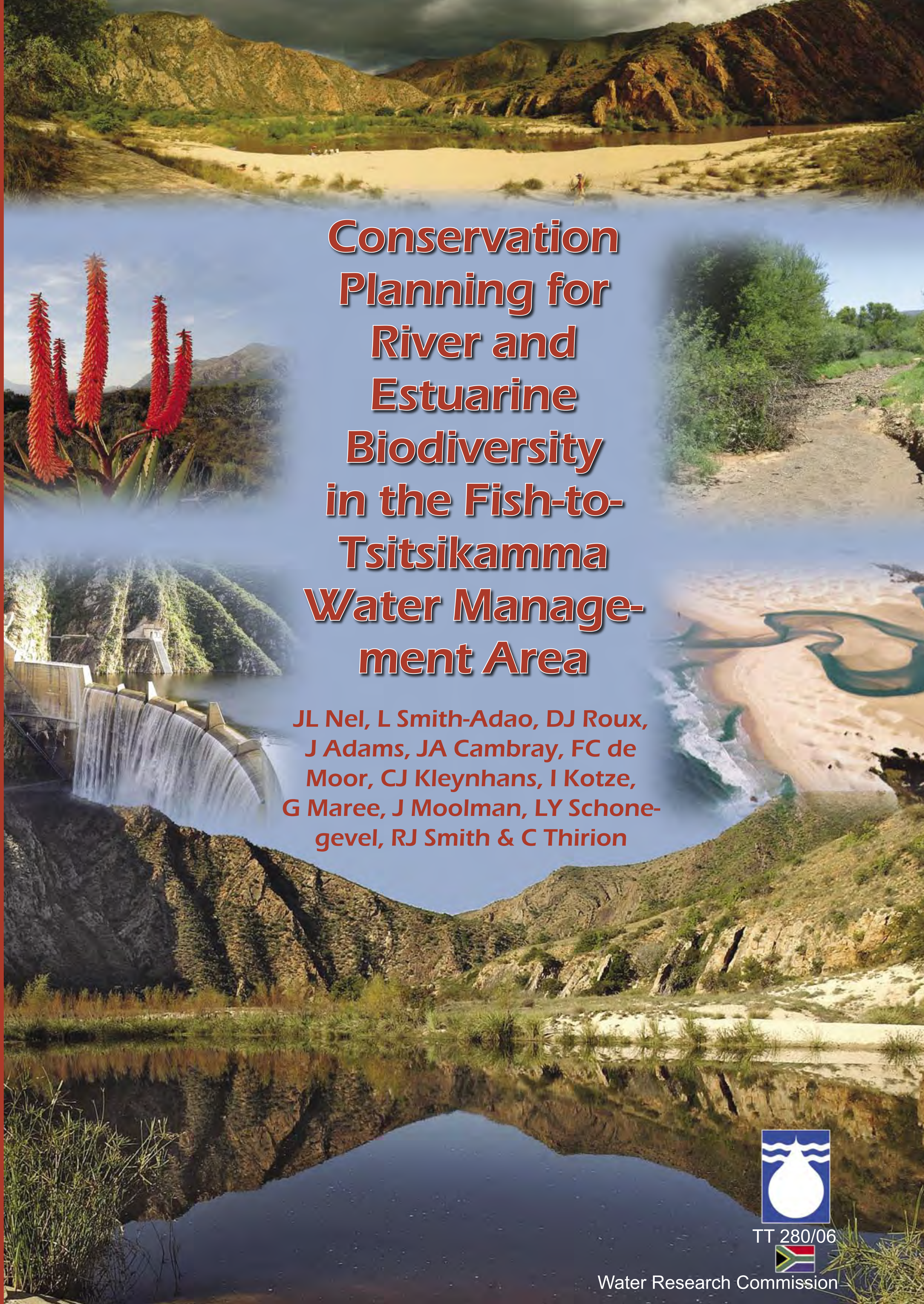

Conservation Planning for River and Estuarine Biodiversity in the Fish-to-Tsitsikamma Water Management Area

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TT 280/06

Water Research Commission

CONSERVATION PLANNING FOR RIVER AND ESTUARINE BIODIVERSITY IN THE FISH-TO-TSITSIKAMMA WATER MANAGEMENT AREA

REPORT TO THE
WATER RESEARCH COMMISSION

by

JL Nel, L Smith-Adao, DJ Roux, J Adams, JA Cambray, FC de Moor, CJ Kleynhans, I Kotze, G Maree, J Moolman, LY Schonegevel, RJ Smith & C Thirion

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Extended Executive Summary

For the benefit of summarizing the approach and results of this project, the executive summary has been extended and cross-referenced with the full report.

1. Background and Approach

This study forms a pilot study for a broader national initiative, which aims to develop a policy and planning framework for systematic conservation of inland water biodiversity in South Africa. The national initiative was set up in 2003 between the Department of Water Affairs and Forestry and CSIR. Subsequently the Water Research Commission added its support by sponsoring this project in the Fish-to-Tsitsikamma Water Management Area, which aims to **facilitate testing, refinement and demonstration of the river prioritization and selection tool at a sub-national scale**, providing an example of the lessons learnt and best practice for use elsewhere in the country.

The formal aims for this project, as stipulated in the Water Research Commission contract, are:

1. To put in practice and refine, through a pilot study in the Eastern Cape, the policy and planning tools developed within the broader national initiative for systematic conservation planning of rivers. This would facilitate testing, refinement and demonstration of the river prioritization and selection tool, and provide an example of best practice for use elsewhere in the country.

2. To ensure local and national stakeholder participation in developing the technical approach to river prioritization and selection, as well as the reviewing of results to facilitate buy-in and ownership of the product.

“Biodiversity conservation” in this project and the broader national initiative refers to the efforts to maintain or restore the ecological integrity (including structure, composition and function) of inland water ecosystems to levels that are in accordance with the most stringent (most highly protected) water resource management class (Roux *et al.* 2006). Initiatives to conserve inland water biodiversity would thus not apply to all water resources, but only to those water resources that are awarded the highest protection level based on the national water resource classification system (DWAF 2004). In policy terms, this is consistent with “Natural” or “Good” rivers within the River Health Programme categorization (Roux 2004) or the “Natural” class within the context of the national water resource classification system (DWAF 2004).

The technical planning approach adopted for this study is based on systematic conservation planning principles and methods. Systematic conservation planning is founded upon several fundamental principles: the principle of representation and efficiency, persistence and quantitative target setting. The first principle requires the efficient conservation of a representative sample of all species, and of the habitats in which they occur (as opposed to focussing only on the ones experts know). However, conserving species and habitats, often referred to as **biodiversity pattern**, is not enough. It simply provides a snapshot of the biodiversity that currently exists. The principle of persistence requires the conservation of the **biodiversity processes** responsible for maintaining and generating biodiversity over time. Finally, the principle of **quantitative target setting** requires the formulation of explicit goals with key stakeholders, which are then translated into quantitative targets for biodiversity features (e.g. length of river, area of catchment, design targets for connectivity). For a more detailed discussion of these principles, the reader is referred to Margules and Pressey (2000) and Roux *et al.* (2006).

The fundamental principles of systematic conservation planning have formed the basis of the step-wise planning framework, which guides the approach of this project. There are seven main steps (Figure 1, p. 22):

(i) Identify and involve key stakeholders during project initiation;
(ii) Develop spatial data layers for biodiversity pattern;
(iii) Develop spatial data layers for biodiversity process;
(iv) Develop spatial data layers for river integrity;
(v) Assess and prioritize estuaries;
(vi) Set quantitative biodiversity targets; and
(vii) Select and design areas for achieving biodiversity targets in both estuaries and rivers.

2. GENERAL DESCRIPTION OF THE STUDY AREA

The Fish-to-Tsitsikamma Water Management Area (WMA 15) is situated mainly in the Eastern Cape Province of South Africa, with small portions of its north-western part within the Northern and Western Cape Provinces (Figure 2, p. 25). Six primary catchments occur within the Fish-to-Tsitsikamma Water Management Area: the Fish (Q-catchment), Sundays (N-catchment), Gamtoos (L-catchment), Algoa (M-catchment) and Bushmans (P-catchment) primary catchments occur completely within the Fish-to-Tsitsikamma Water Management Area, whilst the Tsitsikamma (K-catchment) occurs partially within the area. These primary catchments mark the delineations of sub-water management areas. Major rivers in the Fish-to-Tsitsikamma Water Management Area are the Fish, Kowie, Bushmans, Sundays, Gamtoos, Krom, Tsitsikamma and Groot rivers. A detailed account of the topography, climate, water use and availability characteristics of this water management area have been provided by Basson and Rossouw (2003).

The agencies responsible for implementation of biodiversity conservation and water resource protection, which were involved in the project include national and regional offices of DWAF as well as the bioregional coordination unit in the Eastern Cape (see Table 2 for details).

3. MAPPING BIODIVERSITY PATTERN FOR RIVERS

Rivers were classified into 113 **river types** (Appendix 1) using a geomorphological and hydrological classification system (Dollar *et al.* in press). At the landscape level, rivers were classified according to geomorphic provinces (Partridge *et al.* in prep; Figure 3, p. 36) and a hydrological index which characterizes flow variability (Hannart and Hughes 2003; Figure 4, p. 37). A characterization of geomorphologic (longitudinal) zones at the level of individual streams

(Figure 5, p. 38) was used to supplement these broad landscape-level descriptors of geomorphology and hydrology (Figure 6, p. 43). Using this stream-level descriptor in conjunction with the landscape-level characterization of geomorphology and flow provides a finer-scale surrogate of the biotopes expected within the river reach, which in turn was used as a surrogate for biodiversity pattern within river ecosystems (Figure 7, p. 44).

Future assessments should (i) evaluate whether each river type is a true reflection of river biodiversity or an artefact of combining the GIS layers for geomorphic province and hydrological index classes; and (ii) supplement these physical river types with aquatic species datasets that have been relatively comprehensively surveyed across the planning domain, e.g. fish databases.

4. INCORPORATING BIODIVERSITY PROCESSES

Four key principles were considered when incorporating biodiversity processes into this conservation plan. The first three of these principles require explicit consideration during the selection and design procedures; the last principle requires explicit mapping of large-scale biodiversity processes across the landscape.

Selecting ecosystems of high ecological integrity
Rivers that are currently considered to be of high integrity should ideally be selected for the purposes of conserving biodiversity, since these are the rivers that accurately represent the biodiversity of the region, and in which ecological and evolutionary processes operate within their natural ranges. Incorporating rivers 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 that are currently of high integrity also (i) facilitates operational management - since rivers 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. For the purposes of this project, only rivers with a present ecological integrity of “Natural” or “Good” (equivalent to A or B class rivers; Roux 2004) were selected; and estuaries considered to be in a “Poor” state (Whitfield 2000) were excluded.

Ensuring connectivity
Longitudinal connectivity in the Fish-to-Tsitsikamma Water Management Area was maintained by incorporating, where possible, whole river systems in the conservation plan. It is often not possible to find whole systems that are currently in a consistently high present ecological state (i.e. where the river is Class A or B through its entire tertiary or primary length). Thus, rivers that were selected for conservation in a natural or good class (Class A or B) were connected through rivers that are only moderately used or impacted (Class C). Such connecting rivers were incorporated explicitly into the final conservation plan, with the recommendation that these should be maintained in a state that retains longitudinal connectivity for its associated biodiversity.

Including rivers of sufficient size
Each river reach chosen for high protection status in the Fish-to-Tsitsikamma conservation plan was also evaluated in terms of its size and viability. With a few exceptions, only those reaches that were over 5 km long were chosen for conservation purposes. These exceptions mainly

occurred in headwater streams, where the only option to conserve a representative stretch of river was in a reach that was shorter than 5 km in length, and which was connected to rivers of lower integrity (Classes C-F). Because headwaters are in reality relatively short stretches of river, and can be important and viable for specific aquatic biota despite their small size, it was decided that they should be included in the conservation plan ***provided*** that the length of river contributing to targets (i.e. in a Class A and B) did not fall below 17% of the total length of river in that quaternary catchment. The threshold of 17% was derived by assessing the cost of including quaternary catchments of low overall integrity versus the benefit of meeting targets in the overall plan (see Section 8.8).

Including additional large-scale biodiversity processes

The Fish-to-Tsitsikamma Water Management Area contains many permanently open estuary mouths; these serve as large-scale migration routes for freshwater eels and the freshwater mullet, *Myxus capensis*. The desktop ecological importance and sensitivity scoring system (Kleynhans 2001) was used to identify quaternary catchments of national importance for migration - these quaternary catchments were then explicitly incorporated into the Fish-to-Tsitsikamma conservation plan (Figure 8, p. 49).

5. MAPPING ECOLOGICAL INTEGRITY OF RIVERS

Rivers that are currently of high ecological integrity should ideally be the first choice for biodiversity conservation. This requires a spatial depiction of the integrity of riverine ecosystems. Ecostatus determination techniques (Kleynhans *et al.* 2005) were used to assess the condition of rivers at the level of the landscape, and to derive a spatial depiction of river ecological integrity for the area. However, owing to limited time and inadequate reference site data, only the broadest level 1 ecostatus determination techniques were used; these focus on the derivation of an index of habitat integrity from physical drivers (as opposed to including response variables such as biotic indices). This process involved:

- Dividing the Fish-to-Tsitsikamma Water Management Area into assessment units, based on Level 1 ecoregions (Kleynhans *et al.* 2004), primary catchments, and land cover attributes (Figure 9, p. 56);
- Scoring these assessment units according to the primary determinants of their in-stream and riparian ecological integrity in an expert workshop; and
- Assigning all rivers falling within the same assessment unit the same integrated index of habitat integrity (Figure 10, p. 60).

Field verification of this desktop assessment was undertaken at 48 sites; these sites were located mainly in those areas that were not well known to experts (Figure 10, p. 60). There were a number of sites (12 out of 48; 25%) where there was a discrepancy between the desktop and field ecostatus scores (Figure 11, p. 61). Of these 12 sites, some had an ecological integrity score at the landscape level that was better than at the site level, owing to localized impacts. In these cases, the desktop assessment was not changed. Not all of the discrepancies, however, were explained by localized site impacts. For example, on both the Groot and Klein Brak rivers, surveys were conducted along extensive sections of river and the discrepancies were not a result of localized site impacts. These discrepancies are more likely a consequence of poor resolution in the desktop analysis, resulting from the process of generalisation into broad assessment units. The river ecological integrity in these instances was corrected to derive a final map of ecological integrity of rivers.

Overall, rivers in the region are in relatively good condition (Figure 12, p. 62) compared to other areas of the country, with 46% of the total river length in the Fish-to-Tsitsikamma Water Management Area in an A (natural) or B (largely natural) class, 42% in a C class (moderately modified), and slightly over 12% in D and E classes (largely to seriously modified).

6. SETTING QUANTITATIVE BIODIVERSITY TARGETS FOR RIVERS

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

The recommendations arising from the national cross-sectoral policy process (Roux *et al.* 2006), currently underway as a parallel Water Research Commission project (Project K8/642), were adopted for setting targets for rivers in the area. This process has put together 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 the culmination of analysis, consultation and deliberation amongst the primary agencies responsible for conservation of inland water biodiversity in South Africa. Translating these recommendations to the Fish-to-Tsitsikamma conservation plan, biodiversity targets were calculated as 20% of the total length of each Level 3 river type (Appendix 1). These targets should only be achieved within river reaches that have a present ecological integrity class of “Natural” or “Good” (i.e. Class A or B rivers) - any river reach that is in a class that is lower than A or B class, and which is required for maintaining longitudinal connectivity, should be included explicitly in the plan, but should not contribute towards achieving this 20% biodiversity target.

There are 37 river types which cannot achieve their biodiversity target in river reaches of an A or B class (Appendix 2), 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. Options for rehabilitating examples of these river types within the Fish-to-Tsitsikamma Water Management Area were explored within the context of the potential opportunity for conserving these river types elsewhere in the country. This assessment of rehabilitation potential divided these 37 river types into four categories (Figure 13, p. 68):

(i) Rehabilitation is feasible - quaternary catchments containing good examples of these river types have been flagged for rehabilitation in the subsequent conservation plan.

(ii) Best conserved elsewhere - areas which could adopt the targets for the Fish-to-Tsitsikamma Water Management Area have been identified and listed in Appendix 2.

(iii) Rehabilitation is not feasible and conservation opportunities elsewhere also look bleak - an assessment at the national level should be undertaken to identify where it would be best to rehabilitate these river types.

(iv) Rehabilitation is not feasible and cannot be conserved elsewhere (unique to study area) - these river types are now under-represented in the country (i.e. have failed to meet the national target).

7. ESTUARY ASSESSMENT AND SELECTION

Estuaries in the Fish-to-Tsitsikamma Water Management Area were assessed with the aim of selecting a representative set of estuaries to conserve threatened species, maintain viable populations of all estuarine species, and to maintain in their reference state, or where necessary, to rehabilitate the estuary to a condition where it achieves the above aims. Like rivers, it is envisaged that all estuaries should enjoy some level of protection, being assigned to three protection categories, listed in decreasing order of their level of protection as: Estuarine Protected Areas, Estuarine Conservation Areas and Estuarine Management Areas. This project focuses on identifying estuaries to be earmarked as Estuarine Protected Areas and Estuarine Conservation Areas.

Estuarine biodiversity pattern and process

There are a total of 30 estuaries in the Fish-to-Tsitsikamma Water Management Area, and all fall within the Warm Temperate biogeographical zone (Harrison 2004). The Whitfield (1992) classification was used to further classify **estuary types;** these were used as the physical surrogate to depict the biodiversity pattern of estuaries in the area. This divided the Fish-to-Tsitsikamma estuaries into eight permanently open estuaries; 17 temporarily open estuaries; and five river mouths (Figure 14, p. 72). Only 18% of South Africa's estuaries are permanently open and therefore this area is particularly important in terms of estuarine biodiversity and conservation importance. For example, the importance of this area for large-scale migration of freshwater eel and freshwater mullet are a result of the many permanently open estuaries.

Additionally, the national conservation importance rating of each estuary was used to help choose between estuaries of similar types. This rating was based on quantitative and semi-quantitative biodiversity data for plants, invertebrates, fish and birds, as well as estuarine type and its rarity within each biogeographical zone, and overall estuary size.

Estuarine ecological integrity

Whitfield (2000) conducted an assessment on the ecological integrity of estuaries, which has recently been slightly refined where regional experts deemed it necessary (Turpie 2004b). This classified estuaries broadly as "Excellent", "Good", "Fair", or "Poor". Only two of the permanently open estuaries in the Fish-to-Tsitsikamma Water Management Area are in a "Good" condition, whilst the remaining permanently open estuaries are rated in a "Fair" state. Nine of the 17 temporarily open estuaries are in a ""Excellent" or Good" state, while three are in a "Fair" state and the remaining five are in a "Poor" state (Figure 15, p. 74). The ecological state of the estuaries selected for inclusion in the conservation plan should be given attention to ensure that biodiversity within these estuaries is maintained.

Current protection status

The current status of protection was derived from the Whitfield (2000) classification system, and shows that the present system of formal protection is biased. All five river mouths qualify as Estuarine Protected Areas, there is one temporary estuary (the Tsitsikamma) that qualifies as an Estuarine Conservation Area, and the remaining three are co-managed as Estuarine

Management Areas. There are no permanent estuaries that receive Estuarine Protection or Conservation status. The conservation plan should aim to correct this bias.

Current protection status was also taken into account, in terms of their practical feasibility for protection, in the selection of estuaries for inclusion in the conservation plan.

Setting quantitative biodiversity targets for estuaries

Targets for estuaries were based on methods used in the assessment of estuaries on the Wild Coast (Turpie and Van Niekerk 2004), in which the targets used were set as 20% of estuaries allocated to Estuarine Protected Areas and 30% of estuaries allocated to Estuarine Conservation Areas.

Selecting estuaries for inclusion in the conservation plan

Seven Estuarine Protected Areas and nine Estuarine Conservation Areas were selected (Figure 16, p. 78) based on the following selection protocol to satisfy the biodiversity targets:

(i) Estuaries in “Excellent”, “Good” or “Fair” condition were deemed suitable for selection. Estuaries in “Poor” condition were excluded from selection options.

(ii) Estuaries that already have high protection status (Estuarine Protected Areas) were chosen first to satisfy targets. Estuaries with lower protection status (Estuarine Conservation Areas or Estuarine Management Areas) were favoured, but not necessarily chosen over other more suitable estuaries.

(iii) Spatial distribution was then taken into account, making sure that estuaries are more or less evenly dispersed along the coastline.

(iv) A national importance rating was used to decide between estuaries of the same type and condition that are located no more than 200 km (most often less than this) from each other.

(v) Estuarine Protected Areas were selected based on the feasibility of pure protection. In cases where high protection is not considered feasible, but where the estuary qualifies on the above selections, the estuary was assigned to Estuarine Conservation Area status. This feasibility assessment included criteria such as:
- Current levels of terrestrial and coastal protection in the area. Areas in close proximity to existing protected areas were favoured;
- Current socio-economic activities associated with the estuary; and
- Quality of the river flowing into the river. Rivers with an ecological integrity of A, B or C were favoured over rivers with a lower ecological integrity (D, E or F).

