	1
1_11.01_S	2050.3	0.0	410.1	1
1_7.04_D	74684.6	9793.4	14936.9	1
1_7.04_E	58683.0	24.6	11736.6	1
1_7.05_B	7539.6	31.3	1507.9	1
1_7.05_D	135521.0	12042.4	27104.2	1
1_7.05_E	102571.6	0.0	20514.3	1
1_7.06_B	2057.9	0.0	411.6	1
1_7.06_D	117298.3	16011.9	23459.7	1
1_7.06_E	59669.4	0.0	11933.9	1
1_7.06_R	18963.1	0.0	3792.6	1
1_8.05_B	5692.5	0.0	1138.5	1
1_8.05_D	111703.5	5984.2	22340.7	1
1_8.05_E	377215.8	22602.1	75443.2	1
1_8.05_F	6457.6	0.0	1291.5	1
1_9.03_B	1413.0	0.0	282.6	1
1_9.03_B	80290.0	39030.2	16058.0	0
1_9.03_E	52862.9	6129.7	10572.6	1
2_1.03_D	13790.4	8339.7	2758.1	0
2_1.03_E	7034.9	4588.3	1407.0	0
2_11.09_B	3241.8	3241.8	648.4	0
2_11.09_D	7356.0	7356.0	1471.2	0
2_7.03_B	12616.2	6384.2	2523.2	0
2_7.03_D	91804.3	45324.7	18360.9	0
2_7.03_E	9827.6	6224.9	1965.5	0
2_7.03_R	16457.3	0.0	3291.5	1
2_7.04_B	1112.2	1112.2	222.4	0
2_7.04_D	137570.4	110454.6	27514.1	0
2_7.04_E	61250.2	41809.7	12250.0	0
2_7.04_R	49251.2	20272.9	9850.2	0
2_7.04_S	4090.2	2027.6	818.0	0
2_8.01_B	1368.4	0.0	273.7	1

Stream-level river type	Length (m)	Length AB (m)	Target (m)	Rehabilitation
2_8.01_D	24779.1	0.0	4955.8	1
2_8.01_E	54788.9	0.0	10957.8	1
2_8.05_B	1997.0	1997.0	399.4	0
2_8.05_D	135029.6	90947.1	27005.9	0
2_8.05_E	96227.3	24912.6	19245.5	0
2_8.05_F	30897.5	0.0	6179.5	1
2_8.05_S	874.2	874.2	174.8	0
2_8.06_D	32360.0	27555.0	6472.0	0
2_8.06_E	43796.2	25767.7	8759.2	0
2_8.06_F	49291.6	0.0	9858.3	1
3_1.03_D	30332.9	29344.4	6066.6	0
3_1.03_E	45973.0	42397.5	9194.6	0
3_1.03_F	21543.4	0.0	4308.7	1
3_1.04_E	8368.9	8368.9	1673.8	0
3_1.04_F	56987.8	0.0	11397.6	1
3_11.01_B	962.3	962.3	192.5	0
3_11.01_D	22503.7	21650.3	4500.7	0
3_11.01_E	8885.5	8885.5	1777.1	0
3_11.09_E	21042.5	21042.5	4208.5	0
3_7.03_B	2900.2	2900.2	580.0	0
3_7.03_D	51301.6	51301.6	10260.3	0
3_7.03_E	4399.4	0.0	879.9	1
3_7.03_F	3920.1	0.0	784.0	1
3_7.03_R	10397.9	0.0	2079.6	1
3_7.04_B	1040.2	1040.2	208.0	0
3_7.04_D	100783.1	93704.5	20156.6	0
3_7.04_E	5358.2	3631.0	1071.6	0
3_8.05_B	1796.7	0.0	359.3	1
3_8.05_D	56148.3	39532.3	11229.7	0
3_8.05_E	69913.5	0.0	13982.7	1
3_8.06_D	15778.2	15778.2	3155.6	0
3_8.06_E	34207.0	20645.7	6841.4	0
3_8.06_F	53250.7	0.0	10650.1	1
4_11.01_B	2386.4	232.5	477.3	1
4_11.01_D	24147.8	0.0	4829.6	1
4_7.04_B	622.8	622.8	124.6	0
4_7.04_D	89872.9	17956.3	17974.6	0
4_7.04_R	12794.0	0.0	2558.8	1
4_8.06_D	46400.9	44832.6	9280.2	0
4_8.06_E	100120.7	93228.6	20024.1	0
4_8.06_F	38287.0	8321.8	7657.4	0
5_1.03_D	6314.9	4895.7	1263.0	0
5_1.03_E	9193.2	8670.2	1838.6	0
5_1.03_F	17542.1	83.5	3508.4	1
5_11.09_B	478.0	478.0	95.6	0
5_11.09_D	15881.1	12578.7	3176.2	0
5_11.09_R	3293.6	0.0	658.7	1
5_7.01_D	10819.7	10819.7	2163.9	0
5_7.01_E	31896.2	10045.5	6379.2	0
5_7.01_F	25685.0	0.0	5137.0	1
5_7.04_B	5949.3	5206.6	1189.9	0
5_7.04_D	234476.1	173366.4	46895.2	0

Stream-level river type	Length (m)	Length AB (m)	Target (m)	Rehabilitation
5_7.04_E	82340.9	16405.5	16468.2	0
5_7.04_R	14721.3	0.0	2944.3	1
5_7.05_B	6117.2	1076.4	1223.4	1
5_7.05_D	27171.8	4130.2	5434.4	1
5_7.05_E	38343.7	14050.8	7668.7	0
5_7.05_R	2742.9	0.0	548.6	1
5_8.05_D	64777.0	52327.5	12955.4	0
5_8.05_E	174086.8	52053.8	34817.4	0
5_8.06_D	39701.8	28692.5	7940.4	0
5_8.06_E	141358.7	85295.0	28271.7	0
5_8.06_F	14031.5	0.0	2806.3	1
6_7.04_B	8957.9	6089.5	1791.6	0
6_7.04_D	23426.7	11155.6	4685.3	0
6_8.06_D	57454.3	21681.1	11490.9	0
6_8.06_E	191229.6	54588.7	38245.9	0
7_1.03_E	60418.1	60418.1	12083.6	0
7_1.03_F	27824.8	0.0	5565.0	1
7_1.04_E	76702.7	74444.4	15340.5	0
7_1.04_F	85739.7	0.0	17147.9	1
7_7.01_D	33796.9	23172.1	6759.4	0
7_7.01_E	161200.2	23770.4	32240.0	1
7_7.01_F	1486.7	0.0	297.3	1
7_7.04_B	13882.2	5842.9	2776.4	0
7_7.04_D	72532.2	36563.8	14506.4	0
7_7.04_E	47610.2	30384.9	9522.0	0
7_7.04_S	3845.3	1585.6	769.1	0
7_8.06_D	94584.7	74260.0	18916.9	0
7_8.06_E	265362.7	91289.4	53072.5	0
7_8.06_F	15437.8	0.0	3087.6	1

Appendix D: Description of the Crocodile (West) and Marico WMA special features

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Special feature number	Special feature description and rationale
Marico				
Ngotwane River	A10A A10B	62	1	The Dinokana Springs is a dolomitic eye. The water quality is good; there is high habitat diversity (pristine habitat) and it is considered by the North West Province as a high priority area.
Molemane dolomitic eye (source zone) Molemane se loop (wetland area)	A31C A31D	93	26 27	Molemane dolomitic eye is an unusally unique area both as a source zone and for wetlands. The source zone contains unique species with high taxon richness and is important as a species refuge area. This portion of the Molemane dolomitic eye contains important wetland areas. Groundwater is important; water disappears underground in places and emerges again. The area is dolomitic and characterised by peatlands and floodplains.
Kaaloog se Loop / Grootfontein Rietspruit Ribbokfontein se Loop Draaifontein Vanstraatensvlei (wetlands)	A31A	104	20 21 22 23 24	Kaaloog se Loop (in the vicinity of Grootfontein) is an important dolomitic eye and the area has high habitat diversity. The site is a fairly pristine dolomitic eye with high habitat diversity. The site contains important wetland areas and has high habitat diversity, including gorges. There is a slate mine upstream which threatens the site. The site has high habitat and species diversity. This includes diversity of invertebrate families, isolated fish populations (*Labeobarbus marequensis*) and high bird diversity. The site has high habitat diversity, including various gorges and isolated species populations. It is also fairly pristine but alien vegetation is becoming a problem.
Mainstem of Groot	A31A	80	25	The site is a fairly pristine area and has high species and habitat diversity. It is

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Special feature number	Special feature description and rationale
Marico River	A31B			important for wetland areas, species refugia and as an ecotone.
Mainstem of Groot Marico River, tributaries and Wetlands (rivers in the Madikwe Nature Reserve)	A32D	16	28	Rivers in the Madikwe Nature Reserve have diverse habitats and good riparian vegetation. Hippopotami play an important role in regulating the riparian vegetation. The area is however highly threatened by human activities.
Elands				
Source area of Elands River (Highveld) Source area of Elands River (Bankenveld)	A22A	85	8 9	The upper Elands River is a source area in the Highveld ecoregion. The site contains seepage areas, wetlands and unique pans, as well as diverse habitats. This site comprises the upper Elands River in the Western Bankenveld ecoregion. It contains gorges and very good habitat with high species diversity (e.g. *Barbus motebensis)*.
Unnamed tributary of the Koster River Unnamed tributary of Selons River, Koedoespruit	A22B A22C	98 102	10 11	The site contains an isolated population of *Barbus motebensis* and has high habitat diversity that includes pools, rapids and riffles. The water quality is also very good. This site is a transition zone from the Western Bankenveld to the Highveld ecoregions and contains *Barbus motebensis*.
Waterkloofspruit (tributary of Hex) and proposed RAMSAR wetlands	A22H	86	14	The site is a wetland area in the Magaliesburg Protected Natural Environment (MPNE), to be declared a Ramsar site. It contains high habitat diversity (e.g. riffles, gorge, etc.).
Unnamed tributary of upper Hex River Upper Hex River	A22G A22G	112	12 13	The site contains a population of *Barbus motebensis*. The site is defined by the upper reaches of the Hex River. It contains important species such as *Barbus motebensis*, wetlands and is thought to be a groundwater seepage area after rainfall events (this needs to be investigated further).
LowerCrocodile				
Crocodile River below confluence of Crocodile and Pienaars rivers	A24A	35 49 55	17	The site starts below confluence of the Crocodile and Pienaars rivers. It is an important area for birds and riparian vegetation For example it contains unique examples of *Acacia galpinii* (Monkey thorn) riparian forests**.**

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Special feature number	Special feature description and rationale
(riparian forests and wetlands)				
Crocodile River (riparian forests)	A24J	144	19	These reaches of the Crocodile River form an ecotone between the Western Bankenveld and Limpopo Plain ecoregions. The *Acacia galpinii* (Monkey thorn) riparian forest is unique.
Apies/Pienaars				
Floodplain of Pienaars River	A23J	150	16	The site is upstream of Klipvoor Dam. The floodplain area is one of very few lowland rivers in the study area; it contains wetland meanders and is an important refuge area for water birds.
Upper Crocodile				
Upper Sterkstroom River	A21K	100	7	The site consists of the upper reaches of the Sterkstroom River upstream of Buffelspoort. It contains unique species; fairly pristine and diverse habitat and has excellent water quality.
Maloney's Eye	A21F	115	5	This site contains species naturally intolerant to changes in flow; has high invertebrate species diversity; contains unique habitats and two unique fish species.
Skeerpoort and Wetlands	A21G	110	6	This is a sensitive system that is partly contained within a nature reserve. The river has a very high diversity of habitat types (including a waterfall); contains species naturally intolerant to changes in flow; is a species refuge and has high species diversity.
Sesmylspruit	A21A	114	3	It contains a population of *Labeobarbus polylepis*.
Hennops RIver	A21B	111	4	The site has extensive natural habitat and falls in conservation areas. There are rare and endangered terrestrial plants, and species taxon richness associated with the Hennops River is high.