8. CONSERVATION DESIGN FOR RIVERS, CATCHMENTS AND ESTUARIES

The aim of this stage in the conservation planning process is to locate a set of catchments and estuaries that will achieve riverine and estuarine biodiversity targets. It should be noted that conservation planning should be seen as a process of iterative improvement – ground truthing should be undertaken in selected catchments to verify that they contain the biodiversity features for which they were selected, and this should be fed back into the planning process so that plans can be revised appropriately.

The following steps were used, in the order in which they are listed below, to select rivers and quaternary catchments for inclusion in the Fish-to-Tsitsikamma conservation plan:

1. Use conservation planning decision support software to assist with the derivation of an initial plan that takes into account the following multiple criteria:
   - Complementarity and efficiency in achieving biodiversity targets;
   - Building in longitudinal connectivity ;
   - Where a choice must be made between quaternary catchments with similar biodiversity components, in order of appearance below:
     - Choose rivers located near to or flowing through terrestrial protected areas;
     - Choose rivers that are adjacent to quaternary catchments that are flagged for river rehabilitation.
2. Add in additional quaternary catchments needed for rehabilitation.
3. Add in additional quaternary catchments required for large-scale species migration routes.
4. Build in large-scale connectivity where it is still needed.
5. Remove short stretches of river reach that are deemed too small to be viable.
6. Investigate the removal of marginal quaternary catchments, defined as those quaternary catchments where the percentage length of A or B class rivers is very low compared to the total length of river in that catchment.

This produced a river conservation design (Figure 17, p. 85) that contained quaternary catchments and rivers that are required for:

- Representation/target achievement. Any river selected should maintain its A or B present ecological integrity class.
- Rehabilitation to an A or B ecological integrity status to help achieve biodiversity targets.
- Large-scale migration routes. Catchments selected must be managed in an ecological integrity class that supports connectivity, preferably no lower than a C class.
- Upstream connectivity of river reaches. Catchments need not be in an A or B ecological integrity class, but they need to be managed to facilitate connectivity, preferably no lower than a C class.

The conservation plan requires 55 (27%) quaternary catchments in the Fish-to-Tsitsikamma Water Management Area to achieve the biodiversity targets for Level 3 river types. This translates to 29% of the total river length in the water management area. A further 27 (13%) of the quaternary catchments in the area (translating to an additional 13% of the total river length in the area) are required to maintain upstream and downstream connectivity. These catchments need not be in an A or B ecological integrity class, but will need to be maintained in a state that permits connectivity, ideally these should be no lower than a C state.

The proposed river selections would achieve the biodiversity targets of 76 (67%) river types in the Fish-to-Tsitsikamma Water Management Area. If the proposed quaternary catchments and rivers are rehabilitated, then 14 (12%) additional river types will meet their biodiversity targets. Thus, with feasible rehabilitation, 80% of the river types can meet their targets in the Fish-to-Tsitsikamma Water Management Area. It is not possible to meet biodiversity targets of the remaining 23 (21%) river types, as rehabilitation of examples of these river types is not feasible in this water management area.

9. CONCLUSIONS

Lessons learnt

Conservation planning for inland waters is a new and rapidly evolving field. The Fish-to-Tsitsikamma is the first river conservation plan to be devised for a water management area in South Africa (though some estuarine conservation plans have already been developed, e.g. Turpie and Van Niekerk 2004). Lessons from this planning exercise are already being applied in new conservation planning projects underway in the Crocodile (West) and Marico, and Olifants/Doorn Water Management Areas. Key lessons from this study include:

(i) National context: There is a need to consider the national context within which plans at the water management area level are undertaken, particularly when assessing river types that cannot meet conservation targets. A national process is underway to cascade national targets differentially across South Africa, based on a national conservation assessment of biodiversity. Currently, an assessment of the national context is constrained by data limitations: the assessment requires consideration of the distribution of biodiversity at a national level, combined with the ecological integrity of this biodiversity. Level 3 river types have not yet been developed at a national level as this requires constructing longitudinal zones for at least all 1:500 000 rivers in South Africa, an activity that is currently being undertaken by the Department of Water Affairs and Forestry. Ecological integrity has also not yet been developed for all 1:500 000 rivers, although the Department of Water Affairs and Forestry is currently attempting to initiate a national ecostatus determination process to derive these data. This is a time-consuming process and it is recommended that a suitable model be developed to predict river ecological integrity at finer scales (see Section 9.2).

(ii) Choosing which rivers to assess: Careful consideration needs to be given to choosing which rivers to assess in the conservation plan (i.e. which rivers data layer to use). River data layers for South Africa are available at scales of 1:500 000; 1:250 000 and 1:50 000. The 1:500 000 data layer is based on 1:500 000 topographical maps, but has been refined to include alignment of the rivers to within 50 m of 1:50 000 topographical maps. This is a marked improvement on the 1:250 000 rivers data layer which, although it contains more rivers, consists simply of the blue plates from 1:250 000 topological maps that have not been cleaned or hydrologically corrected. Rivers at the 1:50 000 scale have been hydrologically corrected and coded and may seem ideal; however: (i) using 1:50 000 rivers can lead to selecting streams that are of too small a size to satisfy biodiversity targets; and (ii) constructing longitudinal zones for all 1:50 000 rivers (required for Level 3 river typing) would also be an immense task. Using the 1:500 000 rivers as a base data layer and augmenting this with any other significant river reaches from the 1:50 000 data layer (identified by regional experts) seems to be a good compromise for planning at the level of a water management area.

(iii) Using sub-quaternary catchments: The conservation plan for the Fish-to-Tsitsikamma Water Management Area uses quaternary catchments as the basic units for selection, or planning units. Modelling smaller sub-quaternary catchments would produce a more efficient conservation plan, as this would incorporate specific rivers. This lesson has been carried forward to the Crocodile (West) and Marico conservation plan with some success, and it would be ideal to develop a data layer of such sub-quaternary catchments at a national level (see Section 9.2).

(iv) *Assessing ecological integrity at the level of river reach*: Conservation plans for river biodiversity are often constrained by a shortage of river ecological integrity information across a planning region, particularly in areas where many rivers are in a poor condition. Two methods are commonly used in South Africa to derive ecological integrity at a landscape level, namely present ecological status (Kleynhans 2000) or ecostatus determination approaches (Kleynhans *et al.* 2005). Both of these methods aggregate rivers into broad-scale assessment units. All rivers in the assessment unit are then assumed to have the same generalized ecological integrity class. This ignores the possibility that, at a finer scale within the broad assessment unit, there may be some rivers that are in better condition than others, and therefore limits the options for achieving biodiversity targets. Modelling river ecological integrity at the level of each individual river reach (e.g. reaches between river confluences) would enable a better assessment of options across the landscape (see Section 9.2)

(v) *Using preliminary conservation plans to guide field verification*: Conservation plans are dependent on the data that are used to derive them. Since ecological integrity data are extremely limited in the Fish-to-Tsitsikamma Water Management Area, a desktop ecological integrity score was derived using ecostatus determination techniques (Kleynhans *et al.* 2005). There was a need to undertake field verification in order to test the accuracy of these data before using these in the conservation planning exercise. Field sites were chosen mainly in areas where expert knowledge was lacking, so as to get a more consistent coverage of the landscape. However, in retrospect, to utilize resources most effectively, it would have been better to undertake a desktop conservation plan with preliminary data and then to visit the priority areas emanating from this process to verify that they do, in reality, contain the biodiversity components for which they were selected. Initially, this was not done so as not to bias the conservation plan.

(vi) *Preparation of the spatial data layers*: This is a time consuming process, but it is critical that sufficient time is spent making sure that these data layers are of high quality and contain no errors and data artefacts (e.g. slivers produced from spatial overlays may produce false river types).

(vii) *Hydrological index*: Great care must be taken when hydrological index classes are lumped together without a strong rationale for doing so. Initially, it appeared that it would be easier to deal with only three levels of flow variability. However, on closer inspection of the hydrological index data with regional experts, it seemed the hydrological index classes separated out true river types.

(viii) *Best Attainable Ecological Management Class*: These data (Kleynhans 2000) are broad-scale and outdated (assembled between 1996 and 1998), and should thus be applied with caution when assessing the rehabilitation potential of rivers. The available data tend to suggest that a river can be returned to a higher ecological integrity class than that which is currently deemed feasible by experts.

Future research and monitoring to support implementation of the conservation plan

The future research needs identified below would all feed into developing a national biodiversity assessment and conservation strategy, which is critical to provide context for conservation planning at a sub-national level:

(i) *Collecting and verifying primary data*: Conservation planning outputs are highly dependent on biodiversity pattern and ecological integrity data layers. These data layers have their limitations (Section 3.3 and Section 5.6), and require both expert and field verification. In addition, research on how best to supplement conservation plans with species data should be initiated, e.g. freshwater fish distribution data. Collecting high quality primary data for a region, or at a national scale, is well worth the investment because experience in terrestrial conservation planning (already over a decade old in this country; Driver *et al.* 2003) suggests that the primary data have a much longer life span than the conservation plan itself.

(ii) *Developing a model to predict ecological integrity, using existing data on land cover, dams and surface run-off*: A model has been developed for Australian rivers (Stein *et al.* 2002), which could be used as a basis for South African rivers. This model would need to be verified, a process which could be done together with the regional ecostatus determination due to be launched in the next year. Information Box 5 in Section 6.3 provides an example of what can be done using natural vegetation alone as a predictor of ecological integrity in South Africa. Point (iv) of Section 9.1 explains why this would provide better options for conservation planning.

(iii) *Modelling sub-quaternary catchments*: Point (iii) of Section 9.1 explains how the modelling of sub-quaternary catchments would prove far more efficient for conservation planning. Techniques have already been pioneered in the conservation plan for the Crocodile (West) and Marico Water Management Area, which is currently underway, and this would need to be extended to the entire country. Extending it to the entire country, rather than generating sub-quaternary catchments on a piece-meal basis, would facilitate synergy and alignment of the sub-quaternary catchments used. It would also facilitate efficiency in developing a national biodiversity assessment and conservation strategy.

(iv) *Incorporating wetlands*: There are a number of projects under way to promote the inventorying and classification of wetlands in South Africa. These are challenging in their own right, but once the spatial products are available, wetlands could be relatively easily incorporated into biodiversity pattern targets. The main challenges, related to future research for wetlands with regard to conservation planning, include: deriving wetland condition at a landscape level (this is probably best mapped using a predictive model similar to the one described in Section 9.1, point iii); incorporating the functional importance of wetlands; and setting biodiversity targets for wetland types. Some of these aspects are being pioneered at a very basic level in the conservation plan for the Crocodile (West) and Marico Water Management Area.

(v) *Incorporating ground water*: Research is required on how best to incorporate ground water into conservation planning. Whilst many research projects currently target management of groundwater, research focused on mapping ground water processes is limited. Efforts currently being applied in the Crocodile (West) and Marico conservation plan focus on identifying rivers that are highly dependent on ground water and areas important for ground water recharge. Although there are also preliminary maps of ground water dependent ecosystems, the areas that need managing in order to maintain these can be great distances away - maps of the actual areas that support ground water dependent ecosystems therefore need to be developed.

(vi) *Setting more ecologically meaningful targets for aquatic biodiversity*: It is recognised that the biodiversity target of 20% is arbitrary and not based on a sound scientific understanding of limits of acceptable change and other ecological thresholds. These targets may also differ for different ecosystem types (some may require a larger proportion than others in order to enjoy an adequate level of protection). Scientific research around ecological thresholds should therefore be undertaken to inform the setting of biodiversity targets.

Management actions

The maintenance of ecological integrity in selected river reaches is critical, and these reaches should be connected within the selected quaternary catchments via rivers that facilitate upstream and downstream connectivity. Selected estuaries should be afforded the appropriate level of protection, as suggested by their status as either an Estuarine Protected Area or an Estuarine Conservation Area. They should also have accompanying management plans, and a comprehensive estuary reserve assessment should be undertaken and implemented. Linking selected rivers and estuaries with the national water resource classification process is essential, as well as setting Resource Quality Objectives for all selected rivers and quaternary catchments.

Saunders *et al.* (2002) list the three primary causes of biodiversity loss in inland water systems: (i) land-use disturbances; (ii) altered hydrological regimes; and (iii) alien invasive species. This concurs with the findings of river health surveys in South Africa, where the destruction of riparian zones, flow regulation and alien species (including terrestrial and riparian flora as well as aquatic biota) are typically found to be the main factors having adverse impacts on river health. From these primary impacts, Roux *et al*. (2006) suggest three basic management actions that would go a long way to conserving inland water biodiversity. These are outlined below, with specific recommendations regarding the Fish-to-Tsitsikamma Water Management Area:

(i) *Negate effects of deleterious land-use activities*:
This would include:

- Conserving whole catchments if at all feasible. Where this is not possible, catchment zoning, (where the most deleterious activities for the resource are relegated to the part of the catchment furthest away from the river), should be used as a management option. Where the former options are not available, intact riparian buffer strips may be used to reduce the effects of deleterious land-use practices. Widths of 10-50 m have been found to be effective in maintaining ambient stream temperatures and retaining sediments and nutrients. The effective width of a riparian buffer strip should be determined on a site-specific basis, considering factors such as varying vegetation types channel form, and slope.
- Improving or re-instating extension in agricultural landscapes.
- Avoiding road crossings in selected rivers. Where they are necessary, ensure that their impacts are minimized. For example, bridges are better than causeways – where causeways have to be built, build a reasonable number culverts into the causeway so that water can flow freely in the active channel; build retaining walls for roads next to rivers (especially gravel roads).

(ii) *Retain natural flow regimes*:

This would include:

- Understanding the in-stream flow requirements of rivers.
- Managing the primary drivers of in-stream ecological integrity, i.e. in-stream water abstraction, flow modification, bed modification, channel modification, water quality and inundation (Table 9).
- Developing a water release plan for dammed rivers that is suited to maintaining the river in the desired ecological integrity (A or B class for rivers required to meet targets; preferably a C class for rivers required for maintaining connectivity).
- Building fishways in rivers required for connectivity. NOTE: alien infestations may need to be managed before this is done.
- Removing non-functional weirs, a common occurrence in the Fish-to-Tsitsikamma Water Management Area, particularly in the more arid inland areas of the region. NOTE: alien infestations may need to be managed before this is done.

(iii) *Exclude alien species:*

All selected catchments should have an alien organism management plan, which includes a monitoring component.

Identify a champion institution to coordinate implementation of this plan

Implementation of this conservation plan will require an effective integrated management approach where water resource management, land-use management, and biodiversity conservation are managed in a coordinated manner that aims to achieve ecological and socio-economic sustainability. To achieve this coordination, it is important to identify a regional champion institution to take responsibility for driving this plan forward. Importantly, conservation of inland water biodiversity is a cross-sectoral responsibility and the two departments with the most direct line responsibility are the departments of Water Affairs and Forestry, and Environmental Affairs and Tourism. However, to make cooperative implementation work in practice, one of these departments should take the lead.

The most appropriate framework within which to operate would be the Catchment Management Agencies under the auspices of the Department of Water Affairs and Forestry; however, it may take several years before all of these agencies are fully functional. In the interim, the most appropriated champion institution is the Resource Directed Measures and Water Resources Planning Directorates of the regional and national offices of the Department of Water Affairs and Forestry. This department should develop an implementation strategy and action plan with significant involvement of the provincial Department of Economic Affairs, Environment and Tourism and the Bioregional Coordination Unit (under the auspices of the South African National Biodiversity Institute). Other key stakeholders in the region to include in the implementation are presented in Table 2, but the list should be extended to include local and district municipalities and agriculture.

The implementation strategy and action plan should give due attention to the various roles and responsibilities in this complex cross-sector environment. Aspects that should receive attention in the implementation strategy include:

- Development of a cooperative governance framework which would form the building block for the implementation of the conservation plan for the region;

- Capacity (skills and knowledge) required to implement conservation action and to “do the right thing”;
- Financial resource requirements;
- Providing clear definition of roles and responsibilities, and possibly of required institutional and functional design aspects that are currently lacking;
- Problem-solving, negotiation and conflict management skills (this is an inevitable requirement where overlapping responsibilities and conflict of interests are realities); and
- Developing a monitoring and evaluation system, not only for achievement and revision of ecological and conservation targets or objectives, but also for institutional and individual performance measurements.

1 INTRODUCTION

1.1 Background and objectives

This study is a pilot study that forms part of a broader national initiative (see http://www.csir.co.za/rivercons/index.html as well as the Metadata CD[1] provided with this report). The national initiative aims to develop a policy and planning framework for systematic conservation of inland water biodiversity in South Africa, and was set up in 2003 between the Department of Water Affairs and Forestry and CSIR. Subsequently, the Water Research Commission added its support by sponsoring this project in the Fish-to-Tsitsikamma Water Management Area, which aims to **facilitate testing, refinement and demonstration of the river prioritization and selection tool at a sub-national scale**, and to provide an example of lessons learnt and best practice for use elsewhere in the country.

The formal aims for this project, as stipulated in the Water Research Commission contract are:

1. To put in practice and refine, through a pilot study in the Eastern Cape, the policy and planning tools developed within the broader national initiative for systematic conservation planning of rivers. This would facilitate testing, refinement and demonstration of the river prioritization and selection tool, and provide an example of best practice for use elsewhere in South Africa.

2. To ensure local and national stakeholder participation in developing the technical approach to river prioritization and selection, as well as the reviewing of results to facilitate buy-in and ownership of the final product.

The broad objectives of this project, which are aligned to the broader national conservation planning initiative, include:

- To develop methods and data layers for the spatial representation of both biodiversity pattern (so that a sample of all biodiversity can be conserved) and ecosystem processes (so that the processes that sustain biodiversity can be conserved). This needs to be done at scales that are appropriate to national and sub-national level conservation planning.
- To develop and test a technical selection tool and river prioritization framework for generating spatial options that will satisfy explicit and quantitative biodiversity targets.
- To contribute towards conservation plans and implementation strategies to facilitate the main-streaming of river conservation at sub-national levels (water management areas) across South Africa.

The approach adopted for this study is based on systematic conservation planning principles and methods. Although these are summarized briefly within this report, it is recommended that the reader consult Margules and Pressey (2000) for a more detailed account of systematic conservation planning, and Roux *et al.* (2006) for how it pertains to inland water ecosystems.

[1] Available from the Water Research Commission as part of this report.

1.2 Biodiversity conservation and water resource protection in South Africa

Biodiversity conservation is about sustaining the variety of life on earth. In recent decades inland water biodiversity throughout the world, South Africa included, has been severely impacted by human activities. This is reflected in the index of the world's freshwater species that shows a decline of 50% between 1970 and 2000 (WWF 2004). The indications are that human pressures on water resources will continue to grow at an alarming rate, causing ever-increasing degradation of inland water ecosystems and their biodiversity. This degradation puts aspects of economy and quality of life at risk, thereby reducing the spectrum of socio-economic options available to future generations (see Information Box 1).

Information Box 1: Why concern ourselves with biodiversity and the subsequent degradation of ecosystems?

The traditional rationale behind conserving biodiversity has focussed on biodiversity pattern, emphasizing the intrinsic importance people place on species and habitats – their value irrespective of their utility. Arguments for this approach centre on the right that present and future generations have to enjoy these species and habitats.

In recent times, more compelling arguments have been presented that link biodiversity to ecosystem services. These include **provisioning services**, such as food, and water; **regulating services** such as water flow regulation and purification; **supporting services** required to maintain other services, such as nutrient cycling; and **cultural services** such as recreation and spiritual services (Millennium Assessment 2003). These services are strongly correlated to quality of life, freedom of choice, security and poverty reduction. Loss of biodiversity inevitably leads to ecosystem degradation and subsequent loss of services that are important for all humankind. Moreover, loss of ecosystem services tends to harm rural poor communities more directly – poor people have limited assets and are more directly dependent on common property resources for their livelihoods, whilst the wealthy are buffered against loss of ecosystem services by being able to purchase basic necessities and scarce commodities. Our paths towards sustainable development, poverty reduction and enhanced human well-being for all, are therefore completely dependent on how effectively biodiversity is conserved.

In recognition of this, the South African National Water Act (Act No. 36 of 1998; Section 3) is explicit about the need to protect inland water ecosystems in order to allow for sustainable derivation of social and economic benefits from these systems. Importantly, it is not possible to allocate a high level of protection to all resources throughout the country without prejudicing social and economic development. Equally, it is not desirable for all resources to be classified at a uniformly low level of protection so as to permit maximum use and exploitation. The proposed **national water resource classification** provides a mechanism for balancing protection and utilization by assessing and managing aquatic resources in terms of a selected "ecological state" (Roux 1999, Roux 2001). Each of the proposed states has specific implications regarding the manner and extent to which the resource can be utilized, as well as the types of services that can be provided by the resource on a sustainable basis (Table 1).

To guide water resource classification, a national and sub-national conservation framework is required on the acceptable **proportion** of rivers that should receive high-level protection and be maintained in a natural state. This relates to having an explicit goal and quantitative targets for the protection of rivers. A second related issue is the need to identify **which** rivers should receive a high level of protection to ensure that a representative spectrum of biophysical river types is conserved. In conservation terms, this question relates to the delineation of biodiversity patterns and processes for rivers, as well as the prioritization of rivers for high-level protection. Such prioritization is based on multiple criteria, such as vulnerability, irreplaceability, extent of transformation, associated opportunity costs and biodiversity hotspots (Cowling 1999, Davis *et al.* 1999, Pressey 1999, Cowling and Pressey 2001, Roux *et al*. 2002).

The above two questions are addressed explicitly within this project and the broader national initiative, through application of systematic conservation planning principles. Over the last decade there has been a growing awareness that systematic conservation planning approaches are more effective and efficient at conserving biodiversity than are the *ad hoc* approaches of the past years. Consequently, systematic conservation planning is now a widely accepted approach that is applied by conservation organisations and agencies worldwide (Cowling 1999, Pressey 1999, Margules and Pressey 2000, Groves *et al.* 2002, Noss *et al.* 2002, Salafsky *et al.* 2002), and has recently been applied extensively by the Department of Environmental Affairs and Tourism (DEAT) in the development of South Africa's National Spatial Biodiversity Assessment (Driver *et al.* 2005).

The term biodiversity "conservation" within the context of this project is used to refer to efforts to maintain or restore the ecological integrity (including structure, composition and function) of inland water ecosystems to levels that are in accordance with the most stringent (most highly protected) water resource management class (e.g. the proposed "Natural" class of the water resource classification system, Table 1). Initiatives to conserve inland water biodiversity would thus not apply to all water resources, but only to those water resources that are awarded the highest protection level based on the national water resource classification system.

Table 1: The River Health and water resource classification systems
The relation between the classes used by the River Health Programme and those proposed by the national water resource classification system.

River health categorization (Roux 2004)		**Water resource classification system (DWAF 2004)**	
Category	**Description**	**Proposed class**	**Description**
Natural (Class A)	No or negligible modification of in-stream and riparian habitats and biota.	Natural	Human activity has caused no or minimal changes to the historically natural structure and functioning of biological communities, hydrological characteristics, chemical concentrations and the bed, banks and channel of the resource.
Good (Class B)	Ecosystem essentially in good state; biodiversity largely intact.	Moderately used or impacted	Resource conditions are slightly to moderately altered from the Natural class due to the impact of human activity and water use.
Fair (Class C)	Sensitive species may be lost, with tolerant or opportunistic species dominating.	Heavily used or impacted	Resource conditions are significantly changed from the Natural class due to human activity and water use, but are nonetheless ecologically sustainable.
Poor (Class D, E or F)	Mainly tolerant species present or alien species invasion; disrupted population dynamics; species are often diseased.	Unacceptably degraded resources	Due to over-exploitation, these rivers are already in a state that is ecologically unsustainable.

1.3 Approach

The approach adopted for this project is based on inland water conservation planning techniques that are being pioneered by the national initiative for systematic conservation of inland water biodiversity. The aim of conservation planning is to identify which areas of land, water and sea are crucial for ensuring living landscapes, waters and oceans, and to focus conservation action on those priority areas. Living landscapes, waters and oceans refer to ones that are able to support all forms of life, now and in the future (Driver *et al.* 2003).

Systematic conservation planning is founded upon several fundamental principles: the principle of representation and efficiency, persistence and quantitative target setting (Roux *et al.* 2006). The first principle requires efficient conservation of a representative sample of all species, and of the habitats in which they occur (as opposed to focussing only on the species that experts know well). However, conserving species and their habitats, often referred to as **biodiversity pattern**, is not enough. It simply provides a snapshot of the biodiversity that currently exists. The principle of persistence requires the conservation of the **biodiversity processes** that are responsible for maintaining and generating biodiversity over time. Finally, the principle of **quantitative target setting** requires the formulation of explicit goals with key stakeholders, which are then translated into quantitative targets for biodiversity features (e.g. length of river, area of catchment, design targets for connectivity). For a more detailed discussion of these principles, the reader is referred to Roux *et al.* (2006).

The fundamental principles of systematic conservation planning have formed the basis of the step-wise planning framework that has guided the approach followed in this project. There are seven main steps (Figure 1):

(i) Identify and involve key stakeholders during project initiation;
(ii) Develop spatial data layers for biodiversity pattern;
(iii) Develop spatial data layers for biodiversity process;
(iv) Develop spatial data layers for river integrity;
(v) Assess and prioritise estuaries;
(vi) Set quantitative biodiversity targets; and
(vii) Select and design areas for achieving biodiversity targets in both estuaries and rivers.

The planning framework was designed to engage expert river ecologists, hydrologists, geomorphologists and relevant stakeholders through a series of four workshops (Figure 1), in which participants were provided the opportunity to review the results of previous tasks and influence the approach to be followed in future tasks.

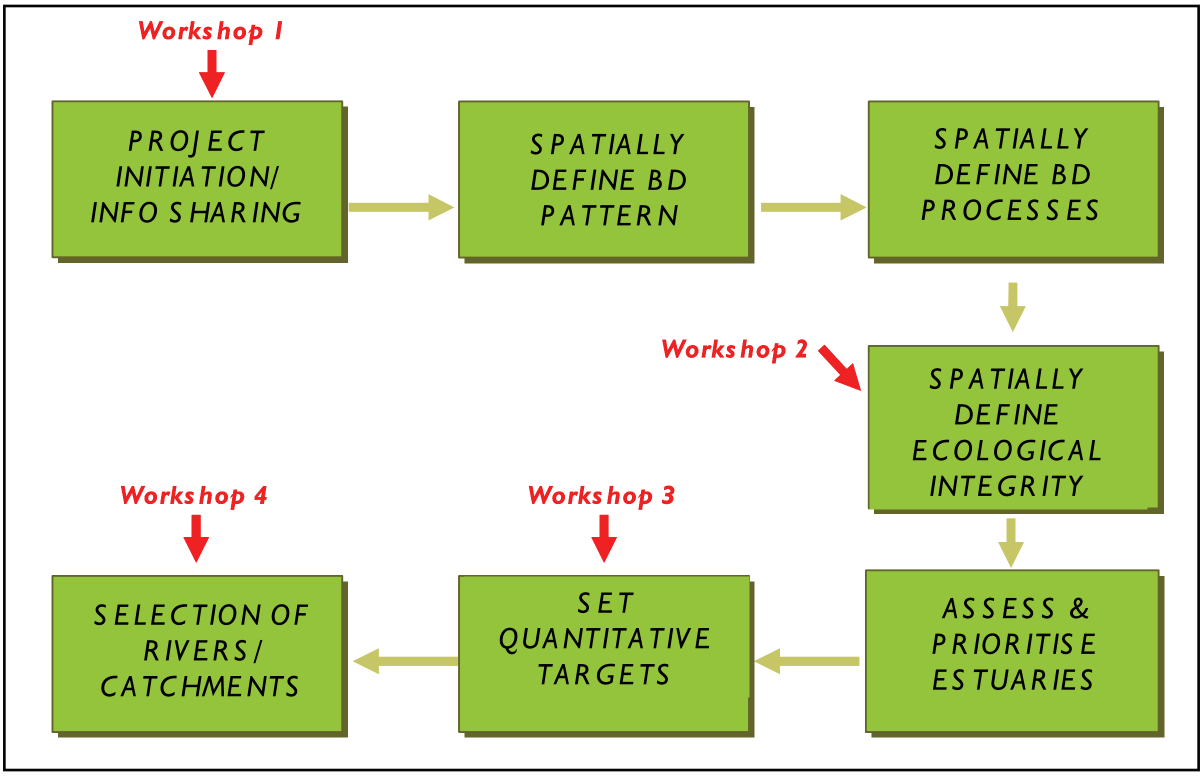


Figure 1: Step-wise planning framework adopted
The framework is based upon the fundamental principles of systematic conservation planning, and includes a series of workshops at key milestones in which workshop participants are provided the opportunity to influence both the approach and the outcomes.

2 DESCRIPTION OF STUDY AREA AND RELEVANT STAKEHOLDERS AND INITIATIVES

2.1 General description

The Fish-to-Tsitsikamma Water Management Area is one of 19 water management areas in South Africa. A summary of the general characteristics of the area is provided below. For a more detailed description, the reader is referred to Basson and Rossouw (2003).

Most of the Fish-to-Tsitsikamma Water Management Area (WMA 15) is situated mainly in the Eastern Cape Province of South Africa (Figure 2), with small portions on the north-western side within the Northern and Western Cape Provinces. It borders on the Mzimvubu to Keiskamma Water Management Area in the east, the Upper and Lower Orange Water Management Areas to the north, the Gouritz Water Management Area on the western side, and the Indian Ocean in the south.

Six primary catchments occur within the Fish-to-Tsitsikamma Water Management Area: the Fish (Q-catchment), Sundays (N-catchment), Gamtoos (L-catchment), Algoa (M-catchment) and Bushmans (P-catchment) primary catchments occur completely within the Fish-to-Tsitsikamma Water Management Area, whilst the Tsitsikamma (K-catchment) occurs partially within the area. These primary catchments mark the delineations of sub-water management areas. Major rivers in the Fish-to-Tsitsikamma Water Management Area are the Fish, Kowie, Bushmans, Sundays, Gamtoos, Krom, Tsitsikamma and Groot rivers.

The topography is characterized by relatively low elevation mountain ranges – with a general orientation parallel to the coast - in the south-western part of the water management area, with undulating terrain and isolated mountains inland and typical Karoo landscape in the north-west (Figure 2). Rainfall is strongly influenced by topography, with the highest mean annual rainfall (> 1000 mm) is recorded in the south-west on the coastal side of the mountains, which diminishes to less than 200 mm per year in the western inland areas. Most surface water is associated with the high rainfall areas, and the Algoa, Bushmans and Tsitsikamma primary catchments within the water management area produce about 40% of the runoff, even though they only comprise 10% of the area. Of the other primary catchments, about 25% of the runoff is contributed by the Fish, approximately 25% from the Gamtoos, and about 10-12% from the Sundays. Vegetation within this water management area ranges from lush forests and fynbos in the Tsitsikamma area, to sub-tropical thicket in the coastal and inland mountain areas (Vlok and Euston-Brown 2002), and sparse grassland and typical Karoo shrubbery inland of the coastal mountain ranges.

The majority of the population (90%) is centred in urban areas, mainly in the Algoa primary catchment. Some 98% of this urban population is concentrated in the Port Elizabeth-Uitenhage area. The rural population is sparsely distributed, particularly in the dry north-western portions of the water management area (Sundays and Gamtoos primary catchments), where most of the rural populations live in small towns. Large quantities of water are transferred into the water management area from the Upper Orange Water Management Area to augment existing quantity, as well as to blend with local brackish water to improve water quality. The transfers come from the Gariep Dam on the Orange River, via the Orange-Fish tunnel to the upper reaches of the Great Fish River, from where a portion of the water is transferred to the Sundays River for irrigation and urban/industrial use at Port Elizabeth. Other transfers within the water management area are from the Gamtoos and Tsitsikamma primary catchments to Port Elizabeth in the Algoa primary catchment, as well as a small transfer from the lower Great Fish River to Grahamstown in the Bushmans primary catchment.

Irrigation is by far the dominant water use in the water management area, representing 85% of the total water requirement, with most (96%) of this occurring in the Fish, Sundays and Gamtoos primary catchments (Basson and Rossouw 2003). Urban and industrial water requirements represent 13% of total water requirements (centred mostly in the Port Elizabeth area), whilst rural domestic use and stock watering represents only 2%. Commercial timber plantations occur in the higher rainfall region of the Tsitsikamma.

The surface water resources naturally occurring in the water management area have been highly developed, with limited ability for further development remaining. The main storage dams are:

- Grassridge Dam on the upper Great Fish River, Kommandodrift and Lake Arthur Dams on the Tarka River, and Katrivier Dam on the upper Kat River, in the Fish sub-area.
- Settlers Dam on the Kariega River in the Bushmans sub-area.
- Van Rynevelds Pass and Darlington Dams on the Sundays River and De Hoop Dam on a tributary, in the Sundays River catchment.
- Beervlei Dam on the Groot River and Kouga Dam on the Kouga River, the two main tributaries forming the Gamtoos River.
- Churchill Dam and Impofu Dam on the Krom River, in the Tsitsikamma sub-area.
- Groendal Dam on the Swartkop River in the Algoa sub-area.

Future proposed dams which are feasible are the Guernakop dam on the Kouga River and the Foxwood dam on the Koonap River near Grahamstown. The possibility also exists of increasing the volume of water transferred from the Orange River into the Great Fish River, with subsequent further transfers to the lower Sundays River.

Future water use/demand scenarios predict the same ratios of irrigation to urban-industrial water use, with the general trend being that of continuing concentration of economic development in the Port Elizabeth region and increased urbanization, resulting in an increase in water requirements in the Algoa primary catchment. Additional water needs are expected in the Bushmans and Tsitsikamma primary catchments; these are associated with the expected increase in standard of living and tourism opportunities in these regions. Much of the increased demand for water supply at the Coega Harbour development will be met by re-cycling of effluent water to be re-used for industrial purposes (Basson and Rossouw 2003).

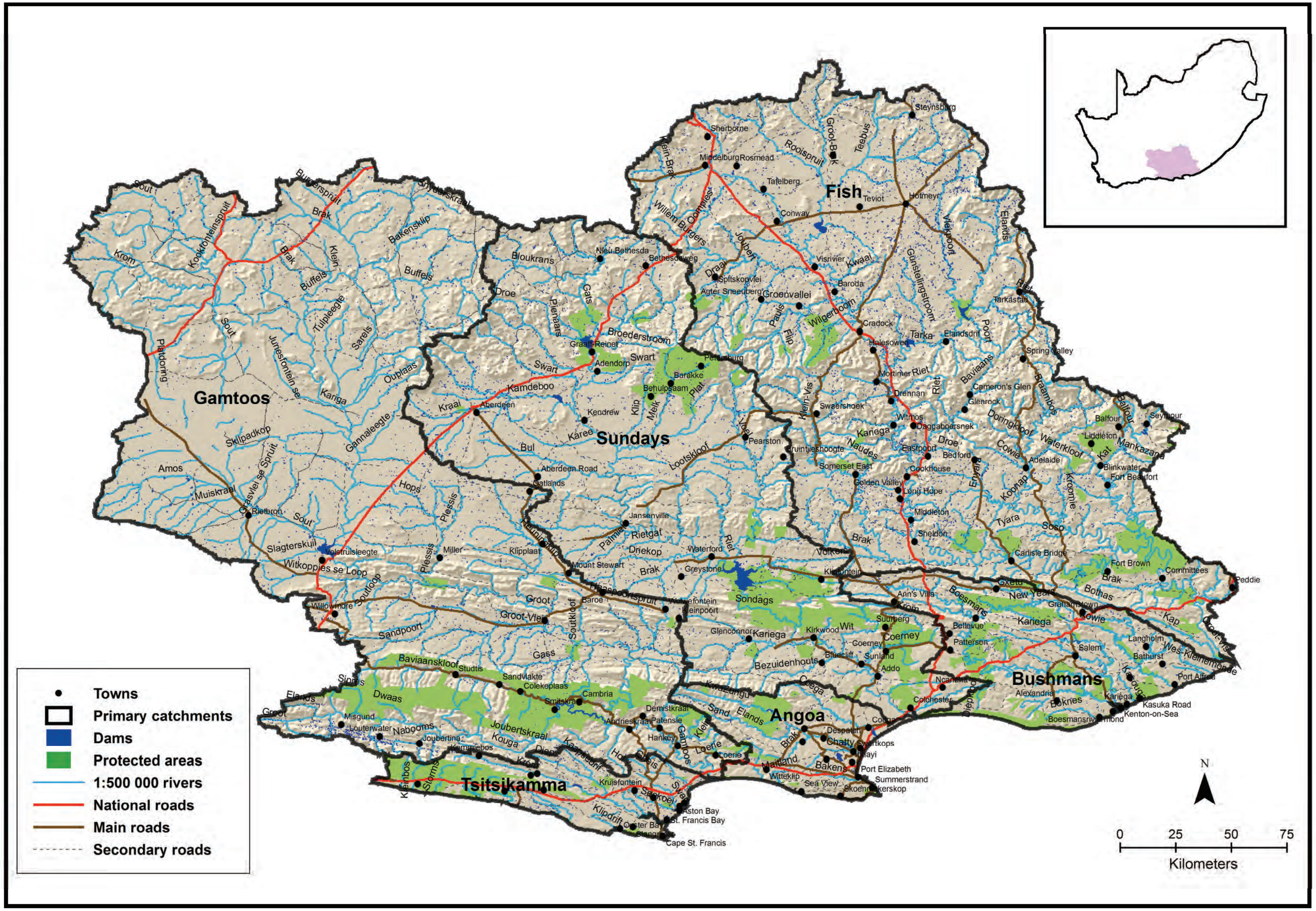


Figure 2: Map of the Fish-to-Tsitsikamma Water Management Area
The location in South Africa is shown in the inset.
The main map shows the 1:500 000 rivers selected for planning purposes, and the major towns and roads.

2.2 Key stakeholders

Lessons learnt from previous conservation planning exercises stress the importance of involving in the planning phase all those people who are responsible for implementation of the planning outcomes (Driver *et al.* 2003, Gelderblom *et al.* 2003). This ensures relevance of the outputs, and general agreement over the approach followed to arrive at those outcomes. A good way to involve stakeholders in the initial planning phase is to hold a series of workshops at project milestones to provide the opportunity for stakeholders to review and influence the planning process. For the Fish-to-Tsitsikamma project, these workshops were run in parallel to the national initiative which held a series of workshops specifically to address the development of a discussion document on cross-sectoral policy for conservation of South Africa's inland water biodiversity (Roux *et al.* 2006). These national and sub-national workshops have been, and will continue to be, instrumental within the community of scientists and resource managers in building a shared understanding of systematic conservation planning and how it can be applied to integrated water resource planning and management in South Africa.

This project comprises a core project team, including members from CSIR, the Directorate: Resource Quality Services within the Department of Water Affairs and Forestry, the Albany Museum, Rhodes University, Nelson Mandela Metropolitan University and South African National Parks (SANParks). In addition to the core project team, a number of stakeholders involved in integrated water resource management in the Fish-to-Tsitsikamma Water Management Area were consulted. Most of these stakeholders attended an initial information sharing workshop during the project initiation phase.

2.2.1 Department of Water Affairs and Forestry: National office

The planning outcomes of this project are intended to feed into the departments' water resource classification system, providing guidelines and recommendations on which rivers, and how many rivers, need to be afforded a high protection status (e.g. "Natural" under the proposed water resource classification system, Table 1). The Directorate of Resource Directed Measures is responsible for the development and implementation of the water resource classification system, and consequently this directorate has been closely involved in this project, as well as the national initiative to ensure that the planning process remains relevant and that the project outcomes can be incorporated into the classification system. At a national level, the Directorate of Water Resources Planning has also been involved, to align this project with the development of the Internal Strategic Perspectives (the pre-cursors to the Catchment Management Strategies) and compulsory licensing processes for each water management area.

2.2.2 Department of Water Affairs and Forestry: Regional office

The Department of Water Affairs and Forestry has four regional offices in the Fish-to-Tsitsikamma Water Management Area, namely:

- King Williams Town – regional coordination and management office;
- Port Elizabeth – focuses on water quality issues;

- East London – focuses on water quality issues; and
- Craddock - focuses on water supply issues.

Relevant representatives from all four offices were invited to participate in an information sharing session at the initiation of the project. Names and affiliations of these key stakeholders are provided in Table 2.

Table 2: Stakeholders consulted or involved in the first information sharing workshop. This workshop was held in Port Elizabeth on the 27 July 2004. DWAF refers to the Department of Water Affairs and Forestry; RDM refers to Resource Directed Measures Directorate

Name	Position	Level of Involvement
Mr Frans Stoffberg	Directorate: National Water Resources Planning ; responsible for this water management area)	Telephonic discussions Unable to attend workshop
Mr Alan Brown	National DWAF	Attended workshop on behalf of Frans Stoffberg
Mr Andrew Lucas	Regional DWAF: East London Water Quality Management	Attended workshop
Mr Pieter Retief	Regional DWAF: Port Elizabeth (water quality)	Attended workshop
Ms Phumza Kaleni	Regional DWAF: Port Elizabeth (water quality)	Invited to workshop Unable to attend workshop
Ms Dale Cobban	Regional DWAF office: King Williams Town (Reserve Determination and River Health)	Invited to workshop (delegated Ms Phumza Gasa-Lubelwana to attend)
Ms Pumza Gasa–Lubelwana	Regional River Health Coordinator (King Williams Town)	Invited to workshop Unable to attend workshop
Mr Theo Geldenhuys	Regional DWAF	Invited to workshop Unable to attend workshop
Mr Glenn Daniels	Regional CMA functions	Invited to workshop Unable to attend workshop
Mr Martin Labuschagne	Regional DWAF: Craddock	Attended workshop
Ms Thokozani Mbele	National RDM office	Attended workshop
Mr Dana Grobler	Consultant representing national Resource Directed Measures office	Attended workshop
Dr Mandy Cadman	Bioregional coordinator	Invited to workshop Unable to attend workshop

2.2.3 Bioregional Programmes Coordination Unit

The South African National Biodiversity Institute (SANBI) has established a Bioregional Programmes Coordination Unit in Port Elizabeth to coordinate the implementation of bioregional programmes in the Eastern Cape.

Bioregional programmes are biome-wide biodiversity initiatives that provide an agreed high-level vision, strategy and action plan for coordinating a wide range of multi-sectoral projects that integrate biodiversity conservation as well as economic development, community involvement and poverty alleviation. These programmes are partnerships that bridge gaps between government and non-government organisations, conservation and development agencies, civil societies and the private sector.