Appendix E: SASS thresholds for guiding management decisions in the Crocodile (West) and Marico study area

Family level data were used to set SASS5 (South African Scoring System Version 5) thresholds for guiding decisions on the state of rivers in the Crocodile (West) and Marico catchment. However, only those taxa that occurred in sufficient numbers frequently enough, and that were indicative of certain biotopes or environmental conditions, were selected. This means that rivers can be managed according to different states of health using SASS indicators as applied in the River Health Programme. SASS thresholds are provided for each Level 1 and 2 ecoregion, based on an assessment of main rivers (recording also the river name on which the assessment was based). These thresholds also apply to any rivers falling into the same ecoregions. Applying these thresholds enables managers to determine what the SASS score needs to be to maintain the river in a particular condition or to improve its condition. Dropping below these thresholds will mean that the condition of the river will slowly degrade. Managers are thus provided with an extra tool that can be applied to meet recommendations regarding rivers that are required: (i) to be in an AB integrity category for meeting biodiversity targets, and (ii) in a state for facilitating connectivity (preferably no lower than a D integrity category).

Method

The WMA was divided into regions taking account of ecoregions (Levels 1 and 2), geomorphological zonation as well as Present Ecological State (PES). The PES was determined by running the Macro Invertebrate Response Assessment Index (MIRAI) for each of the groupings. Targets were set for each of these groupings for the near natural condition (A) as well as for the PES (A/B – C). Targets were set for SASS score; No of Taxa; ASPT and frequency of occurrence of selected taxa. The range of MIRAI values are also given for the total. The 95th percentile values were used to give an indication of the PES A categories and the 75th percentile values for the B/C categories where enough data were available. River sections with a PES of lower than C were not considered.

An example of the above can be seen for the stones biotope in the Sterkstroom River, Ecoregion 7.04 Western Bankenveld (see page 75). The results for this example imply that for SASS scores of 24 to 174, the number of taxa should be between 5 and 27, with ASPT scores ranging between 3 and 7.25. River reaches should be maintained in an A integrity category for SASS scores of >120 while scores between 75 and 120 should accompany river reaches in integrity categories B or C. The benthic macroinvertebrate families Heptageniidae and Elmidae in an A category river reach should be >50 % present while the number of taxa should be >20. Similarly, the ASPT scores in an A category river reach should be > 6.5.

The following taxa were used to indicate conditions in the stones biotope in the Sterkstroom River (values in brackets indicate SASS5 scoring weights):

- C categories: Ancylidae (6); Elmidae (8); Heptageniidae (13); Libellulidae (4); Perlidae (12); Psephenidae (10) and Trichorythidae (9).
- A-B/C categories: Chlorocyphidae (10); >2 spp Hydropsychidae (12); Philopotamidae (10) and Turbellaria (3)
- A-B categories: Athericidae (10).
- A, A/B Categories: Blepharoceridae (15) but only in the colder areas near the higher elevation source areas of the Western Bankenveld.

The following taxa were used to indicate conditions in the vegetation biotope in the Sterkstroom River (values in brackets indicate SASS5 scoring weights):

- A-C categories: Atyidae (8); Coenagrionidae (4) and Hydrophilidae (5).
- A-B/C categories: Belastomatidae (3); Dytiscidae (5); Helodidae (12); Lestidae (8) and Lymnaeidae (3).
- A, A/B Categories: Chlorolestidae (8).

The following taxa were used to indicate conditions in the Gravel, sand and mud biotope in the Sterkstroom River (values in brackets indicate SASS5 scoring weights):

- A-C categories: Caenidae (6); Gomphidae (6) and Tabanidae (5).
- A-B/C Categories: Corbiculidae (5).
- A, A/B Categories: Polymitarcyidae (10) and Sphaeridae (3).

The following taxa were used to indicate general conditions in the Sterkstroom River (values in brackets indicate SASS5 scoring weights):

- A-C categories: Aeshnidae (8), Dixidae (10); Hydracarina (8); Leptoceridae (6); Leptophlebiidae (9); Simuliidae (5) and Tipulidae (5).
- A, A/B: Platycnemidae.

SASS thresholds

Page

Sterkstroom (Marico)

Ecoregion: Western Bankenveld 7.04; PES: B/C; Limiting factor: Poplar leaves

A. STONES

SASS: (24 - 174)	**No of Taxa:** (5 - 27)	**ASPT:** (3 - 7.25)	***Families***
BC>75 A>120	BC>15 A>20	BC>6 A>6.5	

Names	**BC**	**A**
Heptageniidae	Present	>50%
Elmidae	Present	>50%
Chlorocyphidae	>10%	>50%

B. VEGETATION

SASS: (22 - 113)	**No of Taxa:** (6 - 20)	**ASPT:** (3.14 - 5.8)	***Families***
BC>80 A>95	>16 >18	BC>5 A>5.5	

Names	**BC**	**A**
Lestidae	Present	>10%
Atyidae	Present	>60%

C. GRAVEL, SAND and MUD

SASS: (17 - 91)	**No of Taxa:** (4 - 16)	**ASPT:** (3.17 - 5.77)	***Families***
BC>65 A>80	BC>13 A>15	BC>5 A>5.5	

Names	**BC**	**A**
Gomphidae	>70%	>60%

D. TOTAL

SASS: (44 - 203)	**No of Taxa:** (11 - 34)	**ASPT:** (3.36 - 6.19)	***Families***
BC>130 A>165	BC>23 A>30	BC<5.5 A>6	

Names	**BC**	**A**
Dixidae	>10%	>20%
Leptoceridae	>30%	>40%
>2spp Baetidae	>20%	>70%
>2spp Hydropsychidae	>20%	>70%
MIRAI>75		

Ecoregion: Limpopo Plain 1.03; PES: B/C

A. STONES

SASS: (30 - 104)	**No of Taxa:** (6 - 21)	**ASPT:** (4.11 - 6.75)	***Families***
BC>80 A>90	BC>17 A>19	BC>5 A>6	

Names	BC	A
Elmidae	>25	>50
Trichorythidae	>12.2	>30
Chlorocyphidae	>12.5	>40
Libellulidae	>25	>30
Ancylidae	>62.5	>70

B. VEGETATION

SASS: (44 - 124)	**No of Taxa:** (8 - 24)	**ASPT:** (4.21 - 5.77)	***Families***
BC>75 A>85	BC>15 A>18	BC>5 A>5.5	

Names	BC	A
Atyidae	>62.5	>90
Coenagrionidae	>37.5	>90
Belastomatidae	>62.5	>70
Lynaeidae	>0	>10
Dytiscidae	>75	>80
Lestidae	>25	>30

C. GRAVEL, SAND and MUD

SASS: (3 - 103)	**No of Taxa:** (1 - 21)	**ASPT:** (3 - 7.5)	***Families***
BC>80 A>95	BC>18 A>20	BC>5 A>6	

Names	BC	A
Gomphidae	>57%	>80%
Corbiculidae	>14	>50

D. TOTAL

SASS: (70 - 144)	**No of Taxa:** (14 - 32)	**ASPT:** (4.3 - 6)	***Families***
BC>125 A>140	BC>25 A>30	BC<5 A>5.5	

Names	BC	A
Potamonautidae	>87.5	>90
Simuliidae	>75	>90
Baetidae >2 spp		>75
Baetidae 2 spp	>62.5	
Hydropsychidae >2 spp		>20
Hydropsychidae 1 sp	>12.5	
Helodidae	>12.5	>20
Philopotamidae	>12.5	>40
Leptoceridae	>25	>40
Leptophlebiidae	>12.5	>50
Aeshnidae	>62.5	>70
MIRAI>75		

Skeerpoort and Maloney's Eye

Ecoregion: Western Bankenveld 7.06; PES: A

A. STONES				
SASS: (122 - 262) A>170	**No of Taxa:** (18 - 41) A>24	**ASPT:** (6.39 - 7.33) A>6.7	***Families***	
			Names	**A**
			Athericidae	>50
			Elmidae	>75
			Trichorythidae	>75
			Psephenidae	>50
			Chlorocyphidae	>70
			Perlidae	>50
			>2 spp Hydropsychidae	>70
			Ancylidae	>50

B. VEGETATION				
SASS: (84 - 184) A>100	**No of Taxa:** (15 - 32) A>18	**ASPT:** (5.6 - 6.8) A>6	***Families***	
			Names	**A**
			Coenagrionidae	>60
			Belastomatidae	>60
			Lynaeidae	>50
			Planorbidae	>70
			Hydrophilidae	>50

C. GRAVEL, SAND and MUD				
SASS: (33 - 196) A>100	**No of Taxa:** (8 - 31) A>20	**ASPT:** (4.1 - 6.3) A>5.5	***Families***	
			Names	**A**
			Gomphidae	>75
			Corbiculidae	>60
			Caenidae	>75
			Tabanidae	>70

D. TOTAL				
SASS: (188 - 296) A>220	**No of Taxa:** (28 - 49) A>35	**ASPT:** (6.02 - 6.7) A>6	***Families***	
			Names	**A**
			Heptageniidae	>50
			Simuliidae	>75
			Baetidae >2 spp	>70
			Porifera P	>50
			Philopotamidae	>75
			Leptoceridae	>50
			Leptophlebiidae	>75
			Aeshnidae	>75
			Libellulidae	>75
			Hydracarina	>75
			Dixidae	>50
			MIRAI >92	

Upper Groot Marico (VS1, MA5, KL2, BK1)

Ecoregion: Western Bankenveld 7.04 (S, C); PES: A

A. STONES

SASS: (50 - 224) A>170	**No of Taxa:** (9 - 31) A>28	**ASPT:** (4.5 - 7.3) A>.7	***Families***	
			Names	**A**
			Athericidae	>30
			Elmidae	>40
			Chlorocyphidae	>65
			>2 spp Hydropsychidae	>40
			Ancylidae	>50

B. VEGETATION

SASS: (33 - 143) A>110	**No of Taxa:** (7 - 24) A>20	**ASPT:** (4.6 - 6.1) A>6	***Families***	
			Names	**A**
			Coenagrionidae	>70
			Planorbidae	>40
			Lestidae	>15
			Atyidae	>15

C. GRAVEL, SAND and MUD

SASS: (18 - 162) A>100	**No of Taxa:** (5 - 26) A>20	**ASPT:** (3.6 - 6.6) A>6	***Families***	
			Names	**A**
			Gomphidae	>90
			Caenidae	>75
			Tabanidae	>80