The coordination unit facilitates the implementation of terrestrial conservation plans within the region, supporting local authorities with the initiation and implementation of all plans. Three Bioregional Programmes – the Cape Action for People and the Environment (CAPE), the Subtropical Thicket Ecosystem Planning (STEP) project and the Succulent Karoo Ecosystem Project (SKEP) intersect in this region and span a number of fine-scale projects, thus requiring a coordinated response from authorities and land managers. It also aims to integrate land and water management and conservation and is therefore a key stakeholder for this project.

The implementation phase of the Subtropical Thicket Ecosystem Planning project is currently being developed and coordinated through this unit. Several priority areas within the Fish-to-Tsitsikamma Water Management Area have been proposed for biodiversity conservation. These priority areas, or "Megaconservancy Networks" seek to harmonize the goals of agricultural production, water management and nature conservation (see Information Box 2). The Great Fish/Kowie "Megaconservancy Network" is one of six priority areas, and has been identified as a suitable area for the initiation of the implementation phase. The Great Fish/Kowie initiative was launched in March 2004, and aims to develop with stakeholders, a common vision, strategy and action plan for biodiversity related activities in the Great Fish/Kowie catchments, identify and prioritize a number of pilot projects, initiate these and establish an appropriate coordination mechanism. Rehabilitation of parts of the Kowie River system, as recommended in Appendix 2 may very well align with this initiative.

As conservation planners strive for efficiency, it is ideal to establish synergies between terrestrial and inland water conservation plans – wherever possible overlapping priority areas for meeting land and water biodiversity targets should be selected, since this minimizes duplication and maximizes conservation effort.

Information Box 2: Megaconservancy networks identified by the Subtropical Thicket Ecosystem Planning (STEP) project (Cowling *et al.* 2003)

These are large conservation corridors of contiguous habitat, nested within primary water catchments, that achieve conservation targets for both biodiversity process and pattern, and also consider implementation opportunities (e.g. by incorporating existing protected areas) and constraints (by avoiding transformed areas and areas subject to pressures from land uses that are detrimental to biodiversity).

Megaconservancy networks consider spatial priorities for implementation, that *seek to conserve and enhance community resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased* (Knight and Cowling 2003a). This requires that water management, nature conservation and agricultural production are all managed in a coordinated manner aimed at achieving ecological and social sustainability. Knight and Cowling (2003a) list the following set of principles for implementing megaconservancy networks:

- Integrated management of natural resources and associated production systems;
- Integrated regional catchment approach to land management (megaconservancy networks are mostly nested within primary water catchments);
- Focus on land outside of formal protected areas;
- Voluntary cooperative participation; and
- Integration of an optimal mix of implementation instruments that include conservancies, formal protected areas, wildlife ranching, private and communally-owned nature reserves, support through extension, financial incentives, nature-based tourism, and policy and legislation.

The implementation concept recognizes the need for main-streaming the outcomes of conservation planning into the policies and practices of the newly emerging Catchment Management Agencies that are being implemented under the auspices of the Department of Water Affairs and Forestry. Since water catchments are the basic units of the living landscape concept that the Implementation Component of the Subtropical Thicket Ecosystem Planning project seeks to implement (Knight and Cowling 2003b), alignment of Catchment Management Agency activities with the goals of the Subtropical Thicket Ecosystem Planning project is essential.

2.2.4 Working for Wetlands

Ms Lil Haigh, from the Institute of Water Research at Rhodes University, and Mr Japie Buckle of Working for Wetlands (Eastern Cape Technical Advisor) have provided valuable insights and contributions to this project through attendance of the stakeholder meeting (Ms Lil Haigh) and the subsequent ecological integrity workshop (Mr Japie Buckle).

3 MAPPING BIODIVERSITY PATTERN FOR RIVERS

3.1 Introduction

Spatial biodiversity assessments rely on the identification of **biodiversity surrogates** to spatially represent biodiversity. For biodiversity pattern, these surrogates may be habitats, communities, taxonomic groups or species. Historically, biodiversity assessments have often focused on single species, often charismatic ones that catch people's imaginations, such as large mammals in terrestrial conservation plans, and fish in inland water conservation plans. However, unless species datasets are comprehensive, they should be used with caution in conservation planning because they can lead to bias in selecting only those areas which happen to have species data, ignoring potentially important areas where there are data gaps. For this reason, spatial assessments of biodiversity have moved away from using species as their primary biodiversity layer, and have started to focus on surrogates that use physical variables (such as climate, flow, geomorphology) that serve as a template for species. These physically-defined surrogates are preferable as they provide an effective and relatively inexpensive method of sampling biodiversity across the entire region in a consistent manner. Comprehensive species datasets, where they do exist, are then used to **supplement** the physically-defined biodiversity surrogates.

The Fish-to-Tsitsikamma assessment uses river heterogeneity signatures, hereafter referred to as **river types**, as the physically-defined surrogates to depict river biodiversity pattern consistently across the entire landscape. Heterogeneity is the ultimate source of biodiversity (Pickett *et al.* 1997), particularly in naturally disturbed and highly dynamic ecosystems such as rivers. Characterising this heterogeneity in time and space is key to predicting the pattern and distribution of riverine biota (Montgomery 1999, Berman 2002 and Du Toit *et al.* 2003), and can therefore be used as a basis for developing physically-defined biodiversity pattern surrogates for river ecosystems. Future assessments should attempt to supplement the physical river types with aquatic species datasets that have been relatively comprehensively surveyed across the planning domain, e.g. fish databases.

3.2 River typing

Heterogeneity within South African rivers is created primarily through physical processes, the main determinants being *water* acting as system driver on *sediment* as the material within the constraints of the *geomorphological* template (Dollar *et al.* in press). These three variables interact over time and space to drive system heterogeneity and hence biotic pattern and distribution. A hierarchical framework is currently being developed (Dollar *et al.* in press) to characterize South African rivers using these three physical descriptors:

- Geomorphological template (Level 1 descriptor);
- Hydrology (Level 2 descriptor); and
- Sediment (Level 3 descriptor).

The framework makes explicit the physical processes that drive river structure and resource dynamics, and includes reference to disturbance and recovery processes. This enables us to distinguish components of rivers which, under natural conditions, share the same biological response potential and associated biodiversity. These components, or "river types", can therefore be used as surrogates for predicting river biodiversity.

At the broadest level, rivers can be classified across the landscape according to geomorphology (Level 1) and hydrology (Level 2). Rivers have been classified according to these two levels across South Africa in a recent national assessment of rivers (Nel *et al.* 2004, Nel *et al.* in prep), in which geomorphic provinces represented the geomorphological descriptor, and the hydrological index, which characterizes flow variability (Hannart and Hughes 2003), represented the hydrological descriptor. At a finer scale, as in this study, it is appropriate to supplement these broad landscape-level descriptors of geomorphology and hydrology with a characterization of geomorphologic (longitudinal) zones at the level of individual streams. This longitudinal zonation serves as a surrogate for characterising the ability of a river reach to store or transport sediment, each zone representing a different physical template available for biotic habitation. Using this stream-level descriptor in conjunction with the landscape-level characterization of geomorphology and flow provides a surrogate of the biotopes expected within the river reach, which in turn can be used as a surrogate for biodiversity pattern within river ecosystems.

An overview of the three physical descriptors comprising the river types in the Fish-to-Tsitsikamma Water Management Area is provided below.

3.2.1 Level 1: Geomorphic provinces

Geomorphic provinces developed by Partridge *et al.* (in prep) were used to describe the geomorphological template. These geomorphic provinces have recently been refined and mapped according to information in Wellington (1955), King (1959) and Cole (1966). They represent regions of relatively uniform physiography that are more or less independent, though grading into one another, and are based on a hierarchy of criteria that include geomorphic history, geological structure, climate, location, and altitude. Geomorphic provinces impose broad constraints on the types of drainage basins, macro-reaches and channel types, and therefore the physical processes and types of biota that are found within each of these. For example, after severe floods, the subsequent patterns in sandy deposits will be determined by upstream geomorphology (Du Toit *et al.* 2003); these sandy deposits in turn affect the types of habitat and associated biota.

There are 35 geomorphic provinces in South Africa (Partridge *et al.* in prep), which are further divided into 42 sub-provinces. The sub-provinces were used to delineate the geomorphological template, of which ten fell within the Fish-to-Tsitsikamma Water Management Area (Figure 3, Table 3 and Table 4). Two of these provinces have their ranges almost entirely within the Fish-to-Tsitsikamma Water Management Area (Eastern Cape Fold Mountains and Queenstown Basin); thus, the responsibility for conserving representative rivers within these sub-provinces rests mainly with this water management area. Two geomorphic provinces (Southeastern Coastal Hinterland and Upper Karoo) are marginal to the water management area (have less than 10% of their national range).

Table 3: Geomorphic sub-provinces in the Fish-to-Tsitsikamma Water Management Area
After Partridge et al. *in prep.*

Geomorphic provinces (Sub-provinces)	**Description in study area**
Central Cape Fold Mountains	The Cape Fold Mountains province consists of the southern fold belt and an eastern fold belt. The province is composed of rocks of the Cape Supergroup, with the valleys consisting mainly of Bokkeveld shales. The high local relief resulted both from intense folding and faulting and the contrasting resistance of the alternating arenaceous and argillaceous beds. Trellis drainage patterns characterize this province. The province is divided into sub-provinces. The longitudinal profiles of the rivers in this sub-province are usually strongly concave, narrow in valley cross-sectional profile and mainly very steep in slope.
Eastern Cape Fold Mountains	Part of the Cape Fold mountains province (see province above), the Eastern Cape Fold Mountains sub-province runs east-west from the Bushmans River in the east to the Gamtoos River in the west. This sub-province differs from its central sub-province in that longitudinal profiles of these rivers range from medium to very steep and the valley cross-sectional profiles are broad to narrow. However, the valley slopes are gentler and valley cross-sectional profiles broader than those in the Central Cape Fold Mountains sub-province.
East London Coastal Hinterland	Karoo sediments underlie the province. This province was delineated on the basis of two factors. Firstly, remnants of the Cape Fold storm have folded the Karoo sediments in sympathy with the Cape Supergroup rocks resulting in the hydrography being deflected to the east. Secondly, profiles and macro-reaches of rivers are concave as opposed to the convex Southeastern Coastal Hinterland rivers. This combination has produced characteristic linear longitudinal river profiles in the province. In the study area rivers such as the Little Fish and Bushmans flow through this province. Slopes are generally steep and valley cross-sectional profiles are mainly narrow to medium. Concerning the latter exceptions include the Great Fish and Bushmans rivers.
Great Escarpment	The Great Escarpment separates the coastal hinterland of South Africa from the elevated interior plateau and is characterized by a variety of rocks of different ages. It owes its origin to the fragmentation or rifting of Gondwana in the late Jurassic and early Cretaceous. This erosional feature is subject to a very wide variety of climatic regimes and a significant source of runoff for the majority of South Africa's eastern flowing rivers. In the study area the Great Escarpment is bounded to the south by the Queenstown Basin and to the east by the Southern Karoo. It is relatively broad (up to 80 km) and consists of an intricate drainage network. Rivers traversing this area include the Buffels and Pienaars rivers. These rivers are all characterized by very steep and irregular longitudinal profiles and narrow valley cross-sectional profiles.
Queenstown Basin	The province is underlain by Beaufort Group sediments and is predominantly a Post-African I surface with steep dolerite koppies rising above it. It is the analogue of the Ladysmith Basin and also a rain shadow area because of the high mountains that flank it to the south. The Great Fish River that is characterized by mildly concave longitudinal profiles drains this province.

Geomorphic provinces (Sub-provinces)	**Description in study area**
Southeastern Coastal Hinterland	This extensive province is dominated by Karoo rocks (Ecca and Dwyka Groups in the north and Beaufort Group further south) with the southern area being capped by dolerite. The rivers flow off the Great Escarpment onto this province to the Indian Ocean dissecting steep valleys. The rivers flow orthogonally to the valley and ridge features and are therefore transverse to the structural and tectonically induced steps by dolerite sills and other hard lithologies. Uplift events in the Neogene resulted in the province being geologically diverse. Many of the rivers in this province are deeply incised in their middle and lower reaches. The valley slopes (steep and very steep) and valley cross-sectional profiles (mainly narrow with some medium) are also remarkably uniform throughout the province.
Southern Coastal Lowlands	The rivers in this province are underlain by Neogene marine and coastal aeolian sediments, including old dune lines and shoreline ridges. This province has a number of unique features. For example, the flatness of the province results in frequent flooding while the presence of dune ridges from high sea-stands commonly deflect rivers and coastal lagoons behind them, affecting their drainage. Major river systems include the Sundays in the east and the South in the west. Valley cross-sectional widths decreases from east to west and profiles are concave.
Southern Coastal Platform	This province is mainly composed of rocks of the Malmesbury Group and Cape Granite Suite and resistant quartzites of the Cape Supergroup. The province surface is an erosional feature which was produced by marine planation along the southern coastal margin during the Miocene. Much of the rivers in the province are deeply incised and cross the platform in spectacular gorges. They display narrow, deep valleys that are maintained due to the resistance of the Table Mountain group quartzitic sandstones and their longitudinal profiles are concave.
Southern Karoo	The Southern Karoo, an arid province, consists of the flat-lying rocks of the Karoo Supergroup between the Cape Fold Mountains and the Great Escarpment. The Karoo strata are folded in sympathy with the Cape Fold Mountains to the south resulting in the topography being conspicuously more rolling than in the case of the Upper Karoo. Drainage lines are almost ubiquitously ephemeral, following broad, open valleys. Close to the Great Escarpment alluvial fans are very common. Eastern rivers drain south into the Cape Fold Mountains and hence to the Indian Ocean whereas western rivers drain northwest into the Atlantic Ocean. In the study area the rivers are characterized by broad valley cross-sectional profiles and medium to very steep slopes, with a clear trend of wider valleys and flatter slopes in the east and narrower valleys and steeper slopes in the west.
Upper Karoo	Flat-lying sedimentary rocks of the Karoo Supergroup make up this extensive province. These rocks have been intruded by innumerable sills or dykes of dolerite and some in the form of transgressive cone-sheets. The relief associated with the lithologies in the province is varied (e.g. tabular tafelkoppies, bouldery ridges and high steep-sided mountains). Much of the province consists of multi-concave pediments. Rivers rising within this province occupy broad, open valleys, are mostly ephemeral and have braided floodplains and concave longitudinal profiles. However, there is a clear trend from east to west in the province. Flatter valleys slopes and narrower cross-sectional profiles occur in the east and marginally steeper slopes and wider valley cross-sectional profiles occur in the west.

Table 4: Extent of geomorphic sub-provinces
Percentage land surface in the Fish-to-Tsitsikamma Water Management Area (FTT) is calculated as the area of each sub-province within the Fish-to-Tsitsikamma Water Management Area expressed as a percentage of the total area of the water management area. The proportion range in South Africa (SA) is expressed as the percentage area in the Fish-to-Tsitsikamma Water Management Area in relation to its area in South Africa.

Geomorphic sub-province (after Partridge *et al.* in prep)	**% land surface in FTT**	**Proportion range in SA**
(Central) Cape Fold Mountains	7	19
(Eastern) Cape Fold Mountains	13	100
East London Coastal Hinterland	12	62
Great Escarpment	15	28
Queenstown Basin	8	80
Southeastern Coastal Hinterland	9	7
Southern Coastal Lowlands	5	57
Southern Coastal Platform	2	16
Southern Karoo	25	43
Upper Karoo	4	4

3.2.2 Level 2: Hydrological index

South African rivers are largely event-driven. Spatial and temporal distribution patterns of biota are strongly determined by variability, timing, duration, intensity and frequency of flooding (flow) events. The hydrological index (Hannart and Hughes 2003) was used to characterize hydrological variability, measured as a ratio of flow variability to base flow in a river. For South African rivers, a hydrological index value of close to 1 will be found for regions of low variability (commonly referred to as perennial-type rivers) and a value of > 50 would indicate semi-arid regions of high variability (periodic- or ephemeral-type rivers). Hydrological index values for all 1986 quaternary catchments in South Africa were grouped into nine statistical classes (Table 5; Figure 4) using an automated version of the Worsley Likelihood Ratio test (Worsley 1979; Dollar *et al.* submitted). For the purposes of this study, and based on expert evaluation of the nine classes, any quaternary catchments with a hydrological index of 1-5 were assumed to contain rivers that exhibit permanently flowing characteristics.

Table 5: Nine statistical classes of hydrological index
Classes were derived by Dollar et al. *(submitted) using the hydrological indices derived by Hannart and Hughes (2003) for all 1986 quaternary catchments in South Africa, Lesotho and Swaziland.*

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

Seven out of the nine hydrological index classes occur in the Fish-to-Tsitsikamma Water Management Area - hydrological index classes 8 and 9 are absent. As expected, the characteristically drier geomorphic provinces (such as the Upper Karoo and Southern Karoo) generally have higher hydrological index classes reflecting the relatively high proportion of periodic- or ephemeral-type rivers, whilst the Southern Coastal Platform and Cape Fold Mountains contain predominantly lower hydrological index classes, indicative of perennial-type rivers (Figure 4).

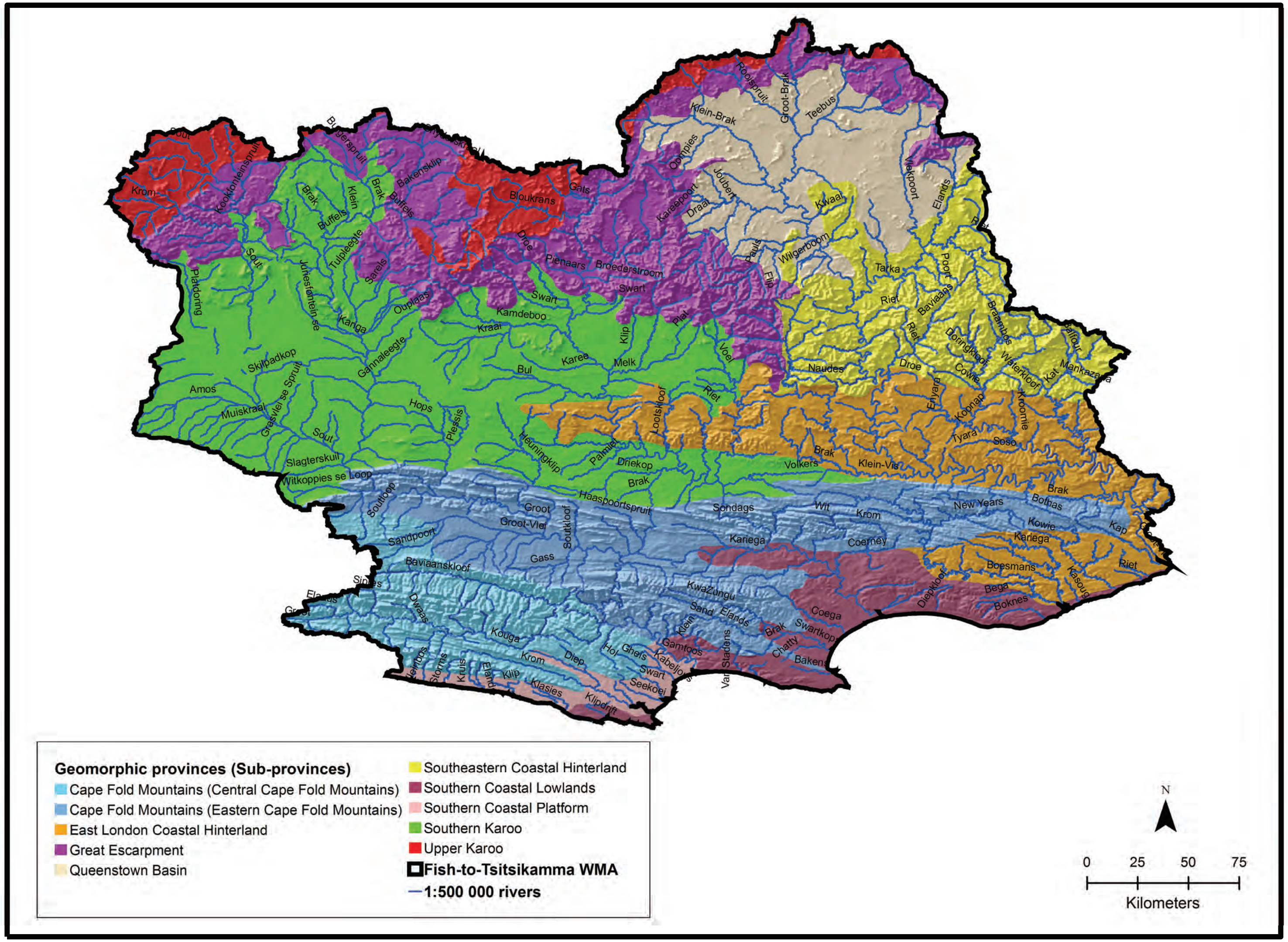


Figure 3: Geomorphic provinces within the Fish-to-Tsitsikamma Water Management Area
Delineated by Partridge et al. *(in prep) on the basis of descriptions by Wellington (1955), King (1959) and Cole (1966).*

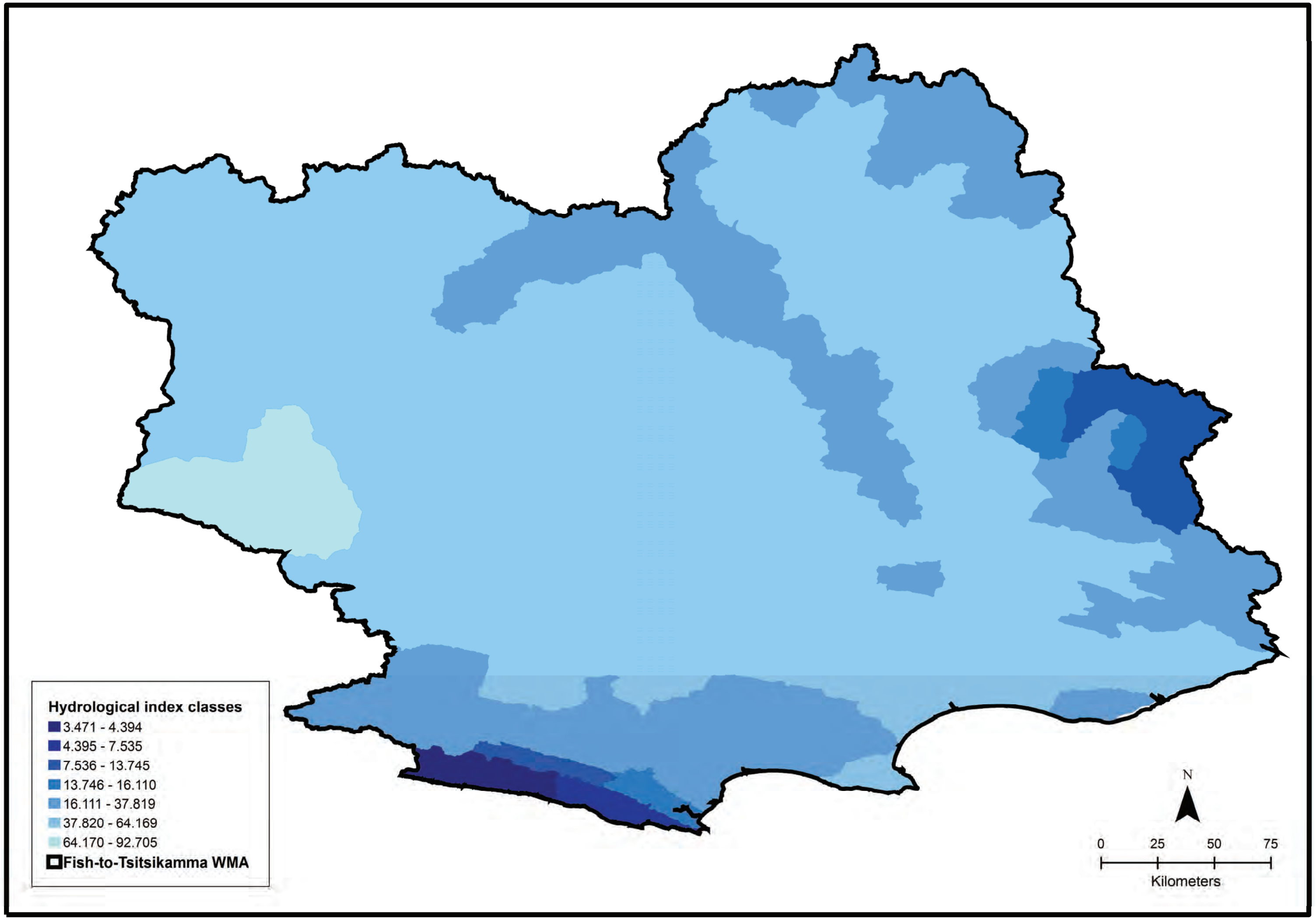


Figure 4: Hydrological index classes in the Fish-to-Tsitsikamma Water Management Area
Based on hydrological indices for quaternary catchments from Hannart and Hughes (2003), which describe hydrological variability as a ratio of flow variability to base flow in a river. This ranges from class 1 (labelled 3.471-4.394 on legend) to 8 (labelled 64.170-92.705 on legend) in the study area.

3.2.3 Level 3: Longitudinal zones

River channels are longitudinal features that are formed by the water that drives the system and the sediment which is transported or deposited in the system. As the river gradient decreases (towards the sea) the velocity of water will slow (Barber-James *et al.* 2002). This also results in changes in the types of particles found where larger, coarser particles are typically found in upper reaches, and finer, siltier particles are located in the lower reaches towards the ocean. These changes in sedimentation create different in-stream biotopes for biota. Longitudinal zones thus represent the physical surrogate for the ability of a stream or river to store and/or move sediment and consequently provide different in-stream biotopes for different biota (Barber-James *et al.* 2002). These longitudinal zones, together with the descriptor of flow regime (Level 2 river type) describe the habitat availability and the type of biota expected in these habitats.

Longitudinal zones, as defined by Rowntree and Wadeson (1999), were used to depict Level 3 river types for individual streams. These zones are determined based on changes in the gradient of a river's longitudinal profile (Figure 5). Table 6 describes the resulting longitudinal zones that are divided spatially along the longitudinal profile of a river, based on gradient.

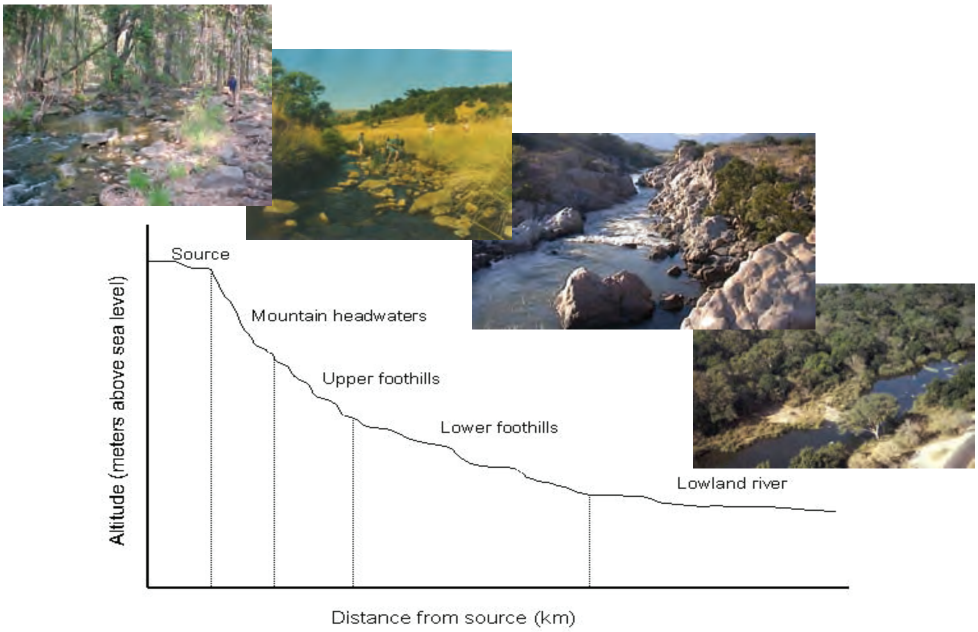


Figure 5: Schematic diagram of longitudinal zones from the source of a river to the sea

Rowntree and Wadeson (1999) use longitudinal channel slope to classify a river into the longitudinal zones described in Table 6. Although only gradient is described in Table 6, valley form is also taken into consideration in the final classification. Based on the model proposed by Rowntree and Wadeson (1999), the longitudinal zones of the rivers of the Fish-to-Tsitsikamma Water Management Area were identified using a semi-automated procedure developed at the

Directorate: Resource Quality Services, Department Water Affairs and Forestry[2], based on the river channels of the DWAF 1:500 000 river coverage (adjusted to within 50m of 1:50 000 rivers) and a 20 x 20m resolution Digital Elevation Model (derived by *Computmaps* from contours at 20m intervals).

For the purposes of depicting biodiversity at the scale appropriate for conservation planning at this sub-national level, the Rowntree and Wadeson (1999) longitudinal zones were combined into seven zones as follows:

1. Source zones kept separate
2. Mountain headwater streams and Mountain streams combined
3. Transitional zones kept separate
4. Upper foothills zones kept separate
5. Lower foothill zones kept separate
6. Lowland rivers kept separate
7. 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.

[2] Available from Directorate: Resource Quality Services, Department Water Affairs and Forestry. Contact Juanita Moolman

Table 6: Description of the longitudinal zones (after Rowntree and Wadeson 1999) This includes information on the channel types characteristics of those zones.

	Longitudinal Zone	*Gradient class*	*Characteristic Channel Types*
S	*Source zone*	Not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
A	*Mountain Headwater stream*	> 0.1	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
B	*Mountain stream*	0.04 - 0.99	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
C	*Transitional*	0.02 - 0.039	Moderately steep stream dominated by bedrock or boulder. Reach types include plain-bed, pool rapid or pool riffle. Confined or semi-confined valley floor with limited flood plain development.
D	*Upper Foothills*	0.005 - 0.019	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present.
E	*Lower Foothills*	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
F	*Lowland river*	0.0001-0.001	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.
Additional zones associated with a rejuvenated profile:			
	Rejuvenated bedrock fall / cascades	> 0.02	Moderate to steep gradient, confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid.
	Rejuvenated foothills	0.001 – 0.02	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge. Characteristics similar to foothills (gravel/cobble-bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.
	Upland flood plain	< 0.005	An upland low gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.

3.2.4 Landscape-level river types

Landscape-level river types, which combine geomorphic provinces and the hydrological index classes, represent the broadest physical surrogate of biodiversity pattern across the landscape; they characterize rivers according to landscape-level features. Finer-scale river types go beyond the landscape to characterize individual rivers and streams.

Rivers used to classify river types for the Fish-to-Tsitsikamma Water Management Area were taken from the 1:500 000 rivers GIS layer[3], available from the Department of Water Affairs and Forestry. First, the river and geomorphic province GIS layers were spatially overlayed to classify rivers according to the geomorphic province within which they occur. Next, the hydrological index class was joined to the rivers using a relational join on the quaternary catchment identifier. 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 up, producing 27 unique combinations of geomorphic provinces and hydrological index, which can be considered Level 2 river types (Figure 6).

Of these 27 Level 2 river types, the Southern Karoo 6, Eastern Cape Fold Mountains 6, and East London Coastal Hinterland 6 river types are the most extensive, being the only river types whose lengths are > 10% of the total river length for the water management area (Table 7, Figure 6). Five river types (Central Cape Fold Mountains 1, Central Cape Fold Mountains 2, Southern Coastal Lowlands 2, Southern Coastal Platform 1, Southern Coastal Platform 2), have river lengths < 1% of the total river length for the water management area but appear to be legitimate types rather than data artefacts created from GIS overlays. Nine of these landscape-level river types have the majority of their range (>75 %) within the Fish-to-Tsitsikamma Water Management Area (Table 7) - the conservation of these river types is largely dependent on efforts within this water management area.

3.2.5 Stream-level river types

The 27 landscape-level river types, classifying rivers according to geomorphic provinces and hydrological index, were overlayed with the longitudinal zones defined at the level of individual streams. This produced 113 combinations, which can be considered Level 3 river types (Appendix 1, Figure 7), which were used as the final river types in the conservation plan.

[3] Owned by Dept Water Affairs and Forestry, Directorate: Business Information; see http://www.dwaf.gov.za/iwqs/gis_data/river/rivs500k.html

Table 7: Level 2 river types for the Fish-to-Tsitsikamma Water Management Area
There are 27 Level 2 river types, made up of unique combinations of geomorphic province and hydrological index class. % WMA length is the length of the river type expressed as a percentage of the total river length within the water management area; % National length is the length of each river type expressed as a percentage of its total length in South Africa.

Level 2 river type	Length in WMA (km)	% WMA length	% National length
(Central) Cape Fold Mountains 1	62	<1	51
(Central) Cape Fold Mountains 2	60	<1	13
(Central) Cape Fold Mountains 5	742	4	30
(Central) Cape Fold Mountains 6	281	2	12
(Eastern) Cape Fold Mountains 5	591	3	97
(Eastern) Cape Fold Mountains 6	1936	11	99
East London Coastal Hinterland 3	179	1	24
East London Coastal Hinterland 5	838	5	46
East London Coastal Hinterland 6	1903	11	100
Great Escarpment 5	891	5	81
Great Escarpment 6	1429	8	50
Queenstown Basin 5	352	2	80
Queenstown Basin 6	783	4	100
Southeastern Coastal Hinterland 3	314	2	3
Southeastern Coastal Hinterland 4	183	1	9
Southeastern Coastal Hinterland 5	437	2	18
Southeastern Coastal Hinterland 6	895	5	100
Southern Coastal Lowlands 2	20	<1	11
Southern Coastal Lowlands 5	224	1	67
Southern Coastal Lowlands 6	507	3	100
Southern Coastal Platform 1	80	<1	64
Southern Coastal Platform 2	52	<1	9
Southern Coastal Platform 5	274	2	43
Southern Karoo 6	3376	19	40
Southern Karoo 7	629	4	77
Upper Karoo 5	282	2	45
Upper Karoo 6	362	2	4

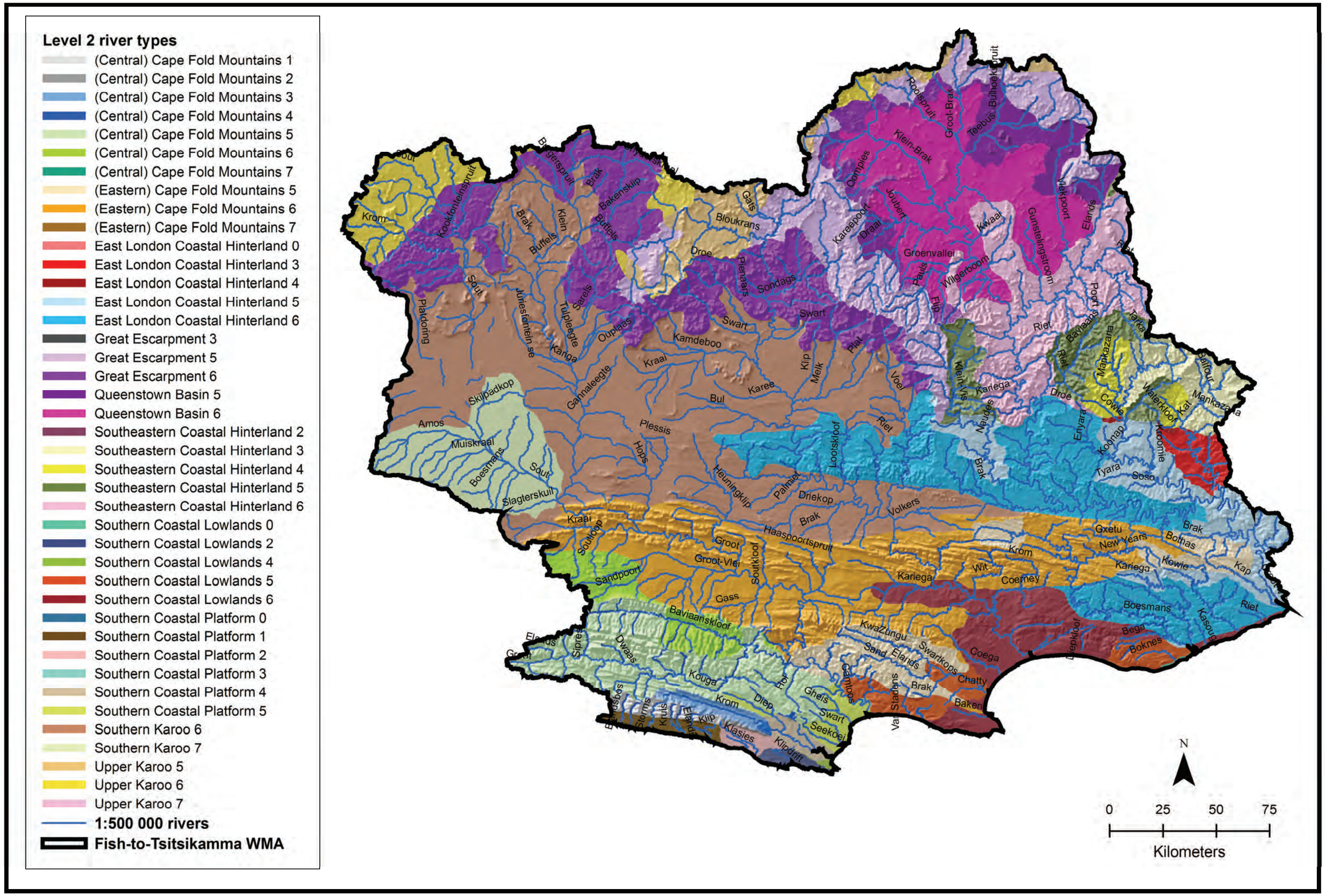


Figure 6: Level 2 river types for the Fish-to-Tsitsikamma Water Management Area
These river types are classified at the landscape level, where unique combinations of geomorphic provinces and the hydrological index produce 27 Level 2 river types.

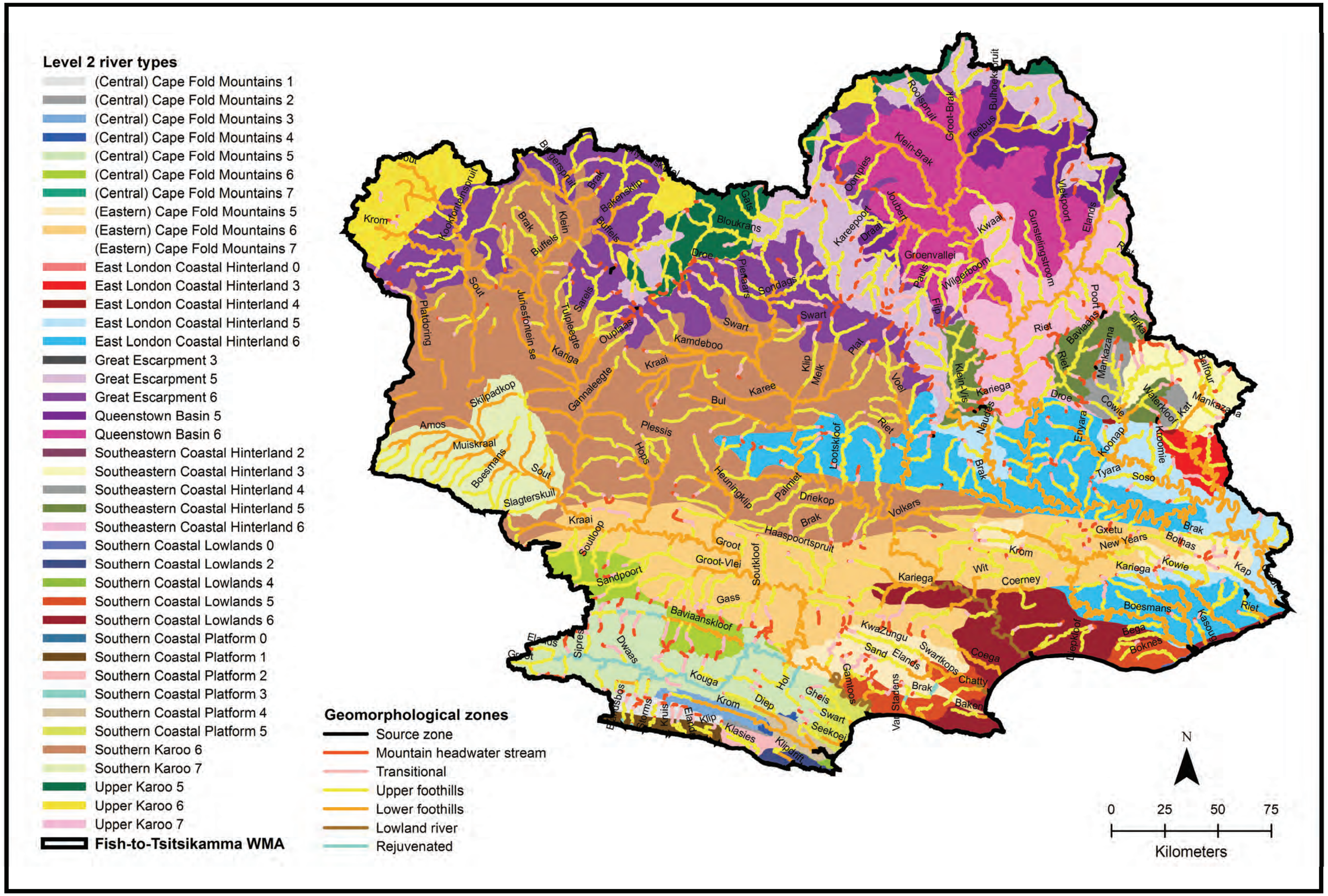


Figure 7: Level 3 river types for the Fish-to-Tsitsikamma Water Management Area
These are classified at the level of individual stream using longitudinal zones and Level 2 river types at the landscape level. Unique combinations of geomorphic province, hydrological index and longitudinal zones produced 113 Level 3 river types.

3.3 Limitations of the river types and recommendations for improvement

River types developed for this assessment are preliminary, and are still in the process of review and refinement. A review of the river types will include aspects such as assessing whether each river type is a true reflection of river biodiversity or an artefact of combining the GIS layers for geomorphic province and hydrological index classes. Boundaries between geomorphic provinces are gradual, not discrete, as depicted in the GIS layer. Combining the GIS layers for geomorphic provinces and hydrological index classes may thus create false river types, particularly for rivers falling near geomorphic province interfaces.