D. TOTAL

SASS: (96 - 279) A>220	**No of Taxa:** (19 - 41) A>35	**ASPT:** (4.4 - 6.8) A>6.5	***Families***	
			Names	**A**
			Heptageniidae	>20
			Simuliidae	>70
			Baetidae >2 spp	>30
			Leptoceridae	>50
			Leptophlebiidae	>60
			Aeshnidae	>75
			Libellulidae	>70
			Hydracarina	>60
			Dixidae	>20
			Trichorythidae	>40
			Chlorocyphidae	>60
			Psephenidae	>20
			MIRAI >92	

Upper Groot Marico (MA16, MA15, KL1, RL1)

Ecoregion: Western Bankenveld 7.04 (D); PES: AB

A. STONES

SASS: (37 - 206)	No of Taxa: (6 - 30)	ASPT: (4.9 - 7.5)	Families
AB>145 A>170	AB>21 A>25	AB>6.5 A>7	

Names	AB	A
Athericidae	>40	>50
Elmidae	>40	>50
>2 spp Hydropsychidae	>20	>30
Ancylidae	>60	>70
Turbelaria	>50	>70
Philopotamidae	>45	>55
Tricorythidae	>20	>30

B. VEGETATION

SASS: (33 - 128)	No of Taxa: (7- 23)	ASPT: (4 - 6.8)	Families
AB>100 A>120	AB>18 A>20	AB>6 A>6.5	

Names	AB	A
Coenagrionidae	>70	>80
Lymnaeidae	>30	>40
Helodidae	>25	>30

C. GRAVEL, SAND and MUD

SASS: (25 - 149)	No of Taxa: (5 - 26)	ASPT: (4 - 6.8)	Families
AB>95 A>100	AB>17 A>20	AB>6 A>6.5	

Names	AB	A
Gomphidae	>80	>90
Caenidae	>80	>90
Tabanidae	>70	>80

D. TOTAL

SASS: (66 - 262)	No of Taxa: (13 - 41)	ASPT: (4-4 - 7.2)	Families
AB>190 A>220	AB>30 A>35	AB>6.5 A>7	

Names	AB	A
Simuliidae	>80	>90
Baetidae >2 spp	>60	>70
Leptoceridae	>60	>70
Leptophlebiidae	>75	>80
Aeshnidae	>75	>85
Libellulidae	>80	>90
Hydracarina	>50	>60
Dixidae	>35	>45
Chlorocyphidae	>50	>60
Perlidae	P	>10
Tipulidae	>30	>40
MIRAI >88		

Middle Groot Marico (MA2, GM1, GM2, GM3, GM4)

Ecoregion: Western Bankenveld 7.04 (E); PES: A

A. STONES

SASS: (55 - 227)	**No of Taxa:** (7 - 33)	**ASPT:** (5.56 - 7.86)	***Families***
A>180	A>27	A>7.5	

Names	A
Elmidae	>70
>2 spp Hydropsychidae	>25
Ancylidae	>70
Tricorythidae	>65
Chlorocyphidae	>90
Heptageniidae	>80
Perlidae	>60
Psephenidae	>65
Blepharoceridae	P
Porifera	>30

B. VEGETATION

SASS: (33 - 151)	A>120	**TAXA:** (7 - 27)	***Families***
A>20	ASPT: (4.4-7.1)	A>6.5	

Names	A
Coenagrionidae	>90
Lymnaeidae	>30
Atyidae	>80
Pleidae	>25
Hydrophilidae	>40

C. GRAVEL, SAND and MUD

SASS: (53 - 198)	**No of Taxa:** (11 - 30)	**ASPT:** (4.6 - 7.9)	***Families***
A>150	A>25	A>6.5	

Names	A
Gomphidae	>85
Caenidae	>90
Tabanidae	>70
Corbiculidae	>60
Sphaeridae	>35
Polymitarcyidae	>10

D. TOTAL

SASS: (115 - 285)	**No of Taxa:** (22 - 43)	**ASPT:** (5.2 - 6.95)	***Families***
A>230	A>38	A>6.5	

Names	A
Simuliidae	>80
Baetidae >2 spp	>45
Leptoceridae	>40
Leptophlebiidae	>95
Aeshnidae	>50
Libellulidae	>80
Hydracarina	>40
Dixidae	>10
Tipulidae	>20
Helodidae	P
Athericidae	>40
Philopotamidae	>65
Platycnemidae	>20
Ceratopogonidae	>80
MIRAI >92	

Ngotwane (NG1, NG2)

Ecoregion: Western Bankenveld 7.04 (C, D); PES: AB

A. STONES

SASS: (58 - 202)		**No of Taxa:** (12 - 32)		**ASPT:** (4.8 - 6.3)		***Families***		
AB>130	A>180	AB>22	A>27	AB>6	A>6.5			
						Names	**AB**	**A**
						>2 spp Hydropsychidae	>50	>60
						Ancylidae	>40	>50
						Tricorythidae	>50	>60
						Psephenidae	>40	>50

B. VEGETATION

SASS: (62 - 101)		**No of Taxa:** (12 - 17)		**ASPT:** (5.2 - 5.9)		***Families***		
AB>85	A>95	AB>15	A>17	AB>5.5	A>6			
						Names	**AB**	**A**
						Coenagrionidae	>80	>90
						Atyidae	>80	>90
						Chlorolestidae	>60	>70

C. GRAVEL, SAND and MUD

SASS: (51 - 84)		**Taxa:** (11 - 16)		**ASPT:** (4.7 - 5.3)		***Families***		
AB>70	A>80	AB>13	A>15	AB>5	A>5.3			
						Names	**AB**	**A**
						Gomphidae	>80	>90
						Caenidae	>80	>90

D. TOTAL

SASS: (84 - 248)		**Taxa:** (18 - 40)		**ASPT:** (4.7 - 6.2)		***Families***		
AB>170	A>200	AB>30	A>35	AB>5.5	A>6			
						Names	**AB**	**A**
						Simuliidae	>80	>90
						Baetidae >2 spp	>40	>50
						Leptoceridae	>30	>40
						Leptophlebiidae	>50	>60
						Aeshnidae	>50	>60
						Libellulidae	>60	>80
						Tipulidae	>30	>40
						Athericidae	>20	>30
						Chlorocyphidae	>50	>60
						MIRAI >88		

Upper Elands (El1, El2, EL3, EL4, EL5, EL6)

Ecoregion: Western Bankenveld 7.04 (D, E); PES: B/C

A. STONES

SASS: (42 - 101) BC>95 A>120	**No of Taxa:** (8 - 17) BC>17 A>20	**ASPT:** (3.8 - 6.3) BC>6 A>6.5	***Families***		
			Names	**BC**	**A**
			Heptageniidae	>30	>50%
			Hydropsychidae >2spp	>30	>50%
			Turbellaria	>50	>60%

B. VEGETATION

SASS: (50 - 90) BC>90 A>100	**No of Taxa:** (12 - 18) >16 >20	**ASPT:** (4.2 - 5.7) BC>5.5 A>6	***Families***		
			Names	**BC**	**A**
			Coenagrionidae	>90	>95%
			Atyidae	>80	>90%

C. GRAVEL, SAND and MUD

SASS: (45 - 90) BC>70 A>80	**Taxa:** (9 - 15) BC>13 A>16	**ASPT:** (5 - 6) BC>5 A>5.5	***Families***		
			Names	**BC**	**A**
			Gomphidae	>50%	>60%
			Caenidae	>80	>90

D. TOTAL

SASS: (102 - 166) BC>160 A>180	**Taxa:** (21 - 28) BC>25 A>30	**ASPT:** (4.9 - 6.4) BC>6 A>6.4	***Families***		
			Names	**BC**	**A**
			Dixidae	Present	>10
			Leptoceridae	>80%	>90%
			>2spp Baetidae	>60%	>65
			Heptageniidae	Present	>40
			Philopotamidae	>50	>70
			Leptophlebiidae	>80	>90
			Psephenidae	Present	>40
			Aeshnidae	>30	>50
			Simuliidae	>80	>90 Less than C abundance
			Tipulidae	>10	>40
			Libellulidae	>50	>70
			MIRAI >78		

Elands tributaries (KO2, DW1)

Ecoregion: Western Bankenveld 7.04 (D); PES: B

A. STONES

SASS: (103 - 104) B>95 A>110	**Taxa:** (16 - 18) BC>16 A>20	**ASPT:** (5.8 - 6.4) B>5.8 A>6	***Families***		
			Names	**B**	**A**
			Heptageniidae	>30	>40%
			Hydropsychidae >2spp	>30	>40%
			Philopotamidae	>50	>60%
			Ancylidae	>50	>60

B. VEGETATION

SASS: (62 - 67) B>65 A>100	**Taxa:** (13) B>13 A>16	**ASPT:** (4.8 - 5.2) B>5.5 A>6	***Families***		
			Names	**B**	**A**
			Coenagrionidae	>60	>80%
			Atyidae	>40	>50%

C. GRAVEL, SAND and MUD

SASS: (39 - 63) B>60 A>80	**Taxa:** (11) B>11 A>15	**ASPT:** (3.6 - 5.7) B>5 A>5.5	***Families***		
			Names	**B**	**A**
			Gomphidae	>50%	>70%
			Caenidae	>80	>90

D. TOTAL

SASS: (136 - 155) B>150 A>180	**Taxa:** (2 3 -30) B>25 A>30	**ASPT:** (5.2- 5.9) B>5.5 A>6	***Families***		
			Names	**B**	**A**
			Leptoceridae	>50%	>70%
			2spp Baetidae	>90	
			>2spp Baetidae		>30%
			Heptageniidae	>30	>40
			Leptophlebiidae	>70	>80
			Aeshnidae	>80	>90
			Simuliidae	>60	>70 Less than C abundance
			Hydracarina	>30	>40
			Chlorocyphidae	>70	>80
			MIRAI>82		

Lower Elands (EL7, EL8, EL9, EL10, EL11)

Ecoregion: Bushveld Basin 8.05, 8.06 (E, F); PES: C

A. STONES

SASS: (20 - 62)	**No of Taxa:** (6 - 14)	**ASPT:** (3.3 - 5.1)	***Families***
C>50 A>100	C>10 A>15	C>4.5 A>5.5	

Names	C	A
Tricorythidae	Present	>60%

B. VEGETATION

SASS: (36 - 88)	**No of Taxa:** (6 - 21)	**ASPT:** (3.5 - 6)	***Families***
C>75 A>100	C>15 A>20	C>5 A>6	

Names	C	A
Coenagrionidae	>85	>90%
Atyidae	>30	>45%
Hydrophilidae	>60	>80

C. GRAVEL, SAND & MUD

SASS: (14 - 41)	**No of Taxa:** (5 - 9)	**ASPT:** (2.8 - 5.1)	***Families***
C>35 A>45	C>8 A>12	C>4.5 A>5	

Names	C	A
Gomphidae	>65%	>90%
Caenidae	>20	>80

D. TOTAL

SASS: (57 - 127)	**No of Taxa:** (15 - 26)	**ASPT:** (3.8 - 5.4)	***Families***
C>100 A>140	C>20 A>25	C>5.3 A>6	

Names	C	A
Leptoceridae	>30%	>50%
2spp Baetidae	>50	
>2spp Baetidae		>30%
Heptageniidae	>30	>40
Leptophlebiidae	>45	>75
Aeshnidae	>30	>70
Simuliidae	>40	>70 Less than C abundance
Chlorocyphidae	>20	>40
Tricorythidae	>10	>60
Libellulidae	>80	>90
MIRAI >62		