Refinements that are beyond the scope of this project will include extending the hydrological descriptor to include a measure of the effectiveness potential of flood flows on the surrounding landscape. At present, the hydrological descriptor merely addresses hydrological variability through the hydrological index developed by Hannart and Hughes (2003). When a flow event occurs, it is important to understand what potential it may have to alter the landscape, and hence patterns and distribution of biota. Stream power per unit area (a combination of depth, velocity and area) would serve as a good surrogate in this regard.

The adequacy of river types as surrogates for riverine biodiversity pattern needs to be rigorously tested. In terrestrial ecosystems, landscape surrogates (such as vegetation types and land classes), which are analogous to the river types, have been found to represent terrestrial biodiversity pattern better than any species surrogate (Lombard *et al.* 2003), but perform particularly poorly at representing range-restricted species. Transferring this understanding of terrestrial biodiversity surrogates to rivers, it is therefore important to consider supplementing the river types with good species datasets, such as fish. Datasets should be assessed for use based on criteria of:

- Geographic coverage with limited survey bias;
- Taxonomic completeness i.e. Records for all or most species within the taxon;
- Sound taxonomic knowledge i.e. High levels of confidence in the taxonomy of the species within the dataset; and
- Spatial resolution.

4 INCORPORATING BIODIVERSITY PROCESSES

4.1 Introduction

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 interspecific interactions, short- and long-term dispersal, nutrient cycling, sediment transport, water recharge areas and flow regimes.

Roux *et al.* (2006) outline four principles that need to be considered in inland water conservation plans to incorporate key biodiversity processes:

- (i) Select ecosystems of high ecological integrity;
- (ii) Ensure connectivity;
- (iii) Include rivers of sufficient size; and
- (iv) Include additional large-scale biodiversity processes.

The first three of these principles require explicit consideration during the selection and design procedures (Section 8); the last principle requires explicit mapping of large-scale biodiversity processes across the landscape. These four key principles are discussed below in terms of how they were used in the Fish-to-Tsitsikamma conservation plan to incorporate biodiversity processes.

4.2 Select ecosystems of high ecological integrity

Ideally, those rivers that are currently considered to be of high integrity should be selected for the purposes of conserving biodiversity, since these are the rivers that accurately represent the biodiversity of the region, and in which ecological and evolutionary processes operate within their natural ranges. Incorporating rivers 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 that are currently of high integrity also: (i) facilitates operational management since rivers 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 estuaries for the region is dealt with in Section 5 and Section 7.3 respectively. For the purposes of this project, only rivers with a present ecological integrity of “Natural” or “Good” (equivalent to A or B class rivers) were selected; and estuaries considered to be in a “Poor” state were excluded.

4.3 Ensure connectivity

4.3.1 Longitudinal connectivity

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

Longitudinal connectivity in the Fish-to-Tsitsikamma Water Management Area was maintained by incorporating, where possible, whole river systems in the conservation plan. However, it is seldom possible to find whole river systems in a consistently high ecological state (where the river is Class A or B throughout its entire tertiary or primary length). Rivers that were selected for conservation in a natural class (Class A or B; Section 5) were connected through rivers that are only moderately used or impacted (Class C; Section 5). Such connecting rivers were incorporated explicitly into the final conservation plan, with the recommendation that these should be maintained these in a state that promotes longitudinal connectivity for its associated biodiversity.

4.3.2 Lateral and vertical connectivity

Since the lateral and vertical zones of a catchment are all interconnected, the ecological integrity of the whole catchment needs to be managed appropriately in order to conserve river and estuary biodiversity. Lateral and vertical connectivity was incorporated into the Fish-to-Tsitsikamma conservation plan by including the entire quaternary catchments within which selected river reaches occurred, highlighting that these quaternary catchments will require careful selection of appropriate land use practices in order to meet the level of protection awarded to the water resource. 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 quaternary catchments.

4.4 Include rivers of sufficient size

Any inland water conservation area should be sufficiently large to allow biodiversity features to recover from natural disturbances and have populations that are large enough and reproduce sufficiently to remain viable in the long term. The actual extent of what constitutes "sufficient size" will vary between systems and what is being conserved, and should be assessed on a case-by-case basis.

Each river reach chosen for inclusion in the Fish-to-Tsitsikamma conservation plan was evaluated in terms of its size and viability. In most cases, only reaches over 5 km were chosen for conservation purposes. However, there were a few instances, mainly in headwater streams, where the only option to conserve a representative stretch of river was in a reach of < 5 km, which was connected to rivers of lower integrity (Class C-F; see Section 5). Because headwaters are by definition shorter rivers and can be important and viable for specific aquatic biota even with their small size, it was decided that they should be included in the conservation plan ***provided*** that the length of river contributing to targets (i.e. in a Class A and B) did not fall below 17% of the total length of river in that quaternary catchment. The threshold of 17% was derived by assessing the cost of including quaternary catchments of low overall integrity versus the benefit of meeting targets in the overall plan (see Section 8.8).

4.5 Include additional large-scale biodiversity processes

Incorporating ecosystems of high ecological integrity also helps to include many of the smaller-scale biodiversity processes that characterize river systems (Section 4.2). However, it is also important to consider any large landscape-level biodiversity processes that often operate over long distances, such as large-scale migration routes.

The Fish-to-Tsitsikamma Water Management Area contains many permanently open estuary mouths (see Section 7), which serve as large-scale migration routes for freshwater eels and the freshwater mullet, *Myxus capensis* (see Information Box 3). The desktop ecological importance and sensitivity scoring system (Kleynhans 2001) was used to identify quaternary catchments of national importance for migration. This system was developed in 1998 by regional experts for all quaternary catchments in South Africa and scores the catchments according to their importance for various criteria, one of which is migration. The scores range from 1 (of low importance) to 4 (of national importance). All quaternary catchments where migration was considered nationally important (i.e. where ecological importance score for migration = 4) were included in the Fish-to-Tsitsikamma conservation plan (Figure 8).

Information Box 3: Importance of migration routes for freshwater eels (*Anguilla* species) and freshwater mullet (*Myxus capensis*) *(after Roux* et al. *(2006) and Skelton (1993) respectively)*

Freshwater eels require marine, estuarine and freshwater habitats to complete their life cycle. Freshwater eels of the family Anguillidae spawn in the ocean near Madagascar and then the almost transparent young float as leaf-like leptocephalus (eel larvae) with the currents along the South African coast. Triggered by freshwater outflows from rivers along the coast the so-called ‘glass eels’ continue the migration through the estuarine into the freshwater ecosystem. Some eels, especially the females, penetrate high up into river systems. They mature for up to 20 years in these rivers after which they start to turn a silver colour, their gonads develop for the first time and they begin their downstream migration to the marine environment, eventually to spawn and die off Madagascar. Their young then float in the currents to restart this interesting life cycle. Rivers in the Fish-to-Tsitsikamma offer eels important habitat to complete the longest of all their life-cycle stages, namely the freshwater stage.

Myxus capensis is endemic to southern Africa and may occur further than 100 km inland. It breeds at sea and then juveniles move into estuaries, entering rivers usually during late winter or early spring. Males remain in freshwater for up to 4 years, females for up to 7 years.

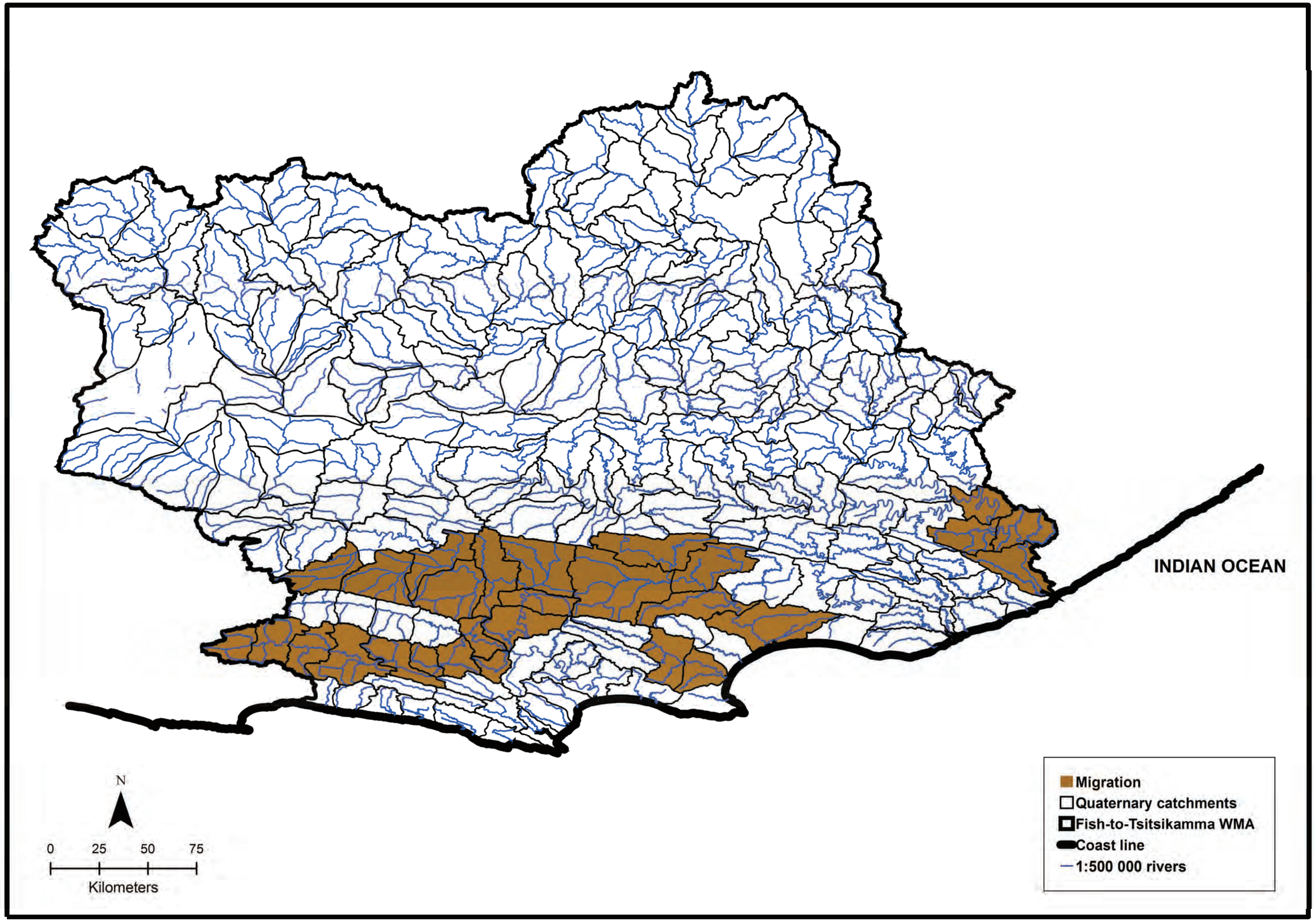


Figure 8: Quaternary catchments of national importance for migration
Catchments of national importance for migration are shaded.
Data are from a desktop assessment of ecological importance and sensitivity (Kleynhans 2001).

5 MAPPING ECOLOGICAL INTEGRITY OF RIVERS

5.1 Introduction

Selecting rivers that are currently of high ecological integrity incorporates many small-scale biodiversity processes (see Section 4.2) and maximizes conservation benefits from functioning ecosystem components that are already in place. Rivers that are currently of high ecological integrity should therefore be the first choice for biodiversity conservation. This requires a **spatial** depiction of the integrity of riverine ecosystems.

For the purpose of this project, river integrity is defined as a river's ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on temporal and spatial scales that are comparable to the natural characteristics of ecosystems of the region (Angermeier and Karr 1994, Kleynhans 1996).

Most ecological (biological and habitat) indices used for river integrity assessments in South Africa are calibrated along six categories reflecting varying degrees of integrity, from A to F (Table 8; Kleynhans 1996, 1999).

Table 8: Categories commonly describing river ecological integrity in South Africa (after Kleynhans 2000)

Ecological integrity category	**Description**
A	Natural, unmodified
B	Largely natural
C	Moderately modified
D	Largely modified
E to F	Seriously to critically modified

Data on the ecological integrity of rivers exist mainly at the reference site level largely through the efforts of the River Health Programme (see Information Box 4; RHP 2001a; RHP 2001b). However, limited River Health Programme data are available for the Fish-to-Tsitsikamma Water Management Area. In addition, conservation planning at national and sub-national levels requires that reference site indices be integrated and generalised to the level of river systems. Available integrated ecological integrity data at the level of river systems exists for main rivers[4] only (Kleynhans 2000; Nel *et al.* in prep) in the Fish-to-Tsitsikamma Water Management Area. These main rivers are highly transformed and little is known about their tributaries (Nel *et al.* 2004), which are often in a better condition, being less subject to flow modification by large

[4] Main rivers are defined as those rivers that pass through a quaternary catchment into a neighbouring quaternary catchment. In those instances where no river passes through the quaternary catchment (e.g. in coastal quaternary catchments which often encompass relatively short, whole river systems, or in quaternary catchments containing only endorheic rivers), the longest river system constitutes the main river.

dams and water transfer schemes. It was therefore not possible to use existing data on ecological integrity of rivers for this project. Instead, the most recent techniques provided by the Department of Water Affairs and Forestry were used to assess the condition of rivers at the level of the landscape (ecostatus determination techniques, Kleynhans *et al.* 2005), and thereby derive a spatial depiction of river ecological integrity.

Information Box 4: The River Health Programme (http://www.csir.co.za/rhp)

The River Health Programme (RHP) was initiated in 1994 by the Department of Water Affairs and Forestry (DWAF). It was developed with the overall goal of expanding the ecological basis of information on aquatic resources, in order to support the rational management of these systems. The programme is a national bio-monitoring program, with a mandate to assess and monitor the ecological integrity of riverine ecosystems in South Africa (Roux *et al.* 1999). Currently, the RHP provides the methodology to monitor changes in the ecological state of aquatic ecosystems; however it lacks a formal management framework for responding to the results of such surveys.

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). The indices used in the RHP represent the most widely available indices for assessing ecological integrity in South Africa, and include the South African Scoring System, SASS (Chutter 1998), the index of habitat integrity (Kleynhans 1996), the riparian vegetation index (Kemper 2001), the fish assemblage integrity index (Kleynhans 1999), the geomorphological index (Rowntree and Ziervogel 1999), the hydrological index (Hughs 2000) and the water quality index using diatoms (Bate *et al.* 2004). Aquatic invertebrates, communities of fish, and riparian vegetation are the primary indicators used. However, to provide a practical framework within which to interpret the biological results, the abiotic indicators such as geomorphology, habitat, hydrology and water quality have also been proposed and are currently either being implemented or tested. The scoring system for the indices is the same as that in Table 8, where a category of (A) generally represents a natural unmodified river system, while a category of (F) represents a very highly modified system with almost a complete loss of natural habitat.

5.2 Overview of the ecostatus determination applied in this project

Ecostatus determination aims to provide a single, integrated index value that indicates the ecological state of a river system in a simple but ecologically relevant way, using the categories in Table 8. Integrated ecological states are derived by a group of regional experts who make use of information from the indices developed for the River Health Programme (see Information Box 4), as well as information on land cover and land use. It was not possible to use River Health Programme data for deriving the integrated ecological states in this project, owing to the limited data available for this region. Thus, a basic **level 1 ecostatus determination** (Kleynhans *et al.* 2005) was undertaken – this focuses on deriving an index of habitat integrity from physical drivers (as opposed to including response variables such as biotic indices).

The index of habitat integrity is derived by scoring criteria for the in-stream channel and riparian zone (Table 9). These criteria are considered the primary determinants of habitat integrity, i.e. anthropogenic modification of these criteria would have a detrimental impact on river integrity. Scoring is based on the impact of modification, and is classified according to six descriptive classes that incorporate a five point rating system to improve the flexibility of scoring within a class (Table 10).

Scores for each criteria are then ranked and weighted within the ecostatus model (Kleynhans *et al.* 2005), placing the resultant total scores of habitat integrity into the specific descriptive ecological integrity class, as shown in Table 8.

Table 9: Criteria used in the assessment of habitat integrity (after Kleynhans 1996)

Criterion	Description
Water abstraction	Direct impact on habitat type, abundance and size. Also implicated in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction, diversion or regulation by impoundments. Changes in temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain biotopes or water at the start of breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation is also included.
Channel modification	May be the result of a change in flow which may alter channel characteristics causing a change in marginal in-stream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse sources. Measured directly, or agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences on water quality and the movement of sediments are implicated.
Alien macrophytes	Alteration of habitat by obstruction of flow, which may influence water quality. Dependent upon the species involved and the scale of infestation.
Alien aquatic fauna	Alien fauna that cause a disturbance of the stream bottom during feeding, which may influence the water quality and increase turbidity. Dependent upon the species involved.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer or barrier that the vegetation forms to the movement of sediment and other catchment runoff products into the river. Refers to physical removal from farming, gathering of firewood and overgrazing.
Alien vegetation encroachment	Alien vegetation that excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochthonous organic matter inputs will also be altered. Riparian zone habitat diversity is also reduced.
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both in-stream and riparian habitats. Increased erosion can be the result of natural vegetation removal. Over-grazing or alien vegetation encroachment.

Table 10: Descriptive classes for modifications to habitat integrity (Kleynhans 1996)

Impact class	**Description**	**Score**
None	No discernible impact, or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1 to 5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6 to 10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11 to 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16 to 20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21 to 25

5.3 Deriving level 1 ecostatus (Index of habitat integrity)

5.3.1 Delineating assessment units

The landscape was divided into assessment units, within which the expert assessment of ecological state was undertaken – all rivers falling within the same assessment unit were assumed to be in similar ecological state. Initial assessment units were delineated using Level 1 ecoregions (Kleynhans *et al.* 2004) and primary catchments. Seven of the 30 Level 1 ecoregions (Table 11) and six primary catchments occur within the Fish-to-Tsitsikamma Water Management Area (Section 2.1). This produced 28 initial assessment units (Figure 9).

On the basis of land cover and expert knowledge, some of the rivers within these initial assessment units were lumped or split further into similar groupings at the expert workshop to produce a total of 34 final assessment units (Figure 9).

5.3.2 Expert workshop

Regional experts from various disciplines (e.g. river ecology, hydrology, geomorphology and spatial technology) were invited to participate in the workshop (Table 12). Participants commented on available data (e.g. land cover and farm dams), adding to it, interpreting the data and scoring criteria according to information in Table 9 and Table 10. Rivers within each assessment unit were coded with the resultant scores in GIS to produce an initial map of landscape-level ecological integrity of rivers. This map was later refined from field verifications of the river ecological integrity (Section 5.5), to produce a final map of landscape-level ecological integrity of rivers (Figure 10).

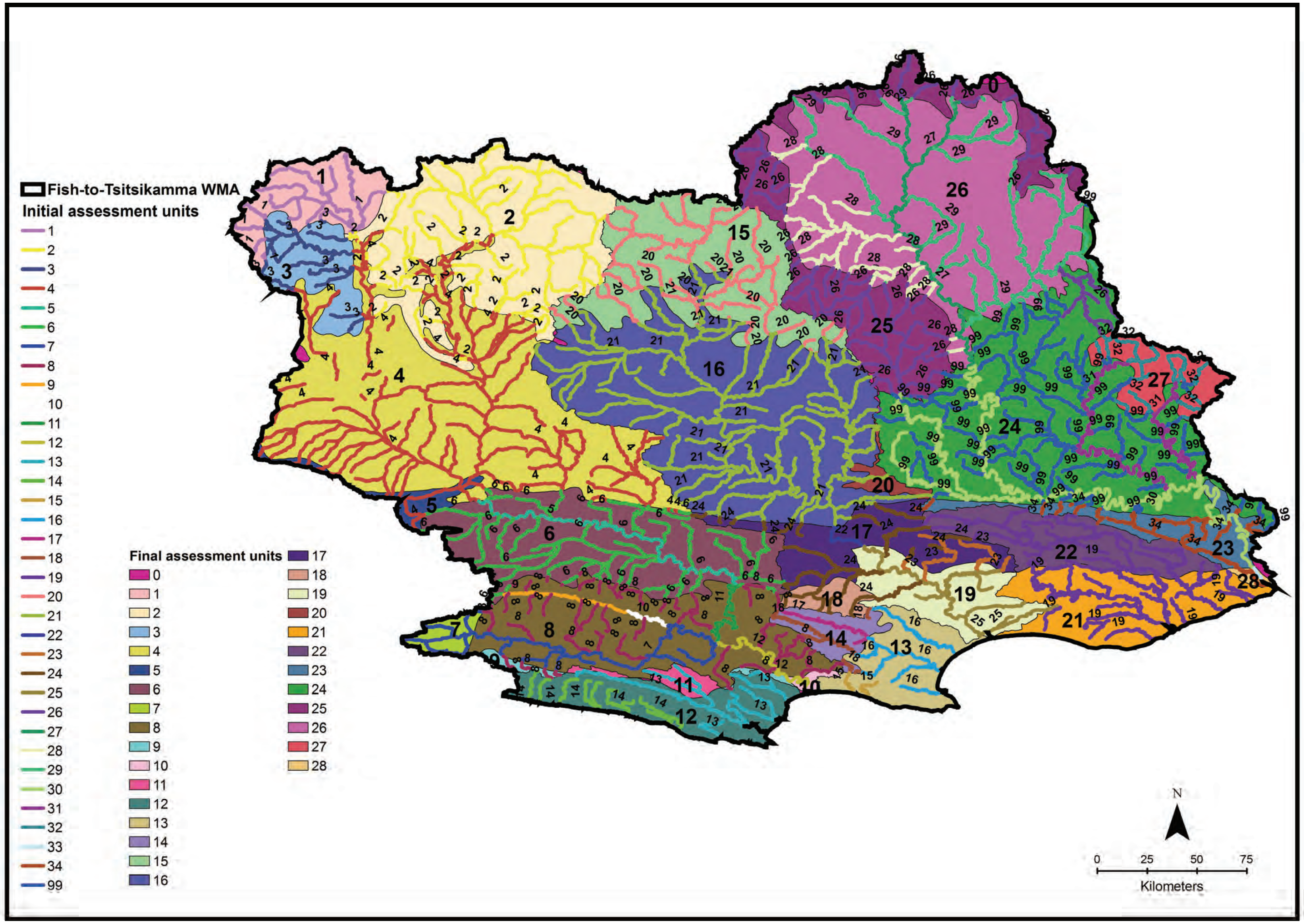


Figure 9: Initial and final assessment units for ecostatus determination
Initial assessment units were delineated using Level 1 ecoregions (Kleynhans et al. *2004) and primary catchments.*
Some rivers within these assessment units were subsequently lumped or split during the Ecostatus specialist workshop (3-4 February 2005), based on expert knowledge and land cover to provide the final unique assessment units.

Table 11: Level 1 ecoregions in the Fish-to-Tsitsikamma Water Management Area
After Kleynhans et al. (2004). Together with the six primary catchments in the area, these formed the basis of the assessment units within which ecological integrity of the rivers was assessed.

Level 1 Ecoregion	Description in study area
South Eastern Uplands (No. 16)	Characterized by a complex range of terrain morphology: moderate relief plains, low and high relief lowlands, open hills with low and high relief, closed hills with a moderate relief and low mountains with a high relief. Vegetation types are equally diverse, including Grassland, Bushveld, Thicket and Afromontane Forest. Mean annual precipitation is generally high (500-1000 mm) and rainfall seasonality is early to late summer.
Eastern Coastal Belt (No. 17)	Located in the eastern portion of the study area. A diversity of terrain morphology occurs, with closed hills and mountains with a moderate to high relief dominating. Altitude varies from sea level to 700 m.a.m.s.l. Vegetation types consist of a variety of Thicket, Grassland and Bushveld types. Mean annual precipitation is predominantly high (400-1000 mm), and rainfall seasonality is early to very late summer to all year.
Drought Corridor (No. 18)	Occupies approximately 35% of the water management area. Characterized by lowlands, hills and mountains with moderate and high relief, and closed hills and mountains with moderate and high relief. South Eastern Mountain Grassland and Eastern Mixed Nama Karoo are the dominant vegetation types. The Great Fish River is the prominent river in the region. Mean annual precipitation is low (200-500 mm), and rainfall seasonality is late to very late summer.
Southern Folded Mountains (No. 19)	Occupies just over 15% of the water management area. Has a diverse topography, but closed hills and mountains with a moderate to high relief are dominant. The vegetation is also highly diverse with various Fynbos, Karoo, Renosterveld and Thicket types but Mountain Fynbos, Grassy Fynbos and Little Succulent Karoo are generally distinctive. The Gourits River and its main tributaries traverse this area. Mean annual precipitation is 200-1500 mm, and rainfall seasonality is variable.
South Eastern Coastal Belt (No. 20)	Although plains occur in this region, closed hills and mountains primarily characterize the topography with a moderate to high relief. Altitude varies mostly from sea level to 500 m.a.m.s.l. Fynbos, Renosterveld, Grassland, and Thicket vegetation types occur, but the dominant types are Afromontane Forest and Mesic Succulent Thicket. The Swartkops, Gamtoos and Keurbooms Rivers flow through this region. Mean annual precipitation is moderate to high (300 to 1000 mm), and rainfall seasonality is very late summer to all year.
Great Karoo (No. 21)	This ecoregion is extensive in the area. Plains with low to moderate relief are often distinctive, but significant areas contain closed hills and mountains with moderate to high relief. Vegetation consists of a diversity of Nama Karoo, Succulent Karoo, Renosterveld and thicket types. Rivers such as the Gamtoos flow through his region. Mean annual precipitation is arid to low (0 to 500 mm), and rainfall seasonality is very late summer to winter.
Nama Karoo (No 26)	Topography is diverse, but plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief are dominant. Vegetation consists almost exclusively of Nama Karoo types. Mean annual precipitation is moderate/low in the east, decreasing to arid in the west (0 to 500 mm).

Table 12: Participants in the Fish-to-Tsitsikamma ecostatus determination workshop

Name	Position	Affiliation
Mao Angua-Amis	Masters of Science student: Conservation planning	University of Cape Town
Japie Buckle	Study area expert	Working for Wetlands
Jim Cambray	Fish expert	Albany Museum
Leanne Du Preez	Geomorphology Doctorate student	Rhodes University
Kate Rowntree	Geomorphologist	Rhodes University
Stephen Holness	Geomorphologist and ecologists	SANParks
Denis Hughes	Hydrological expert	Department of Water Affairs and Forestry
Neels Kleynhans	Ecoregion and river integrity expert	Department of Water Affairs and Forestry
Gillian Maree	Conservation planner	CSIR
Lindie Smith-Adao	Geomorphologist and conservation planner	CSIR
Juanita Moolman	River GIS specialist	Department of Water Affairs and Forestry
Jeanne Nel	Conservation planner	CSIR
Dirk Roux	River ecologist and conservation planner	CSIR
Christa Thirion	River integrity expert	Department of Water Affairs and Forestry

5.4 Ground verification of the desktop ecostatus analysis

5.4.1 Choosing of sites and field methods

A rapid survey methodology was devised for a number of sites according to the large area and short time available. Forty-eight sites were visited during the day recording coordinates, taking photographs and making notes (all site data sheets, photographs and digital data are provided on the Metadata CD accompanying this report). Sites were chosen on the following basis:

Sites in the Bushman's primary catchment (Sites 1-6; 48) – All rivers in this catchment were lumped into the same assessment unit in the desktop ecostatus analysis. This meant that the desktop ecostatus results were not at a fine enough resolution to distinguish tributaries that may have been in a better condition within the Bushman's catchment. An attempt was made to source tributaries in an A or B present ecological class, which could be included within the Fish-to-Tsitsikamma conservation plan.

Sites in the Upper Gamtoos primary catchment (Sites 28-47) – This is an area that was not well known to experts in the ecostatus determination workshop.

Sites in the Upper Great Fish primary catchment (Sites 7-27) – All tributaries were generalised into a single assessment unit and thus integrity class, and the level of resolution was believed not to be sufficiently accurate. This was validated by a comparison of the Klein and Groot Brak Rivers. The upper Klein Brak has been virtually destroyed and there is a series of diversion weirs leading the water to flow away from the eroded main channel.

5.4.2 Comparison of desktop and field results

There were a number of sites (12 out of 48; 25%) where there was a discrepancy between the desktop and field ecostatus scores (Table 13; Figure 11A). For some of these sites, the general condition of the river at the level of the landscape was better than that at the site level, owing to localised impacts (e.g. erosion caused by a causeway at site 29). In these instances, the desktop assessment score was not changed. Not all discrepancies, however, could be explained by localised site impacts. For example, on both the Groot and Klein Brak Rivers, surveys were conducted along extensive sections of river and the resulting discrepancies were therefore not purely site recordings. These discrepancies are more likely a consequence of poor resolution in the desktop analysis resulting from generalisation into broad assessment units. The desktop values for river ecological integrity in these instances was corrected.

The desktop ecostatus scores and the field scores were compared by disaggregating the scores into in-stream (Figure 11B) and riparian (Figure 11A) components. In-stream discrepancies were found to be mainly a result of localised impacts. However, field assessment scores tended to be consistently higher than the scores designated by the experts.

Table 13: Comparison of overall ecostatus integrity class for desktop and field assessments Only sites where overall ecostatus integrity class differed by more than 2 classes are shown

Site number	Desktop assessment class	Field assessment class
2	C	A
3	C	F
10	B	D
15	C	A
16	D	A
19	B	D
24	C	A
25	D	A
42	C	A
43	C	A
44	C	A
48	C	A

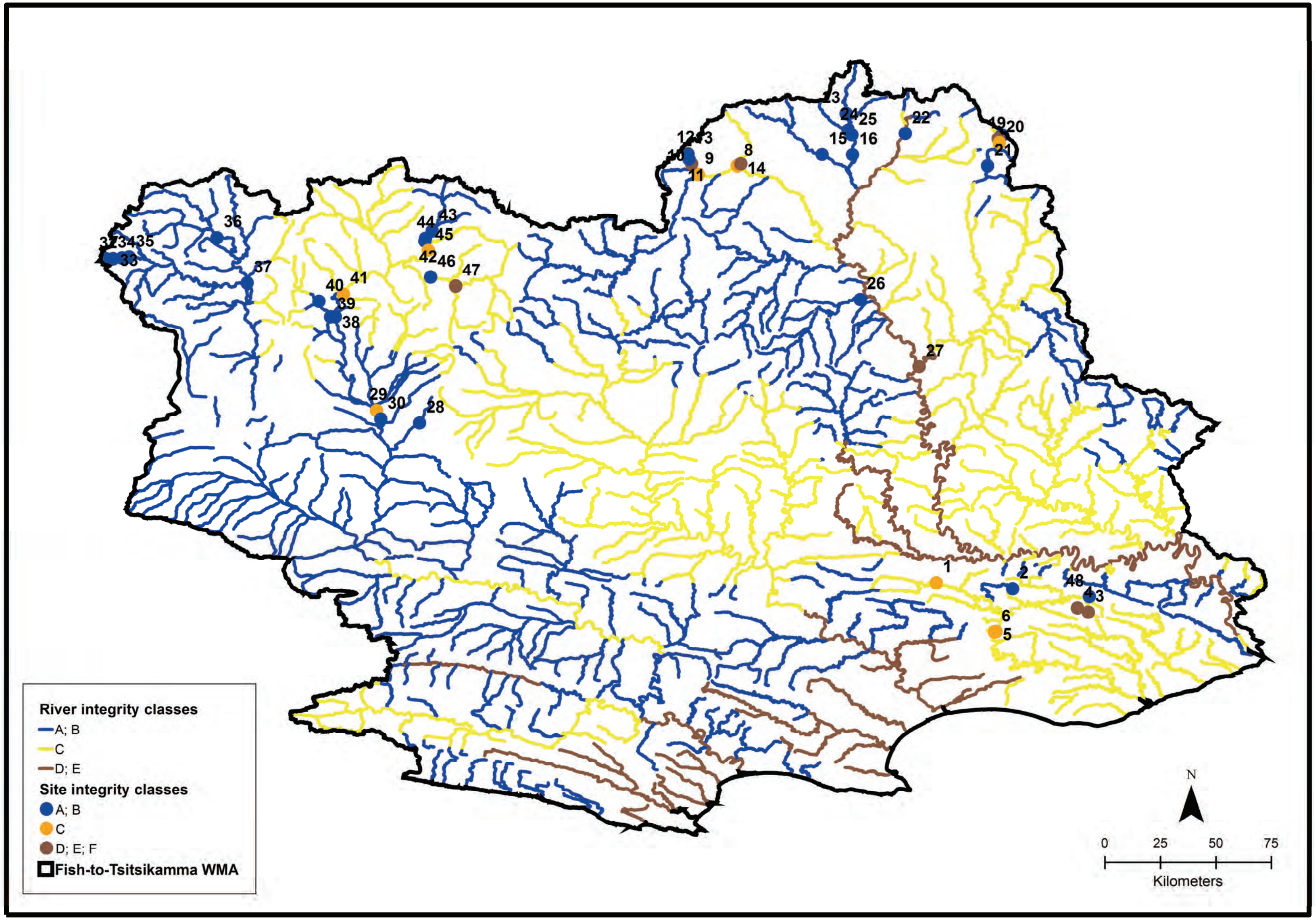


Figure 10: River ecological integrity and field sites for the Fish-to-Tsitsikamma
First assessed according to the desktop Ecostatus method within unique assessment units and then corrected according to field verification.

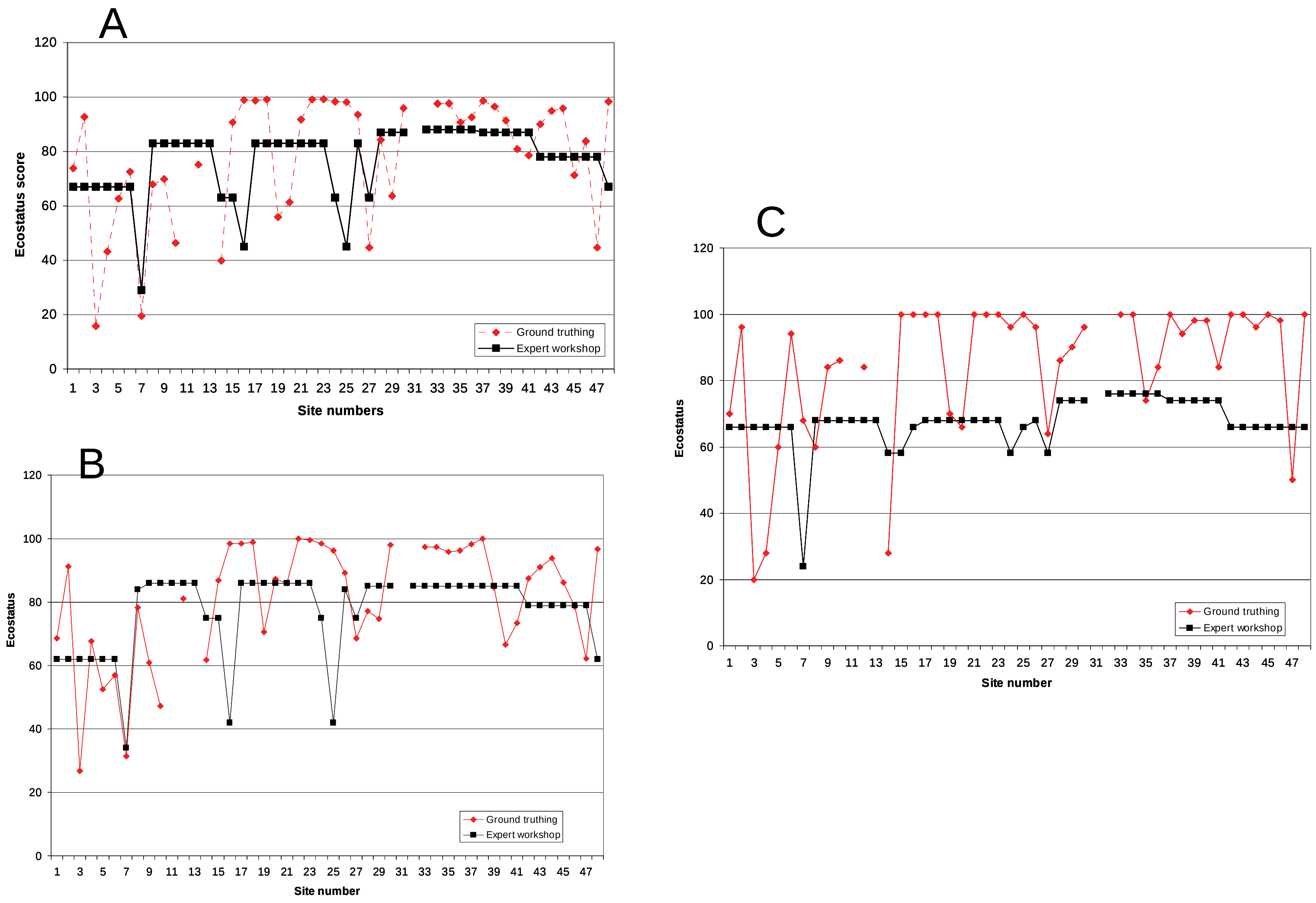


Figure 11: Comparison of ecological integrity of sites using desktop and field assessments
Showing (a) the combined ecostatus score for in-stream and riparian integrity, as well as the separate (b) in-stream and (c) riparian ecostatus scores. Ecostatus scores are the percentages before assigning ecological classes.

5.5 Pattern of ecological integrity in the area

Rivers in the Fish-to-Tsitsikamma study area are in relatively good condition (Figure 12) compared to other areas of the country, with almost 50% of the river length in an A (natural) or B (largely natural) class, 42% in a C class (moderately modified), and just over 10% in D and E classes (largely to seriously modified). However, the occurrence of natural and largely natural river reaches is uneven spread across the water management area: the drier parts are generally in better condition, while the coastal, more populated areas are in poorer condition (Table 14, Figure 10). The Sundays and Great Fish rivers are heavily impacted by water transfer schemes (Section 2.1).

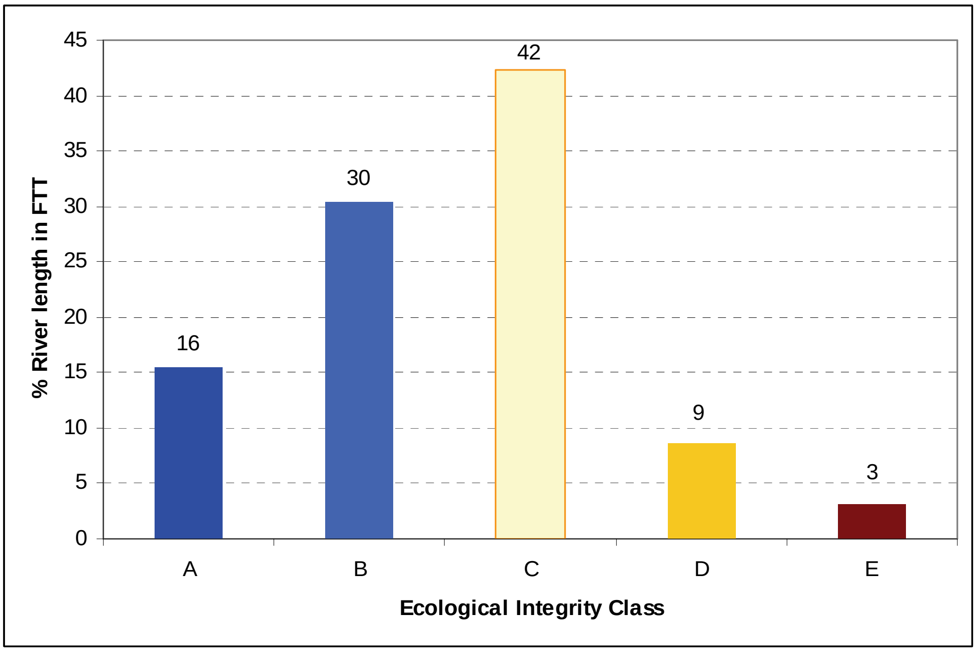


Figure 12: Percentage river length in each ecological integrity class

Table 14: Ecological integrity within the primary catchments
Values are expressed as percentage river length within that primary catchment.
Letters in brackets are primary catchment codes

Ecological integrity class	Tsitsikamma (K)	Gamtoos (L)	Algoa (M)	Sundays (N)	Bushmans (P)	Fish (Q)
A	36	26	27	15	0	5
B	0	45	0	22	3	32
C	0	26	0	56	97	45
D	0	3	23	8	0	17
E	64	0	50	0	0	0

5.6 Limitations of the integrity data and recommendations for improvement

The river ecological integrity map derived for this project is based on a desktop index of habitat integrity, which has been field verified to some extent. Over time, and once more River Health Programme data become available, this assessment should be expanded to a full ecostatus assessment, which would include an analysis of biotic indices, as well as estimates of ecological importance and sensitivity.

Ecological integrity as determined by the ecostatus methods is relatively robust according to field verification results. However, the results generated using this technique are still quite broad for conservation planning at a sub-national scale – there is not enough differentiation between river systems that have been lumped together into coarse-scale assessment units, resulting in an inability to assess conservation options adequately within the region. Developing models to predict the ecological integrity of rivers using remote sensing techniques at a higher mapping resolution (i.e. finer scale) may be a better, faster and more cost effective option for fine-scale conservation planning in the future. These models have been developed for Australian rivers (Stein *et al.* 2002), and rely on modelling anthropogenic disturbances (e.g. land use and dams) in relation to surface runoff.

6 SETTING QUANTITATIVE BIODIVERSITY TARGETS FOR RIVERS

6.1 Introduction

Biodiversity targets (also referred to as conservation targets) set minimum, quantitative requirements for biodiversity conservation in order to: 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 (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 thus be subject to review over time.

6.2 Targets for rivers in the Fish-to-Tsitsikamma Water Management Area

The recommendations emanating from the national cross-sectoral policy process (Roux *et al.* 2006) that is currently underway as a parallel Water Research Commission project (Project K8/642) were adopted in setting biodiversity targets for rivers in the area. This process has put together 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 following recommendations made by Roux *et al.* (2006) are pertinent to the setting of targets for the Fish-to-Tsitsikamma conservation plan:

(i) The quantitative target for inland water biodiversity conservation in South Africa should be to maintain (and restore where necessary) at least 20% of each inland water ecosystem type 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. 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 (in an ecological integrity class of A or B) should, where relevant, be connected through river systems that are in an ecological state that supports ecological connectivity. This functionality commonly concurs with an ecological integrity class C. However, this relationship should not be seen as a given and each potential connecting river should be assessed on the basis of process attributes such as 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 connecting rivers are in less than an A or B ecological class, they should not, in addition to their status as connectors, contribute towards satisfying the 20% biodiversity target.