Hex Upper (HX1, HX2, HX3, KH1)

Ecoregion: Western Bankenveld 7.04 (C, D); PES: C

A. STONES

SASS: (61 - 97)	**No of Taxa:** (10 - 16)	**ASPT:** (5.3 - 6.1)	***Families***
C>80 A>120	C>12 A>20	C>5.5 A>6.5	

Names	**C**	**A**
Hydropsychidae 2spp	>30	
Hydropsychidae		>40

B. VEGETATION

SASS: (33 - 53)	**No of Taxa:** (8 - 12)	**ASPT:** (4.1 - 5.4)	***Families***
C>50 A>80	C>10 A>18	C>5 A>6	

Names	**C**	**A**
Coenagrionidae	>60	>70%

C. GRAVEL, SAND and MUD

SASS: (29 - 66)	**No of Taxa:** (8 - 11)	**ASPT:** (3.6 - 6)	***Families***
C>45 A>70	C>10 A>15	C>4.5 A>5.5	

Names	**C**	**A**
Gomphidae	>40%	>80%

D. TOTAL

SASS: (81 - 144)	**No of Taxa:** (15 - 23)	**ASPT:** (4.9 - 6.3)	***Families***
C>95 A>150	C>20 A>25	C>5.5 A>6.5	

Names	**C**	**A**
>2spp Baetidae	>40	>60%
Leptophlebiidae	>60	>70
Aeshnidae	>60	>80
Simuliidae	>80	>90 Less than C abundance
Hydracarina	>60	>80
Dixidae	Present	>40
Ceratopogonidae	>80	>90
Caenidae	>60	>80
Hydrophilidae	>60	>70
MIRAI >62		

Highveld (BR1, CR1, SV1, KC1)

Ecoregion: Highveld 11.01, 11.03 (C, D); PES: C

A. STONES

SASS: (31 - 101)	**No of Taxa:** (8 - 16)	**ASPT:** (3.8 - 7.3)	***Families***
C>80 A>120	C>15 A>20	C>6 A>6.5	

Names	C	A
Hydropsychidae 2spp	>50	
Hydropsychidae >2spp		>50
Tricorythidae	>60	>90

B. VEGETATION

SASS: (32 - 85)	**No of Taxa:** (8 - 16)	**ASPT:** (4 - 5.5)	***Families***
C>80 A>100	C>15 A>20	C>5 A>5.5	

Names	C	A
Coenagrionidae	>40	>80%

C. GRAVEL, SAND and MUD

SASS: (37 - 85)	**No of Taxa:** (7 - 16)	**ASPT:** (4.7 - 5.3)	***Families***
C>60 A>80	C>12 A>18	C>5 A>5.5	

Names	C	A
Gomphidae	>40%	>80%
Caenidae	>40	>70

D. TOTAL

SASS: (85 - 143)	**No of Taxa:** (14 - 26)	**ASPT:** (5.1 - 6.8)	***Families***
C>100 A>150	C>20 A>25	C>5.5 A>6.5	

Names	C	A
>2spp Baetidae	>20	>50%
Simuliidae	>80	>90 Less than C abundance
Dixidae	Present	>20
Ceratopogonidae	>80	>90
Elmidae	>40	>80
Ancylidae	>50	>60
Leptoceridae	>20	>40
Tipulidae	>40	>60
Libellulidae	>20	>30
MIRAI >62		

Magalies and Bloubank (MG2, MG3; BB2, BB3)

Ecoregion: Western Bankenveld 7.05, 7.06 (E; C, D); PES: BC

A. STONES

SASS: (83 - 106) BC>100 A>120	**No of Taxa:** (13 - 20) C>16 A>20	**ASPT:** (4.4 - 5.6) BC>5.5 A>6	***Families***		
			Names	**BC**	**A**
			Hydropsychidae >2spp	>40	>50
			Tricorythidae	>80	>90
			Elmidae	>80	>90
			Ancylidae	>60	>80

B. VEGETATION

SASS: (60 - 78) BC>75 A>120	**No of Taxa:** (9 - 15) BC>15 A>18	**ASPT:** (4.9 - 6.7) BC>6 A>6.5	***Families***		
			Names	**BC**	**A**
			Coenagrionidae	>80	>90%
			Atyidae	>20	>30

C. GRAVEL, SAND and MUD

SASS: (57 - 99) BC>80 A>100	**No of Taxa:** (1 1 - 19) BC>18 A>20	**ASPT:** (4.8 - 6.2) BC>5 A>5.5	***Families***		
			Names	**BC**	**A**
			Gomphidae	>60%	>80%
			Caenidae	>80	>90
			Tabanidae	>40	>70

D. TOTAL

SASS: (107 - 147) BC>120 A>150	**No of Taxa:** (19 - 28) BC>25 A>30	**ASPT:** (4.5 - 5.6) BC>5.5 A>6.3	***Families***		
			Names	**BC**	**A**
			>2spp Baetidae	>40	>50%
			Simuliidae	>80	>90 Less than C abundance
			Leptoceridae	>40	>70
			Tipulidae	>40	>70
			Libellulidae	>40	>70
			Leptophlebidae	>40	>60
			Athericidae	Present	>15
			Corbiculidae	>60	>70
			MIRAI >78		

Pienaars (PN4, PN5, BH1)

Ecoregion: Bushveld Basin 8.05 (E); PES: C

A. STONES

SASS: (47 - 116)	**No of Taxa:** (7 - 21)	**ASPT:** (5.2 - 6)	***Families***
C>100 A>120	C>16 A>20	C>5.5 A>6.5	

Names	**C**	**A**
Hydropsychidae 2 spp	>30	
Hydropsychidae >2spp		>30
Elmidae	>50	>80
Ancylidae	>60	>90

B. VEGETATION

SASS: (47 - 97)	**No of Taxa:** (7 - 16)	**ASPT:** (4.9 - 6.7)	***Families***
C>85 A>100	C>15 A>18	C>6 A>6.5	

Names	**C**	**A**
Coenagrionidae	>70	>90%
Atyidae	>60	>90

C. GRAVEL, SAND and MUD

SASS: (60 - 98)	**No of Taxa:** (9 - 18)	**ASPT:** (5.2 – 7)	***Families***
C>80 A>100	C>17 A>20	C>5.5 A>6	

Names	**C**	**A**
Gomphidae	>90%	>95%
Caenidae	>60	>90

D. TOTAL

SASS: (82 - 149)	**No of Taxa:** (13 - 28)	**ASPT:** (5.2 – 6.3)	***Families***
C>140 A>160	C>25 A>30	C>6 A>6.5	

Names	**C**	**A**
>2spp Baetidae	>80	>90%
Simuliidae	>80	>90 Less than C abundance
Leptoceridae	>50	>75
Libellulidae	>25	>60
Leptophlebidae	>80	>90
Heptageniidae	>50	>90
Chlorocyphidae	>50	>90
Tabanidae	>80	>85
MIRAI>62		

Pienaars (PN3, ED1)

Ecoregion: Eastern Bankenveld 9.03 (D); PES: C

A. STONES

SASS: (65 - 95)	**No of Taxa:** (10 - 17)	**ASPT:** (5.5 - 6.5)	***Families***		
C>90 A>110	C>16 A>18	C>6 A>6.5			
			Names	**C**	**A**
			Hydropsychidae 2 spp	>25	
			Hydropsychidae >2spp		>50
			Elmidae	>20	>70
			Ancylidae	>70	>80

B. VEGETATION

SASS: (52 - 58)	**No of Taxa:** (7 - 12)	**ASPT:** (4.3 - 8.2)	***Families***		
C>50 A>80	C>10 A>15	C>5.5 A>6			
			Names	**C**	**A**
			Coenagrionidae	>20	>80%
			Atyidae	>20	>80

C. GRAVEL, SAND and MUD

SASS: (34 - 97)	**No of Taxa:** (6 - 18)	**ASPT:** (4.9–7.8)	***Families***		
C>80 A>100	C>17 A>20	C>5.5 A>6			
			Names	**C**	**A**
			Gomphidae	>50%	>85%
			Caenidae	>70	>90

D. TOTAL

SASS: (88 - 129)	**No of Taxa:** (14 - 23)	**ASPT:** (4.95 - 6.3)	***Families***		
C>120 A>160	C>20 A>25	C>6 A>6.5			
			Names	**C**	**A**
			>2spp Baetidae	>50	>55%
			Simuliidae	>70	>90 Less than C abundance
			Leptoceridae	>50	>90
			Leptophlebidae	>70	>90
			Tipulidae	>70	>75
			MIRAI>62		

Buffelspruit and Sundays (BF1, SD1)

Ecoregion: Western Bankenveld 7.03 (D, E); PES: C

A. STONES

SASS: (46 - 91) C>80 A>100	**No of Taxa:** (7 - 12) C>10 A>15	**ASPT:** (6.6 – 7.6) C>6 A>6.5	***Families***		
			Names	**C**	**A**
			Hydropsychidae 2 spp	>60	
			Hydropsychidae >2spp		>60
			Perlidae	>50	>60
			Psephenidae	P	>50
			Heptageniidae	50%	>80

B. VEGETATION

SASS: (63 - 82) C>70 A>90	**No of Taxa:** (12) C>12 A>15	**ASPT:** (5.3 - 6.8) C>6 A>6.5	***Families***		
			Names	**C**	**A**
			Coenagrionidae	>70	>90%
			Atyidae	>50	>80

C. GRAVEL, SAND and MUD

SASS: (35 - 53) C>40 A>60	**No of Taxa:** (8 - 10) C>8 A>10	**ASPT:** (4.5 - 7.8) C>5 A>6	***Families***		
			Names	**C**	**A**
			Gomphidae	>80%	>85%
			Tabanidae	>Present	>50

D. TOTAL

SASS: (94 - 110) C>100 A>140	**No of Taxa:** (17 - 18) C>17 A>20	**ASPT:** (5.5 - 6.1) C>6 A>6.5	***Families***		
			Names	**C**	**A**
			>2spp Baetidae	>50	>70%
			Hydracarina	>40	>75
			Philopotamidae	>50	>75
			Aeshnidae	>70	>80
			MIRAI >62		

Plat, Tooyspruit and Tolwane (PL, TS, TW, VL1 and SN1)

Ecoregion: Bushveld Basin 8.01, 8.05, 8.06 (D, E); PES: C

A. STONES					
SASS: (65-95) C>90 A>110	**No of Taxa:** (10-17) C>16 A>18	**ASPT:** (5.5–6.5) C>6 A>6.5	***Families***		
			Names	**C**	**A**
			Hydropsychidae 2 spp	>25	
			Hydropsychidae >2spp		>50
			Elmidae	>20	>70
			Ancylidae	>70	>80

B. VEGETATION					
SASS: (52-58) C>50 A>80	**No of Taxa:** (7-12) C>10 A>15	**ASPT:** (4.3–8.2) C>5.5 A>6	***Families***		
			Names	**C**	**A**
			Coenagrionidae	>20	>80
			Atyidae	>20	>80

C. GRAVEL, SAND and MUD					
SASS: (34 - 97) C>80 A>100	**No of Taxa:** (6 - 18) C>17 A>20	**ASPT:** (4.9 - 7.8) C>5.5 A>6	***Families***		
			Names	**C**	**A**
			Gomphidae	>50%	>85%
			Caenidae	>70	>90

D. TOTAL					
SASS: (94 - 110) C>100 A>140	**No of Taxa:** (17 - 18) C>17 A>20	**ASPT:** (5.5 - 6.1) C>6 A>6.5	***Families***		
			Names	**C**	**A**
			>2spp Baetidae	>50	>55
			Simuliidae	>70	>90 Less than C abundance
			Leptoceridae	>50	>90
			Leptophlebidae	>70	>90
			Tipulidae	>70	>75
			MIRAI >62		

Appendix F:
Assessment of rehabilitation potential

The rehabilitation potential of the 49 stream-level river types that cannot achieve their 20 % targets was examined. The table below shows stream-level river types nested within landscape-level rivers using table shading. "AB" is total length of each river type in an A or B ecological integrity category: "Total" is the total length irrespective of ecological integrity category; "Target" is the target expressed as 20 % of the total length. The national range within the study area of the landscape-level river types (i.e. Level 2 river type) is expressed as a percentage in "% National". Rehabilitation assessment was based on feasibility of rehabilitation in the study area using the best Attainable Ecological Management Class (AEMC) as a guideline (Kleynhans, 2000). Conservation opportunities were assessed based on the extent of Level 2 river type elsewhere in the country and the predicted ecological integrity of those rivers.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
1_11.01_B	A21B	4750.0	0.0	950.0	45	Best conserved elsewhere	Rehabilitation is not feasible. This stream-level river type is located in the Johannesburg area and urbanization plays a major role. River channels also have total bed modification. Could be conserved elsewhere in tertiary catchment C23.
1_11.01_D	A21B	266741.5	0.0	53348.3	45	Rehabilitation feasible for AB	Rehabilitate tributary, Sesmulspruit, of Hennops River in sub-quaternary catchment 111. The integrity of the tributary is not intact (Z category) and connected to an E category Hennops River. The AEMC is C for the Hennops River. However, the Hennops River must be maintained in a C category.
1_11.01_E	A21B	36417.5	0.0	7283.5	45	Best conserved elsewhere	Rehabilitation is not feasible. This stream-level river type is located in the Johannesburg area with urbanization playing a major role. River channels also have total bed modification. Could be conserved elsewhere in tertiary catchment C23.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
1_11.01_S	A21B	2050.3	0.0	410.1	45	Best conserved elsewhere	The river length is very small and rehabilitation is not feasible. However, the river in sub-quaternary catchments 123 and 116 must be maintained in a C category for connectivity. Could be conserved elsewhere in tertiary C23 (e.g. quaternary catchment C23H). South Africa integrity = AB and D.
1_7.04_D	A21F	74684.6	9793.4	14936.9	102	Rehabilitation feasible for AB	Rehabilitate tributary of Magalies River in sub-quaternary catchment 118. However, integrity is a D and C category. AEMC = B. This area is important for refugia.
1_7.04_E	A21F	58683.0	24.6	11736.6	102	Rehabilitation feasible for C	Rehabilitate Magalies River in sub-quaternary catchment 115. It has a special feature upstream of the stream-level river type. Intolerant species (flow); Malony's Eye; high invertebrate species diversity; unique habitat and two unique fish species. However, integrity is a Z category i.e., not intact. AEMC = B. It is refuge area. There is a protected area in the sub-quaternary catchment. Could also rehabilitate the Pienaars River in sub-quaternary catchments 44 (located in a protected area), 50 and 150 (connectivity). There are no special features in sub-quaternary catchment 44 but there are in sub-quaternary catchment 150 (Pienaars River floodplain). The AEMC = C and the integrity C in all sub-quaternary catchments.
1_7.05_B 1_7.05_D	A21K A21K	7539.6 135521.0	31.3 12042.4	1507.9 27104.2	105 105	Rehabilitation feasible for AB Rehabilitation feasible for AB	Rehabilitate Sterkstroom River in sub-quaternary catchments 100 and 81 (connectivity). The ecological integrity is a D category and AEMC = C. There is a special feature in the upper reaches (upstream of Buffelspoort Dam), unique species, diverse habitats and excellent water quality. The river is also located in a protected area. Rehabilitate Sterkstroom River in sub-quaternary catchments 100 and 81 (connectivity). The ecological integrity is a D category and AEMC = C. There is a special feature in the upper reaches (upstream of Buffelspoort Dam), unique species, diverse habitats and excellent water quality. The river is also located in a protected area.
1_7.05_E	A21F	102571.6	0.0	20514.3	105	Rehabilitation feasible for C	Rehabilitate Magalies River in sub-quaternary catchment 109. Integrity D but AEMC = B. No protected area or special features and refugia area. Rehabilitate Magalies River in sub-quaternary catchments 107 and 106 (connectivity). This area

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
							consists of rare areas of riffles, rapids, pools and valleys. The integrity is Z and D categories while AEMC = C.
1_7.06_B	A21H	2057.9	0.0	411.6	101	Not feasible and unique	This is a short stretch of river (only 2km). It is not feasible to rehabilitate the river in sub-quaternary catchment 106. It has an integrity of Z and AEMC = C. There are no special features but it is located in a rare area.
1_7.06_D	A21G	117298.3	16011.9	23459.7	101	Rehabilitation feasible for AB	Rehabilitate Skeerpoort River in sub-quaternary catchment 110. The river is located in a protected area with a special feature. It is a sensitive system; partly located in a nature reserve; has very high diversity types; intolerant flow species; a waterfall area; high habitat diversity; a refuge area and high species diversity. The AEMC = B while the integrity is AB and Z categories.
1_7.06_E	A21A A21B	59669.4	0.0	11933.9	101	Rehabilitation feasible for C	Rehabilitate Hennops River in sub-quaternary catchments 111 and 114 (connectivity). It has a special feature with very high natural and conservation areas; rare and endangered terrestrial plants and species richness associated with the river. River type located in a very rare area. The AEMC =A. However, integrity is D and E categories. There is a protected area in both sub-quaternary catchments. Maintain river in a C category for connectivity.
1_7.06_R	A21B	18963.1	0.0	3792.6	101	Rehabilitation feasible for C	Rehabilitate Hennops River in sub-quaternary catchment 111 (connectivity). It has a special feature with very high natural and conservation areas; rare and endangered terrestrial plants and species richness associated with the river. River type located in a very rare area. The AEMC =A. However, integrity is D and E categories. There is a protected area in both sub-quaternary catchments. Maintain river in a C category for connectivity.
1_8.05_B	A21K	5692.5	0.0	1138.5	101	Rehabilitation feasible for AB	Rehabilitate Maretlwana River in sub-quaternary catchment 101. Magaliesberg is a protected natural environment. The stream-level river type represent a relatively short stretch of river (only 6km) and the integrity is a Z category i.e., not intact. The AEMC = C. The tributaries are located in a protected area and next to a refugia area. There are no special features.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
1_8.05_D	A21K	111703.5	5984.2	22340.7	101	Rehabilitation feasible for AB	Rehabilitation is feasible for the Strerkstroom River, not for the remaining rivers. The Sterkstroom River in sub-quaternary catchment 100 has integrity of a D, AEMC =C and it has a special feature in the upper section of the river. The special feature is located in a protected area. The upper Sterkstroom River is almost pristine. It contains unique species, habitat diversity and excellent water quality.
1_8.05_E	A23J	377215.8	22602.1	75443.2	101	Rehabilitation feasible for C	Rehabilitate the Pienaars River upstream of the Klipvoor Dam in sub-quaternary catchments 150 and 154 (connectivity). The river type has special features such as wetland meanders and very important refuge areas for water birds. Upstream of the Klipvoor Dam the AEMC = C and B and the integrity C and D.
1_8.05_F	A21L	6457.6	0.0	1291.5	101	Not feasible and unique	Rehabilitation of Sterkstroom River in sub-quaternary catchment 65 is not feasible but river must be maintained in a C category. An ecological integrity of A or B category is not possible and it is a very short stretch of river (only 6km).
1_9.03_B	A23K	1413.0	0.0	282.6	45	Best conserved elsewhere	This river length is very short and not intact. Urbanization is a very big problem and the AEMC = C. Rehabilitation is not feasible on the tributary of the Tolwane River in sub-quaternary catchment 152. This river type is best conserved elsewhere in tertiary catchment B42 (e.g. quaternary catchment (B42H) or B24E (Spekboom). AEMC = B, South Africa integrity = A and B categories for rivers in B42H and B42E. However, there are probably no headwaters in tertiary catchment B42.
1_9.03_E	A23B A23E	52862.9	6129.7	10572.6	45	Best conserved elsewhere	Rehabilitation of the Pienaars River in sub-quaternary catchments 71 and 156 is not feasible. Urbanization is a very big problem in the upper reaches. However, the river must be maintained in a C category. Integrity is in a C, D and AB categories. Could be conserved elsewhere in tertiary

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
							catchment B42.
2_7.03_R	A24H	16457.3	0.0	3291.5	97	Not feasible and unique	Rehabilitattion is not feasible due to mining activities. However rivers in sub-quaternary catchments 12 and 5 must be maintained in a C category for connectivity. The river is located close to a protected area and rare area consisting of riffles, pools, and the Apies Doring floodplains (*Acacia galpinii,* Monkey thorn). The integrity is a C category and AEMC = C for both rivers in above sub-quaternary catchments.
2_8.01_B	A23H	1368.4	0.0	273.7	35	Best conserved elsewhere	This river type is best conserved in tertiary catchments B51 and B52. South Africa integrity is in B and Z categories at B51 and in D and Z categories at B52 respectively. However, there are probably no headwaters in tertiary catchments B51 and B52 but it is not worth rehabilitating the tributary Droekloofspruit in sub-quaternary catchment 149. There are no special features. At present the integrity is in a Z category, i.e. not intact and AEMC = C.
2_8.01_D	A23H A23G	24779.1	0.0	4955.8	35	Best conserved elsewhere	It is not worth rehabilitating the Plat River in sub-quaternary catchment 148. There are better examples elsewhere in quaternary catchments B51G (Nkumpi River) and B52E (Olifants River). The latter is close to a protected area. The AEMC = C for rivers in both quaternary catchments. South Africa integrity is a B category for Nkumpi River and a D category for the Olifants River.
2_8.01_E	A23H A23G	54788.9	0.0	10957.8	35	Best conserved elsewhere	It is not worth rehabilitating the Plat River in sub-quaternary catchment 148. There are better examples elsewhere in quaternary catchments B51G (Nkumpi River) and B52E (Olifants River). The latter is close to a protected area. The AEMC = C for rivers in both quaternary catchments. South Africa integrity is a B category for Nkumpi River and a D category for the Olifants River.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
2_8.05_F	A24B	30897.5	0.0	6179.5	101	Rehabilitation feasible for C	Rehabilitate the river in sub-quaternary catchments 55, 35 and 53 (connectivity). There are special features in sub-quaternary catchments 35 and 53. The riparian forest is unique. The ecological integrity in sub-quaternary catchments 55 and 53 is a D category. The integrity in sub-quaternary catchment 35 is D and C categories. The AEMC = C and river type not located in a protected area. However, maintain the river in a C category for connectivity.
2_8.06_F	A24C A24H	49291.6	0.0	9858.3	103	Not feasible and unique	Rehabilitate the river in sub-quaternary catchments 12, 17 and 23 (connectivity). River integrity is in a C category and AEMC = C. River is not located in a protected area and it does not have special features. Maintain the river in a C category for connectivity.
3_1.03_F	A24J	21543.4	0.0	4308.7	71	Rehabilitation feasible for AB	Rehabilitate the Crocodile River in sub-quaternary catchment 144. Select sub-quaternary catchments 141, 2 and 142 also. A-B category integrity tributaries are connected to a C integrity category Crocodile River. There is a special feature on the Crocodile River, the Apies Doring forest (*Acacia galpinii,,* Monkey thorn) in the riparian zone is unique. The AEMC = B and a rare feature is present the in sub-quaternary catchment (e.g. riffles, rapids, pools and the Apies Doring floodplains. However, this will need ground verification. There are also no protected areas in the area. Elsewhere in the country there is no river length available except in quaternary catchments A62G, A61G and A62B. The AEMC = C and B and South Africa integrity = C.
3_1.04_F	A24J	56987.8	0.0	11397.6	97	Rehabilitation feasible for AB	Rehabilitate the Crocodile River in sub-quaternary catchment 144. The river is connected to two AB category tributaries in sub-quaternary catchments 141 and 2. Also, select sub-quaternary catchments 145 and 143 for connectivity. There is a special feature on the Crocodile River in sub-quaternary catchment 144. The Apies Doring riparian forest (*Acacia galpinii,* Monkey thorn) is unique. The river is also located in a rare area consisting of riffles, pools and the Apies Doring floodplains. The river integrity is a C category and AEMC = B. This will need ground verification. No protected area in the

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
							catchment area.
3_7.03_E	A24F	4399.4	0.0	879.9	37	Best conserved elsewhere	This river type is best conserved elsewhere in tertiary catchment A61 (e.g. quaternary catchment A61E (Andriesspruit) or A61D (Tobiaspruit), A61C (Badselooop). The AEMC = B. South Africa integrity is A for A61D and Z for A61E. Tertiary catchment A61 is also close to a protected area. There are platinum mining activities in this area hence, rehabilitation is not feasible. The integrity is C category on the Crocodile River in sub-quaternary catchment 144 and the AEMC = B. The river is located close to a protected area and has a special feature. However, the river length is very short and disconnected for rehabilitation. Rather look after the Apies Doring riparian forest (*Acacia galpinii,* Monkey thorn) on the Olifants River near the rejuvenated and lowland longitudinal zones.
3_7.03_F	A24J	3920.1	0.0	784.0	37	Best conserved elsewhere	This river type is best conserved elsewhere in tertiary catchment A61 (e.g. quaternary catchment A61E (Andriesspruit) or A61D (Tobiaspruit), A61C (Badselooop). The AEMC = B. South Africa integrity is A for A61D and Z for A61E. Tertiary catchment A61 is also close to a protected area. There are platinum mining activities in this area hence, rehabilitation is not feasible. The integrity is a C category on the Crocodile River in sub-quaternary catchment 144 and the AEMC = B. The river is located close to a protected area and has a special feature. However, the river length is very short and disconnected for rehabilitation. Rather look after the Apies Doring riparian forest on the Olifants River near the rejuvenated and lowland longitudinal zones.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
3_7.03_R	A24J	10397.9	0.0	2079.6	37	Best conserved elsewhere	This river type is best conserved elsewhere in tertiary catchment A61 (e.g. quaternary catchment A61E (Andriesspruit) or A61D (Tobiaspruit), A61C (Badselooop). The AEMC = B. South Africa integrity is A for A61D and Z for A61E. Tertiary catchment A61 is also close to a protected area. There are platinum mining activities in this area hence, rehabilitation is not feasible. The integrity is C category on the Crocodile River in sub-quaternary catchment 144 and the AEMC = B. The river is located close to a protected area and has a special feature. However, the river length is very short and disconnected for rehabilitation. Rather look after the Apies Doring riparian forest on the Olifants River near the rejuvenated and lowland longitudinal zones.
3_8.05_B	A23K	1796.7	0.0	359.3	61	Best conserved elsewhere	The river length is very small. Rehabilitation of the Sand River in sub-quaternary catchment 152 is not feasible in this WMA. The river type is best conserved elsewhere in tertiary catchment B31 (e.g. B31C, Elands River or B31D, Enkeldoringspriut). The AEMC = B and C for quaternary catchments B31C and B31D. Both catchments are located in a protected area. South Africa integrity is A for quaternary catchment B31D and C for quaternary catchment B31C.
3_8.05_E	A23K	69913.5	0.0	13982.7	61	Rehabilitation feasible for AB	Rehabilitate the Tolwane River in sub-quaternary catchment 152. There are no special features present. The Integrity is a C category and the AEMC = C. This is a rural area and natural habitat diversity is low.
3_8.06_F	A31F	53250.7	0.0	10650.1	103	Rehabilitation feasible for AB	Rehabilitate the Groot Marico River in sub-quaternary catchments 77, 73 and 59. If the ecological reserve is determined and maintained, this river can attain a B integrity category. The integrity is a D category for the river. The AEMC = C and no special features or protected areas are present.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
4_11.01_B	A22B	2386.4	232.5	477.3	14	Rehabilitation feasible for AB	Rehabilitate sub-quaternary catchment 98, Koster River headwaters. The integrity is a C category and the AEMC=B. There is a special feature on the tributary of the Koster River in sub-quaternary catchment 98. No protected area. The possibility exists in rehabilitating Rietspruit in quaternary catchment C70E; the AEMC=B. Elsewhere in the country rehabilitation does not look good. At the Suikerbosrant River in quaternary catchment C21C the AEMC=C.
4_11.01_D	A22A	24147.8	0.0	4829.6	14	Rehabilitation feasible for AB	Rehabilitate the Elands River in sub-quaternary catchment 85. There is a special feature but no protected area The integrity at present is a C category while the AEMC = B. Elsewhere in country it does not look good. At the Suikerbosrant River (quaternary catchment C21C) the AEMC = C.
4_7.04_R	A22A	12794.0	0.0	2558.8	113	Not feasible and unique	Rehabilitation is not feasible because the Lindleyspoort Dam is located on river.
5_1.03_F	A32D	17542.1	83.5	3508.4	72	Rehabilitation feasible for AB	Rehabilitate the river in sub-quaternary catchment 16. The river has a C integrity category; the tributary has an AB category; there is a special feature and the river is located in a protected area (Madikwe Nature Reserve). The riparian vegetation is in a good condition but threatened; hippopotami are present and the AEMC = B. If the ecological reserve is determined and maintained this river can attain a B category. Elsewhere in quaternary catchments A41B (Mamba River) and A41A the AEMC = B, South Africa integrity = A and B categories. Both quaternary catchments are located in a protected area.
5_11.09_R	A31D	3293.6	0.0	658.7	102	Rehabilitation feasible for AB	Rehabilitate the Molemane se loop in sub-quaternary catchment 93. It has a special feature and very important wetland areas. Groundwater is very important. The water disappears in places and emerges again. This is a unique dolomitic area with peatlands, floodplains and it is located next to a refugia area. However, it is a very short stretch of river (only 3km).The AEMC = B while the integrity is a category C. It is not located in a protected area.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
5_7.01_F	A32D	25685.0	0.0	5137.0	114	Rehabilitation feasible for AB	Rehabilitate a tributary of the Marico River in sub-quaternary catchment 16. It has a special feature and is located in protected area, Madikwe Nature Reserve. The riparian vegetation is in a good condition but threatened; hippopotami are also present. The integrity is a C category and the AEMC = B. The river is connected to the Maselje River, an intact tributary. The AEMC = B. If the ecological reserve is determined and maintained this river can attain a B category.
5_7.04_R	A31D	14721.3	0.0	2944.3	106	Rehabilitation feasible for AB	Rehabilitate the Molemane se loop in sub-quaternary catchments 93 and 92 (connectivity). Upstream of this river type a special feature occurs. This is a very important area for wetlands and groundwater. This is a unique dolomitic area with peatlands and floodplains, and it is located next to a refugia area. The integrity is in C category and the AEMC = B.
5_7.05_B	A22H	6117.2	1076.4	1223.4	116	Rehabilitation feasible for AB	Rehabilitate the Waterkloofspruit River in sub-quaternary catchment 86. There is a special feature and the wetland in the Magaliesburg Protected Natural Environment is to be declared a Ramsar site. This is habitat is very diverse (e.g. riffles, gorge, etc). The Integrity is D and Z categories while the AEMC = C. The river is located in protected area.
5_7.05_D	A22H	27171.8	4130.2	5434.4	116	Rehabilitation feasible for AB	Rehabilitate the Waterkloofspruit River in sub-quaternary catchment 86. There is a special feature and the wetland in the Magaliesburg Protected Natural Environment is to be declared a Ramsar site. This is habitat is very diverse (e.g. riffles, gorge, etc). The Integrity is D and Z categories while the AEMC = C. The river is located in protected area.
5_7.05_R	A22H	2742.9	0.0	548.6	116	Rehabilitation feasible for AB	Rehabilitate the Waterkloofspruit River in sub-quaternary catchment 86. There is a special feature and the wetland in the Magaliesburg Protected Natural Environment is to be declared a Ramsar site. This is habitat is very diverse (e.g. riffles, gorge, etc). The Integrity is D and Z categories while the AEMC = C. The river is located in protected area.

Stream-level river types	Quaternary catchment code	Total (m)	AB (m)	Target (m)	% National	Rehabilitation assessment	Notes
5_8.06_F	A32A	14031.5	0.0	2806.3	99	Rehabilitation feasible for AB	Rehabilitate rivers in sub-quaternary catchments 30 and 36. The Integrity of the rivers is a D category and the AEMC = B. There are no special features, rare areas or protected areas. This river type can not be conserved elsewhere in the country. The ecological reserve must be maintained and the dam in the area is a concern.
7_1.03_F	A32E	27824.8	0.0	5565.0	84	Rehabilitation feasible for AB	Rehabilitate the Marico River in sub-quaternary catchment 4. The integrity is a C category and the AEMC = B. There are no special features. Elsewhere in quaternary catchments A50J (AEMC = A), A62H (AEMC = A) and A41D, the AEMC is B. South Africa integrity for quaternary catchment A50J is an A, for quaternary catchment A62H it is a B and for quaternary catchment A41D it is a C. If the ecological reserve is determined and maintained this river can attain a B category.
7_1.04_F	A32E	85739.7	0.0	17147.9	111	Rehabilitation feasible for AB	Rehabilitate the Marico River in sub-quaternary catchments 3, 128 (in a protected area), 126, 127 (located next to a rare area) and 132 (in a protected area). The integrity is a C category, the AEMC = B. There are no special features present. These sub-quaternary catchments are needed for connectivity. If the ecological reserve is determined and maintained this river can attain a B category.
7_7.01_E	A32B A32C	161200.2	23770.4	32240.0	138	Not feasible and unique	Rehabilitation of this river type is not feasible in the WMA. This is a very dry seasonal river. The consequence is that this river type cannot meet any of its 20 % target in the country.
7_7.01_F	A32C	1486.7	0.0	297.3	138	Not feasible and unique	Rehabilitation of this river type is not feasible in the WMA, because of the Maraqwani Dam. The consequence is that this river type cannot meet any of its 20 % target in the country.
7_8.06_F	A31J	15437.8	0.0	3087.6	102	Not feasible and unique	Rehabilitation is not feasible for rivers in sub-quaternary catchments 47 and 40. These are very dry seasonal rivers. The AEMC = B, there are no protected areas, the integrity is a C and there are no special features.

Appendix G:

Management guidelines for the Crocodile (West) and Marico WMA

See Figure 3 for the sub-quaternary catchment numbers that relate to this appendix.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
Marico				
Ngotwane	A10A A10B	62	7_Bushveld Basin-6_Lower foothills 7_Western Bankenveld-4_Headwater streams 7_Western Bankenveld-4_Upper foothills 7_Western Bankenveld-4_Lower foothills 7_Western Bankenveld-4_Source zone Special feature 1: Dinokana Eye, pristine area, unique, refugia, headwaters are very important, ecotone	The Ngotwane River is connected to a groundwater system in the adjacent catchment (not in the study area). The sub-quaternary catchment consists of refugia and a high invertebrate diversity. This is an important source of water for the Dinokana rural community. Medium impact catchment management with low impact around the wetlands and the riparian zones.
Malmanieloop	A31C A31D	93	3_Highveld-9_Lower foothills 3_Highveld-1_Lower foothills Wetland - Carbonate Wetland - Fractured sedimentary Special feature 26: Molemane dolomitic eye, unique area, pristine wetlands, peatlands, ecotone Special feature 27: Molemane se loop, unique species, habitat diversity, isolated fish populations, refugia and taxon Fish species: Marico barb (*Barbus motebensis*)	Molemane se loop and associated dolomitic eye represents a unique and relatively undisturbed wetland ecosystem that is rich in invertebrate species with some unique and isolated fish populations. This sub-quaternary catchment has a high conservation value that will need low impact catchment management with river bed rehabilitation.
Marico; Klein Marico	A31D A31E	97	5_Highveld-9_Headwater streams 5_Highveld-9_Upper foothills 5_Western Bankenveld-4_Headwater streams 5_Western Bankenveld-4_Upper foothills	The Klein Marico River, a seasonal river. Medium impact catchment management with low impact around the wetlands and the riparian zones.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			3_Highveld-1_Headwater streams 3_Highveld-1_Upper foothills Wetland - Carbonate Wetland - Extrusives Wetland - Fractured sedimentary	
Doringrivier (tributary of Klein Marico) and Wetlands	A31F A31E	89	5_Western Bankenveld-4_Headwater streams 5_Western Bankenveld-4_Upper foothills 5_Western Bankenveld-4_Lower foothills Wetland - Extrusives Wetland - Fractured sedimentary	A seasonal tributary of the Klein Marico River. Medium impact catchment management with low impact management around the wetlands and the riparian zones.
Tributary of Klein Marico	A31F	79	5_Western Bankenveld-4_Lower foothills Wetland - Basement complex Wetland - Fractured sedimentary	A seasonal tributary of the Klein Marico River that will require medium impact catchment management with low impact around the wetlands and the riparian zones
Kaaloog se Loop Rietspruit Ribbokfontein se Loop Draaifontein Vanstraatensvlei	A31A	104	2_Highveld-9_Headwater streams 2_Highveld-9_Upper foothills 2_Western Bankenveld-4_Headwater streams 2_Western Bankenveld-4_Upper foothills 2_Western Bankenveld-4_Rejuvenated river 2_Western Bankenveld-4_Source zone Wetland - Carbonate Wetland - Extrusives Wetland - Fractured sedimentary Special feature 20: Kaaloog se Loop, Grootfontein dolomitic eye at the origin of Kaaloog se Loop, contains unique species Special feature 21: Dolomitic eye, pristine area, Rietspruit, Special feature 22: Ribbokfontein se Loop, wetlands, high habitat diversity but upstream slate mining Special feature 23: Draaifontein, high habitat and invertebrate species diversity, isolated fish species Special feature 24: Vanstraatensvlei, habitat diversity, isolated fish populations, deep pool areas, pristine area	This sub-quaternary catchment should be conserved as a unit with sub-quaternary catchment 80. The whole catchment should be managed for low impact activities. It is an important invertebrate condition reference site. The ecological reserve should be determined with special consideration of conservation priorities. This is the highest conservation importance site.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			Fish species: Stargazer or mountain catfish (*Amphilius uranoscopus*); Marico barb (*Barbus motebensis*); and Shortspine suckermouth or rock catlet (*Chiloglanis pretoriae*)	
Mainstem of Groot Marico	A31A A31B	80	Special feature 25: habitat diversity, unique species, refugia, pristine area and the ecotone is very important Fish species: Stargazer or mountain catfish (*Amphilius uranoscopus*); Shortspine suckermouth or rock catlet (*Chiloglanis pretoriae*); and Canary kurper (*Chetia flaviventris*)	This sub-quaternary catchment should be conserved as a unit with sub-quaternary catchment 104. The whole catchment should be managed for low impact activities. The ecological reserve must be determined with special consideration of conservation priorities.
Tributaries (Tholwane, Thulane) and Wetlands	A31G	60 68	4_Bushveld Basin-6_Lower foothills 4_Bushveld Basin-6_Lowland river Wetland - Fractured sedimentary Wetland - Surficial deposits	This sub-quaternary catchment should be conserved as a unit with sub-quaternary catchment 68 (i.e. Tholwane and Thulane rivers, tributaries of the Marico River), seasonal flow. Medium impact catchment management with low impact management will be required around the wetlands and riparian zones.
Lethlakane/Rooisloot and Wetlands	A31F	76	3_Bushveld Basin-6_Lower foothills 3_Western Bankenveld-4_Upper foothills 3_Western Bankenveld-4_Lower foothills Wetland – Extrusives Wetland - Fractured sedimentary	A seasonal tributary of the Marico River, medium impact catchment management with low impact around the wetlands and the riparian zones.
Tributaries (Sandsloot, Springboklaagte) and Wetlands	A31J	52	7_Bushveld Basin-6_Upper foothills 7_Bushveld Basin-6_Lower foothills 7_Western Bankenveld-4_Headwater streams 7_Western Bankenveld-4_Upper foothills Wetland - Fractured sedimentary Wetland - Surficial deposits	Medium impact catchment management with low impact around wetlands and riparian zones
Brakfonteinspruit and Wetlands	A32C	32	7_Bushveld Basin-6_Upper foothills 7_Bushveld Basin-6_Lower foothills Wetland - Extrusives	The Brakfonteinspruit; seasonal flow; medium impact catchment management with low impact around the wetland areas and riparian

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			Wetland - Fractured sedimentary Wetland - Surficial deposits	zones.
Tributaries and Wetlands	A32C	22	7_Bushveld Basin-6_Lower foothills 7_Western Bankenveld-1_Lower foothills Wetland - Extrusives Wetland - Fractured sedimentary Wetland - Surficial deposits	In this sub-quaternary catchment medium impact catchment management with low impact around wetland areas and the riparian zones will be required.
Mainstem of Groot Marico, tributaries and Wetlands	A32D	16	5_Limpopo Plain-3_Upper foothills 5_Limpopo Plain-3_Lower foothills 5_Limpopo Plain-3_Lowland river Wetland - Basement complex Wetland - Carbonate Wetland - Extrusives Wetland - Fractured sedimentary Special feature 28: Riparian vegetation very diverse but threatened, Madikwe Nature Reserve, bedrock	
Tributary and Wetlands	A10C	9	5_Western Bankenveld-1_Upper foothills 5_Western Bankenveld-1_Lower foothills 7_Western Bankenveld-1_Upper foothills Wetland - Basement complex Wetland - Carbonate Wetland - Extrusives Wetland - Surficial deposits	Catchment land managed for low impact around wetlands and in riparian zones and medium impact elsewhere.
Tributary and Wetlands	A32E	131	7_Limpopo Plain-4_Lower foothills 7_Limpopo Plain-3_Lower foothills Wetland - Basement complex Wetland - Surficial deposits	Medium impact catchment management with low impact around the wetlands and the riparian zones are required for this sub-quaternary catchment.
Elands				
Upper reaches	A22A	85	Special feature 8: Upper Elands River (transformed downstream), important source zone, pans, wetlands Special feature 9: Different minnow species, waterfalls, gorges, very important habitats	Upper reaches of the Elands River, above the slate mines, consist of high in-stream and terrestrial habitat diversity. Recommend as conservation priority with a statutory status.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
Brakkloofspruit and Wetlands	A22E	88	5_Western Bankenveld-4_Headwater streams 5_Western Bankenveld-4_Upper foothills 5_Western Bankenveld-4_Lower foothills Wetland - Extrusives Wetland - Fractured sedimentary	Brakkloofspruit, a tributary of Elands River; medium impact catchment management with low impact management around the wetlands and the riparian zones.
Mainstem and Wetlands	A22E	83	5_Western Bankenveld-4_Lower foothills Wetland - Fractured sedimentary Wetland - Surficial deposits	The main stem of the Elands River, medium impact catchment management with low impact around the wetlands and the riparian zones.
Koster, tributary Selons, Koedoespruit	A22B A22C	98 102	5_Western Bankenveld-4_Upper foothills 5_Western Bankenveld-4_Lower foothills 4_Highveld-1_Headwater streams 4_Western Bankenveld-4_Upper foothills Wetland - Extrusives Wetland - Fractured sedimentary Special feature 10: Tributary of the Koster River, unique fish species 5_Western Bankenveld-4_Lower foothills 4_Highveld-1_Headwater streams 3_Bushveld Basin-6_Upper foothills 3_Bushveld Basin-6_Lower foothills 3_Highveld-1_Upper foothills 3_Western Bankenveld-4_Headwater streams 3_Western Bankenveld-4_Upper foothills Wetland - Extrusives Wetland - Fractured sedimentary Special feature 10: Transition zone from the Western Bankenveld to the Highveld ecoregions and contains *Barbus motebensis*.	This sub-quaternary catchment should be conserved as a unit with catchments 102 and 84. Medium impact catchment management with low impact management around the wetlands and the riparian zones. This sub-quaternary catchment should be conserved as a unit with sub-quaternary catchments 84 and 98. Medium impact catchment management with low impact management around the wetlands and the riparian zones.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
Koster, Dwarsspruit and Wetlands	A22D	84	5_Bushveld Basin-6_Upper foothills 5_Bushveld Basin-6_Lower foothills 5_Western Bankenveld-4_Headwater streams 5_Western Bankenveld-4_Upper foothills 5_Western Bankenveld-4_Lower foothills Wetland - Extrusives Wetland - Fractured sedimentary	This sub-quaternary catchment should be conserved as a unit with sub-quaternary catchments 102 and 98. Medium impact catchment management with low impact around the wetlands and the riparian zones will be required.
Tributaries (Sandspruit) and Wetlands	A22F	63	5_Bushveld Basin-5_Lower foothills 5_Bushveld Basin-6_Upper foothills 5_Bushveld Basin-6_Lower foothills 5_Western Bankenveld-5_Lower foothills Wetland - Extrusives Wetland - Fractured sedimentary Wetland - Surficial deposits	Sandspruit, a tributary of the Elands River, adjacent to Pilansberg (possible expansion). Medium impact catchment management with low impact management around the wetlands and the riparian zones.
Leragane and Wetlands	A22F	74	5_Bushveld Basin-5_Upper foothills 5_Bushveld Basin-5_Lower foothills 5_Western Bankenveld-5_Headwater streams 5_Western Bankenveld-5_Upper foothills Wetland - Extrusives Wetland - Fractured sedimentary	Leragane River, a tributary of the Elands River, medium impact catchment management with low impact around the wetlands and the riparian zones. Mining is a threat in this area.
Tributaries (Mankwe) and Wetlands	A22F	57	5_Bushveld Basin-5_Upper foothills 5_Bushveld Basin-5_Lower foothills Wetland - Basement complex Wetland - Extrusives	The sub-quaternary catchment consists of two important tributaries upstream from the Vaalkop Dam. Medium impact catchment management with low impact around the wetland areas and riparian zones.
Waterkloofspruit (tributary of the Hex) and proposed RAMSAR wetlands	A22H	86	Special feature 14: Upper Waterkloofspruit, pristine area, Ramsar site, wetlands, riffles, waterfall, gorge Fish species: Canary kurper (*Chetia flaviventris*)	The site is a wetland area that originates in the Magaliesburg Protected Natural Environment. The wetlands have been nominated as a Ramsar site in the Kgathwane Mountain Reserve. This sub-quaternary catchment will require low impact management.
Tributary of Hex	A22G	112	Special feature 12: Pristine tributary with unique fish species such as the Marico barb (*Barbus motebensis*).	This sub-quaternary catchment will need low impact catchment management.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
Upper Hex			Special feature 13 : Upper Hex River, fish species, wetlands, seepage areas, groundwater areas	
Lower Crocodile				
Tributaries (Kolobeng) and Wetlands	A24D	48	5_Bushveld Basin-6_Upper foothills 5_Western Bankenveld-4_Headwater streams 5_Western Bankenveld-4_Upper foothills 6_Bushveld Basin-6_Upper foothills 6_Bushveld Basin-6_Lower foothills 6_Western Bankenveld-4_Headwater streams 6_Western Bankenveld-4_Upper foothills Wetland - Extrusives Wetland - Surficial deposits	Next to Pilanesberg (possible expansion towards Madikwe); medium impact catchment management with low impact around the wetland areas and riparian zones.
Tributaries and Wetland	A24E	29	5_Bushveld Basin-5_Upper foothills 6_Bushveld Basin-6_Upper foothills 6_Bushveld Basin-6_Lower foothills 6_Western Bankenveld-4_Headwater streams 6_Western Bankenveld-4_Upper foothills Wetland - Basement complex Wetland – Extrusives	Partial overlap with Pilanesberg Nature Reserve; important refuge area for larger river system; important wetland area; low impact catchment management.
Riparian forests and Wetlands	A24A A24A	35 and 55 49	Special feature 17: Apies Doring, *Acacia galpinii* (Monkey thorn), riparian forest 2_Bushveld Basin-5_Upper foothills 2_Western Bankenveld-4_Lower foothills Wetland - Basement complex Wetland - Carbonate Wetland - Extrusives Wetland - Fractured sedimentary Special feature 17: Apies Doring, *Acacia galpinii*	Sub-quaternary catchments 35, 49, and 55 should be managed as a unit, with emphasis on the Apies Doring riparian forest and groundwater contribution through wetlands in sub-quaternary catchment 49.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			(Monkey thorn), riparian forest	
Tributaries and Wetland	A24B	24	2_Bushveld Basin-5_Headwater streams 2_Bushveld Basin-5_Upper foothills 2_Bushveld Basin-5_Lower foothills 2_Western Bankenveld-4_Lower foothills Wetland - Basement complex Wetland - Extrusives Wetland - Fractured sedimentary	There is a relatively intact tributary of the Crocodile River to the north of the Borakalalo Nature Reserve (potential for future inclusion); medium impact catchment management with low impact around wetland areas and the riparian zones.
Klipspruit and Wetlands	A24C	27	2_Bushveld Basin-5_Upper foothills 2_Bushveld Basin-6_Upper foothills 2_Bushveld Basin-6_Lower foothills Wetland - Basement complex Wetland - Carbonate Wetland - Fractured sedimentary	Klipspruit, a tributary of the Crocodile River, between Borakalalo and Pilanesberg is a potential future corridor; medium impact catchment management with low impact around the wetland areas and the riparian zones.
Upper Plat and Wetlands	A23G	135	3_Bushveld Basin-5_Upper foothills 3_Western Bankenveld-3_Headwater streams 3_Western Bankenveld-3_Upper foothills Wetland - Basement complex Wetland - Extrusives Wetland - Fractured sedimentary Wetland - Surficial deposits Special feature 15: Upper Plat River, pristine wetland source areas, fish species, habitat diversity	Medium impact catchment management with low impact around the wetlands and the riparian zones are required for this sub-quaternary catchment.
		148	Special feature 15: Upper Plat River, pristine wetland source areas, fish species, habitat diversity	This sub-quaternary catchment will require low impact catchment management.
Sundays	A24H	6	2_Limpopo Plain-3_Upper foothills 2_Limpopo Plain-3_Lower foothills	There is high invertebrate and fish diversity in this sub-quaternary catchment (i.e. Sundays

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			2_Western Bankenveld-3_Headwater streams 2_Western Bankenveld-3_Upper foothills 2_Western Bankenveld-3_Lower foothills Wetland - Fractured sedimentary Wetland - Surficial deposits Special feature 18: Pristine source zone, habitat diversity (this needs to be field verified)	River). Manage the land use in the whole catchment for low impact with special care to the riparian area and around the wetlands.
Sundays tributaries Wetland	A24H	10	2_Bushveld Basin-6_Upper foothills 2_Bushveld Basin-6_Lower foothills 2_Western Bankenveld-3_Headwater streams 2_Western Bankenveld-3_Upper foothills Wetland - Basement complex Wetland - Surficial deposits	This is a relatively intact landscape that will require medium impact catchment management. Low impact catchment management is required around the wetland areas and the riparian zones.
Non Perennial and Wetlands	A24J	142	7_Western Bankenveld-1_Upper foothills 3_Limpopo Plain-4_Lower foothills 3_Limpopo Plain-3_Upper foothills 3_Limpopo Plain-3_Lower foothills Wetland - Basement complex Wetland - Surficial deposits	Medium impact catchment management with low impact around the wetlands and the riparian zones are required for this sub-quaternary catchment.
Riparian forests	A24J	144	Special feature 19: Apies Doring, *Acacia galpinii* (Monkey thorn), riparian forest	Low impact catchment management around the special feature.
Apies/Pienaars				
Boekenhoutspruit and Wetlands	A23B	69	1_Bushveld Basin-5_Lower foothills 1_Eastern Bankenveld-3_Upper foothills 1_Eastern Bankenveld-3_Lower foothills Wetland - Basement complex Wetland - Extrusives Wetland - Fractured sedimentary	Boekenhoutspruit, a tributary of the Pienaars River, inside the Dinokeng Game Reserve, medium impact catchment management with low impact around the wetlands and the riparian zones.
Tooyspruit and Wetlands	A23H	137	2_Bushveld Basin-5_Upper foothills 2_Bushveld Basin-5_Lower foothills 2_Bushveld Basin-5_Source zone 2_Western Bankenveld-3_Headwater streams	Medium impact catchment management with low impact around the wetlands and the riparian zones are required for this sub-quaternary catchment.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			Wetland - Basement complex Wetland - Fractured sedimentary	
Lepenya, Marierietsa, Riet and Wetlands	A23H	138	2_Bushveld Basin-5_Upper foothills 2_Bushveld Basin-5_Lower foothills Wetland - Basement complex Wetland - Extrusives Wetland - Fractured sedimentary	Medium impact catchment management with low impact around the wetlands and the riparian zones are required for this sub-quaternary catchment.
Floodplain of Pienaars	A23G A23C A23F A23F A23J	148 151 155 154 150	Special feature 15: Upper Plat River, wetland source areas, rare and endangered fish species Special feature 16: Pienaars River floodplain, upstream of the Klipvoor Dam, refuge area for water birds	The sub-quaternary catchment will require low impact catchment management. Requires conservation management of the buffered floodplain area.
Upper Crocodile				
Upper Sterkstroom	A21K	100	1_Western Bankenveld-5_Headwater streams Special feature 7: Upper Sterkstroom River, upstream of the Buffelspoort Dam, pristine area, excellent water quality Fish species: Stargazer or mountain catfish (*Amphilius uranoscopus*) and Marico barb (*Barbus motebensis*)	The site originates in the Magaliesburg Protected Natural Environment. Medium impact catchment management with low impact around the wetlands and the riparian zones, The area is very important for invertebrate reference conditions.
Maloney's Eye	A21F	115	Special feature 5: Malony's Eye, unique habitat and taxa	Low impact catchment management around the eye is required. Assess and manage the groundwater linkages.
Skeerpoort and Wetlands	A21G	110	1_Western Bankenveld-5_Upper foothills 1_Western Bankenveld-6_Upper foothills Wetland - Carbonate Wetland - Extrusives Wetland - Fractured sedimentary Special feature 6: Skeerpoort River, waterfalls, habitat	This sub-quaternary catchment is located within a private nature reserve and is a world heritage area with high biodiversity. It is an important remaining invertebrate reference site with high conservation importance.

Sub-management area / river name	Quaternary catchment code	Sub-quaternary catchment	Biodiversity feature	Management guidelines
			types diverse, species refuge, high species diversity Fish species: Stargazer or mountain catfish (*Amphilius. uranoscopus*); Shortspine suckermouth or rock catlet (*Chiloglanis pretoriae*); and Canary kurper (*Chetia flaviventris*)	
Sesmylspruit	A21A	114	Special feature 3: Sesmylspruit, contains a population of *Labeobarbus polylepis*.	A rehabilitation plan and management plan are required.
Hennops	A21B	111	Special feature 4: Hennops River, high terrestrial plant diversity	This sub-quaternary catchment requires only a medium conservation priority for the freshwater conservation plan. The terrestrial conservation plan may cater for this area because of its high plant diversity.

Appendix H: Contents of Metadata CD for data used in the Crocodile (West) and Marico WMA study

Large amounts of data were collated as part of the Crocodile (West) and Marico assessment. These data are provided on a Metadata CD accompanying this report.

The contents on this CD are as follows:

Crocodile (West) and Marico Report

Background information

- Digital Elevation Model (DEM), 90 m resolution
- Hillshade (i.e. Shuttle Radar Topographic Mission), 90 m resolution

Boundaries

- Crocodile (West) and Marico WMA.
- Crocodile (West) and Marico WMA without quaternary D41A
- Sub-quaternary catchments

Rivers

- DWAF 1:500 000 rivers
- DWAF 1: 50 000 rivers

Features

- Protected areas
- Special features
- Potential wetlands

Fish species

- Six GIS shapefiles for the following fish species:
  - *Amphilius uranoscopus*
  - *Barbus motebensis*
  - *Aplocheilicthys johnstoni*
  - *Clarias theodorae*
  - *Chiloglanis pretoriae*
  - *Chetia flaviventris*

Conservation plan

- Conservation plan GIS shapefile.