(iii) Where a particular inland water ecosystem that has been identified as important for achieving targets, but through past or current over utilization has been transformed to an ecological state that is lower than B, 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 that associated with a defined (not necessarily pristine) ecological state such as B.

Translating these recommendations to the Fish-to-Tsitsikamma project, biodiversity targets were calculated as 20% of the total length of each Level 3 river type (Section 3.2). These targets should only be achieved within river reaches that have a present ecological integrity class of A or B (Table 8; Figure 10) - any river reach lower than an A or B class, included in the plan for maintaining longitudinal connectivity, did not contribute towards achieving this 20% biodiversity target.

Those river types where the length in A or B class has dropped below 20% of the total length of that river type cannot meet their biodiversity target and the feasibility of rehabilitating examples of these river types should be investigated. The biodiversity targets derived for each Level 3 river type are shown in Appendix 1, together with an assessment of the ability to achieve this target in the water management area. There are 37 river types which cannot achieve their biodiversity target in river reaches of an A or B class (Appendix 2), i.e. their lengths in A or B class has fallen below 20% of the total length of that river type. Options for rehabilitating examples of these river types within the Fish-to-Tsitsikamma Water Management Area were explored within the context of the potential opportunity for conserving these river types elsewhere in the country.

6.3 Potential for rehabilitation

The river types that could not achieve their biodiversity targets in the Fish-to-Tsitsikamma Water Management Area were assessed in terms of their potential for rehabilitation. This assessment used the best attainable ecological management class (AEMC) as a guideline (Kleynhans 2000). However, these data are for main rivers only and are outdated. Thus, where expert opinion differed from the attainable ecological management class, the expert opinion was applied.

The **consequences** of not being able to meet targets in the water management area were also examined. For unique river types (those that have more than 80% of their national range within the Fish-to-Tsitsikamma Water Management), not meeting targets in the Fish-to-Tsitsikamma Water Management Area implies that a national target will not be met. Under these circumstances, rehabilitation should be a serious consideration. Where examples of the river type occur elsewhere, a rapid (qualitative) assessment was made of the potential for that area to adopt the 20% portion of the Fish-to-Tsitsikamma target. This was based on an assessment of **Level 2** river types (longitudinal zones for the whole country do not exist and therefore Level 3 river types cannot be derived for all of South Africa at present), and a preliminary analysis of river ecological integrity for the entire country, using existing data for main rivers[4 (p. 50)] and the percentage natural vegetation as a proxy for the integrity of tributaries (see Information Box 5: Deriving preliminary ecological integrity for South Africa's 1:500 000 rivers).

This assessment of rehabilitation potential divided these 37 river types into four categories (Figure 13, Appendix 2):

(i) Rehabilitation is feasible

- Includes 14 river types
- Quaternary catchments containing good examples of these river types have been flagged for rehabilitation in the subsequent conservation plan (Section 8.5).

(ii) Best conserved elsewhere

- Includes 10 river types
- Areas which could adopt the targets for Fish-to-Tsitsikamma Water Management Area have been identified and listed in Appendix 2.

(iii) Rehabilitation is not feasible and conservation opportunities elsewhere also look bleak

- Includes 7 river types
- An assessment at the national level should be undertaken to identify where it would be best to rehabilitate these river types.

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

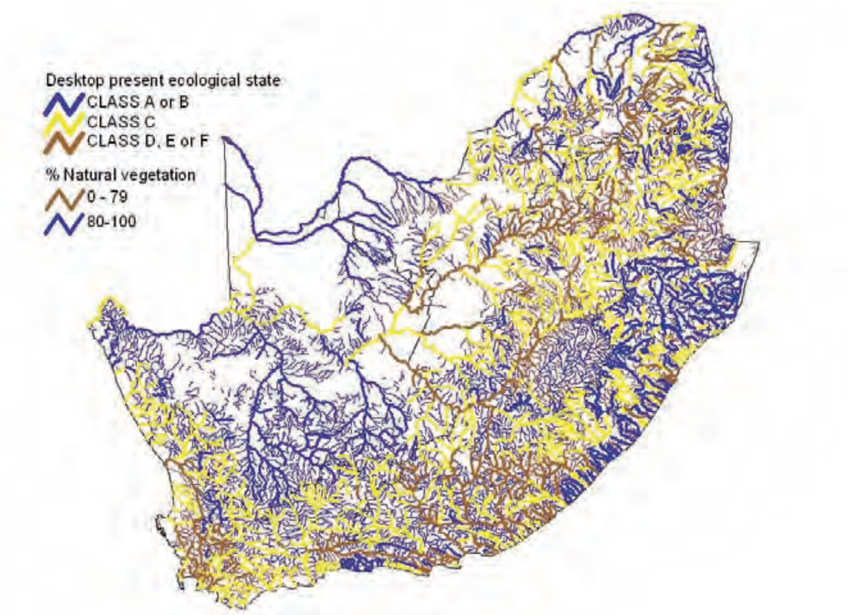
- Includes 6 river types
- These river types are now critically endangered in the country (i.e. have failed to meet the national target).

Information Box 5: Deriving preliminary ecological integrity for South Africa's 1:500 000 rivers

Data on river ecological integrity for the entire country is only available for main rivers[4] of quaternary catchments, using the desktop estimate of present ecological status developed for the national Water Situation Assessment Model (Kleynhans 2000). However, main rivers are often heavily utilized and regulated to improve water security for socio-economic use. Tributaries, which are often in a better condition, therefore have a crucial role to play in meeting biodiversity targets in South Africa (Nel *et al.* 2004; Nel *et al. in prep*). Thus, conservation assessments of rivers need to include an assessment of both main rivers and tributaries. In order to assess both main rivers and tributaries, ecological integrity for South Africa's 1:500 000 river data layer[3] was derived as follows:

- The desktop present ecological status (Kleynhans 2000) was assigned to main rivers of quaternary catchments
- For tributaries (any river not defined as a main river), the percentage of natural vegetation was used as a proxy, based on the study by Amis *et al.* (submitted) which found that where no other data exist, the % natural vegetation serves as the best proxy (see Section 5.6 and Appendix 4). Both a catchment disturbance index (% natural vegetation within a 2.5 km buffer of a river) and a riparian zone disturbance index (% natural vegetation within a 500 m buffer of a river) were derived; the minimum of these two indices was assigned to each reach. Any river reach where the minimum natural vegetation ≥ 80% was assumed to be in a Class A or B and able to contribute towards achieving river biodiversity targets.

The resulting river ecological integrity map is shown in the figure below. These data are preliminary and need to be refined and verified to consider the cumulative upstream impacts of dams and water transfer schemes. This should then ideally be ground-truthed. 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 most tributaries are probably less subject to large upstream impacts than main rivers).



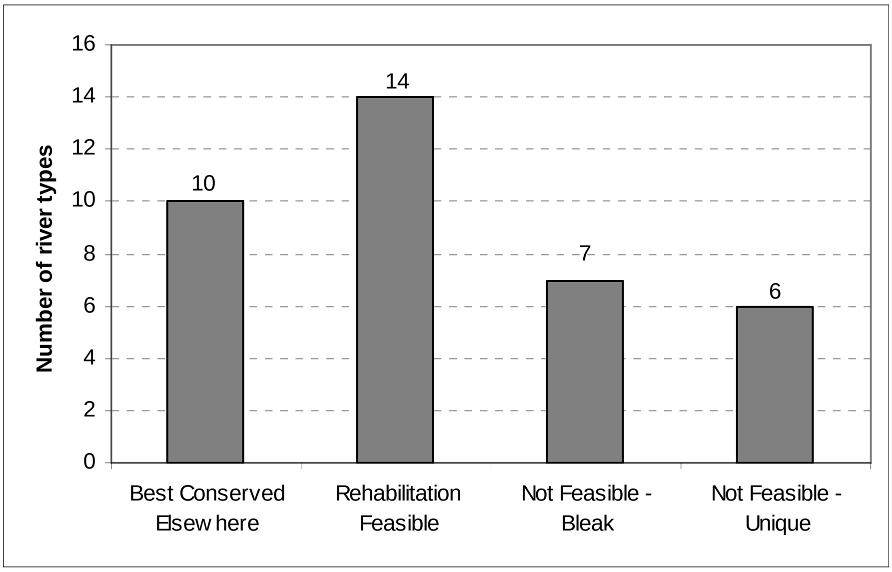


Figure 13: Assessment of river types that cannot meet their targets

Showing river types that
(i) are best conserved elsewhere;
(ii) should be rehabilitated to an A or B ecological integrity
within the Fish-to-Tsitsikamma Water Management Area;
(iii) not feasible to rehabilitate in the study area and conserving elsewhere looks bleak; and
(iv) not feasible to rehabilitate in the Fish-to-Tsitsikamma Water Management Area and
unique to the area. See text in Section 6.3 on the implications of each category.

7 ESTUARY ASSESSMENT AND SELECTION

7.1 Introduction

An estuary is defined as a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with freshwater derived from land drainage. Estuaries in the Fish-to-Tsitsikamma Water Management Area were assessed with the aim of selecting a representative set of estuaries to conserve threatened species, maintain viable populations of all estuarine species, and to be maintained in their reference state, or where necessary, to rehabilitate the estuary to a condition where it achieves the above aims.

Like rivers, it is envisaged that all estuaries should enjoy some level of protection, being assigned to one of three categories, as follows (Turpie 2004a):

(i) Estuarine Protected Areas (EPAs), in which part or the entire estuary is a sanctuary, providing protection from consumptive use: EPAs should be selected with both biodiversity representation and socio-economic considerations in mind.
(ii) Estuarine Conservation Areas (ECAs): co-managed estuaries in which general regulation is augmented by estuary-specific regulation. These are particularly suited to estuaries used primarily for recreation.
(iii) Estuarine Management Areas (EMA), to which general regulation applies.

The estuaries selected for incorporation into the Fish-to-Tsitsikamma conservation plan target categories (i) and (ii) above. This section describes the information assembled for estuaries on their biodiversity pattern and process, their current ecological integrity, and their national conservation score and rank. It then provides an overview of the estuaries that were selected for incorporation into the conservation plan, as either an EPA or ECA, using a hierarchical selection protocol and expert judgement.

7.2 Estuarine biodiversity pattern and process

7.2.1 Estuary typing

At the broadest level of classifying biodiversity, estuaries fall into three biogeographical zones in South Africa: the Cool Temperate zone on the west coast, the Warm Temperate zone which extends approximately from Cape Point to the Mbashe River in the Eastern Cape, and the Subtropical Zone on the east coast. Estuaries within these zones have been shown to have relatively distinct faunal communities, and have also been found to differ significantly in their physico-chemical characteristics (Harrison 2004). There are 30 estuaries found in the Fish-to-Tsitsikamma Water Management Area, and all fall within the Warm Temperate biogeographical zone.

The Whitfield (1992) estuary classification system was used to further depict biodiversity pattern of estuaries in the area, which recognises five estuary types (Estuarine Bay, Permanently Open, River Mouth, Estuarine Lake, and Temporarily Open). Fish-to-Tsitsikamma estuaries were thus divided into eight permanently open estuaries; 17 temporarily open estuaries; and five river mouths (Table 15, Figure 14).

Only 18% of South Africa's estuaries are permanently open and therefore this area is particularly important in terms of its estuarine biodiversity and conservation importance. For example, the importance of this area for large-scale migration of freshwater eel and freshwater mullet are a result of the many permanently open estuaries (Section 4.5, Information Box 3). River mouths in this area can also make a significant contribution towards biodiversity targets for the country, since they belong to highly natural rivers which run through the Tsitsikamma Wilderness Area on the Garden Route.

7.2.2 National conservation importance score and rank of estuaries

Turpie (2004a) has rated all South African estuaries in terms of their conservation importance (Table 16). This rating was based on quantitative and semi-quantitative biodiversity data for plants, invertebrates, fish and birds of each estuary, as well as estuarine type and its rarity within each biogeographical zone, and overall size.

Out of the 250 ranked estuaries, seven of the eight permanently open estuaries in the Fish-to-Tsitsikamma Water Management Area fall within the top 50 estuaries in the country (i.e. they are in the top 20% of ranked estuaries in South Africa), namely:

- Swartkops (national rank = 12);
- Great Fish (national rank = 13);
- Gamtoos (national rank = 16);
- Krom (national rank = 20);
- Kariega (national rank = 28);
- Bushmans (national rank = 35); and
- Sundays (national rank = 41).

Four of the temporarily open estuaries are also ranked in the top 50 estuaries in the country, namely:

- Kabeljous (national rank = 45);
- Seekoei (national rank = 48);
- Kleinemonde West (national rank = 54); and
- Kleinemonde East (national rank = 55).

The conservation importance status of an estuary is currently applied as part of the process in determining the future freshwater requirements of estuaries. Within the Fish-to-Tsitsikamma conservation plan, these ranks were also applied in selecting estuaries where choices between estuaries of similar types existed (Section 7.6).

Table 15: Estuaries in the Fish-to-Tsitsikamma Water Management Area
Listed from west to east along the coast. All estuaries lie within the Warm Temperate biogeographical zone, and are further classified according to Whitfield type (Whitfield 1992). Current protection status and ecological integrity are from Whitfield (2000), which have recently been updated by Turpie (2004b). The importance score and national rank are according to Turpie (2004a).

Estuary	Whitfield Type	Current protection status	Ecological integrity	Importance score	National rank
Lottering	River mouth	EPA	Good		River mouth
Elandsbos	River mouth	EPA	Good		River mouth
Storms	River mouth	EPA	Excellent		River mouth
Elands	River mouth	EPA	Good		River mouth
Groot (East)	River mouth	EPA	Good		River mouth
Tsitsikamma	Temp	ECA	Good	21.8	229
Klipdrif	Temp		Fair	18.5	237
Slang	Temp		Poor	7.9	256
Krom East (Kromme)	Perm		Fair	86.4	20
Seekoei	Temp	EMA	Poor	75.4	48
Kabeljous	Temp		Good	75.8	45
Gamtoos	Perm	EMA	Fair	90.9	16
Van Stadens	Temp	EMA	Good	46.3	139
Maitland	Temp		Fair	34.8	181
Baakens	Temp		Poor		Canalized
Papkuils	Temp		Poor		Canalized
Swartkops	Perm		Fair	92	12
Coega (Ngcura)	Temp		Poor	46.9	135
Sundays	Perm		Good	77.4	41
Boknes	Temp		Good	55.1	104
Bushmans	Perm		Fair	79.8	35
Kariega	Perm		Fair	82.3	28
Kasuka	Temp		Excellent	61.4	84
Kowie	Perm		Fair	80.5	32
Rufane	Temp		Fair	23	222
Riet	Temp		Good	70.9	60
Kleinemond West	Temp		Good	72.5	54
Kleinemond East	Temp		Good	72.5	55
Klein Palmiet	Temp		Good	8	255
Great Fish	Perm		Good	91.5	13

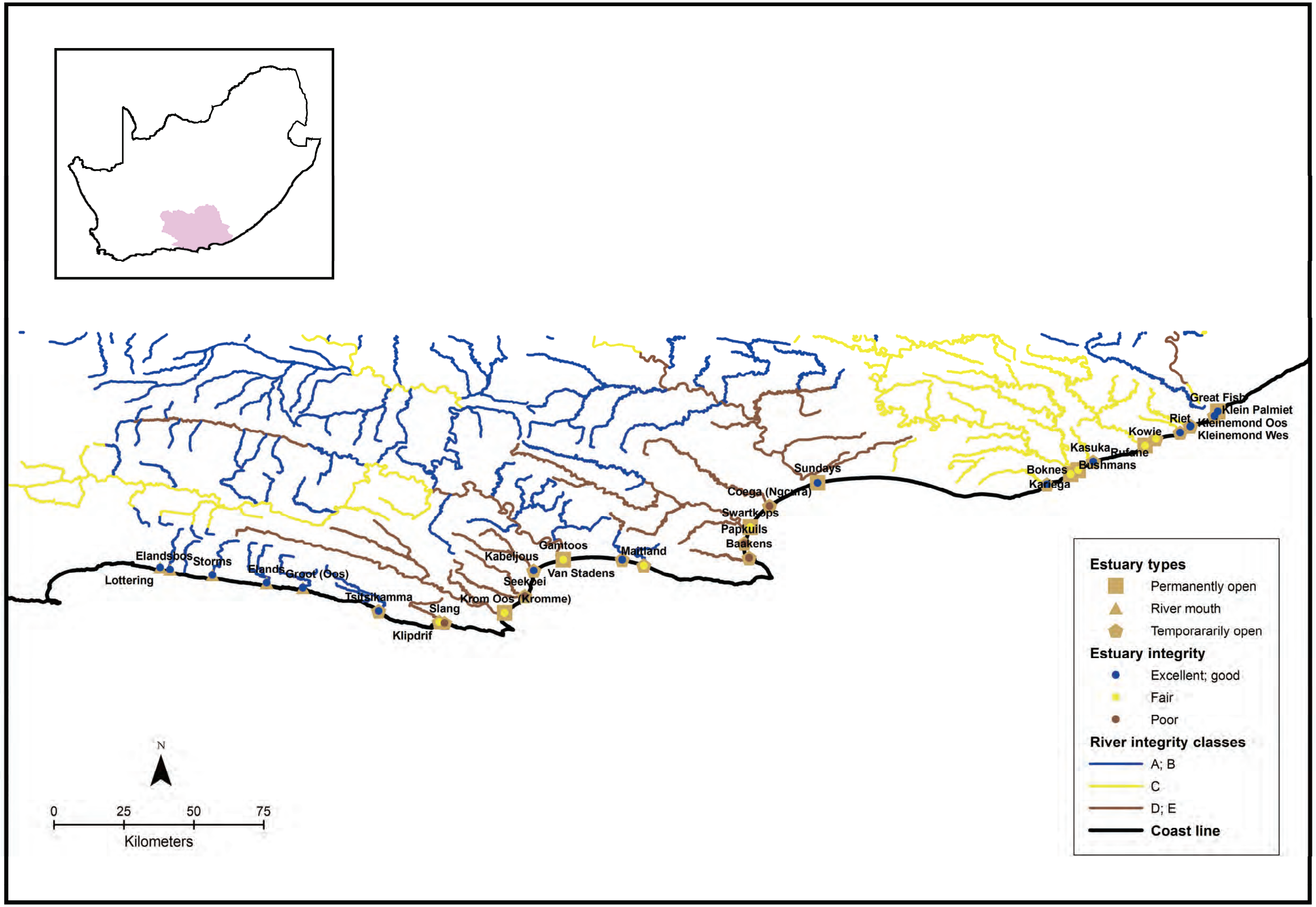


Figure 14: Estuary types and ecological integrity in the Fish-to-Tsitsikamma
Estuary types are according to Whitfield (1992), and ecological integrity is according to a modified version of Whitfield (2000) by Turpie (2004b).

Table 16: National conservation importance rating of Fish-to-Tsitsikamma estuaries
Data are from Turpie (2004a). Size, habitat importance, zonal type rarity, biodiversity importance were combined into a single importance score and ranked nationally out of 250. River mouths and canalized rivers were excluded, therefore no rank is provided for the Lottering, Elandsbos, Storms, Elands and Groot (East) River Mouths, or the canalized rivers of the Baakens and Papkuils.

Estuary	Size	Habitat importance	Zonal type rarity	Biodiversity importance	Importance score	National rank
Boknes	60	50	10	70.5	55.1	104
Bushmans	100	60	20	91	79.8	35
Coega (Ngcura)	40	40	10	79.5	46.9	135
Gamtoos	100	100	20	95.5	90.9	16
Great Fish	100	100	20	98	91.5	13
Kabeljous	90	80	10	75	75.8	45
Kariega	90	80	20	97	82.3	28
Kasuka	70	70	10	59.5	61.4	84
Klein Palmiet	10	0	10	12	8	255
Kleinemond East	70	90	10	84	72.5	55
Kleinemond West	80	90	10	68	72.5	54
Klipdrif	10	10	10	44	18.5	237
Kowie	90	80	20	90	80.5	32
Krom	100	90	20	87.5	86.4	20
Maitland	10	70	10	49	34.8	181
Riet	80	80	10	71.5	70.9	60
Rufane	10	10	10	62	23	222
Seekoei	90	80	10	73.5	75.4	48
Slang	10	0	10	11.5	7.9	256
Sundays	90	70	20	87.5	77.4	41
Swartkops	100	100	20	100	92	12
Tsitsikamma	10	20	10	47	21.8	229
Van Stadens	60	30	10	55	46.3	139

7.3 Estuarine ecological integrity

Whitfield (2000) conducted an assessment on the ecological integrity of estuaries, which has recently been slightly refined where regional experts deemed it necessary (Turpie 2004b). This classified estuaries broadly as follows:

- **Excellent**: estuary in near pristine condition (negligible human impact).
- **Good**: no major negative anthropogenic influences on either the estuary or catchment (low impact).
- **Fair**: noticeable degree of ecological degradation in the catchment and/or estuary (moderate impact).

- **Poor**: major ecological degradation arising from a combination of anthropogenic influences (high impact).

Only two of the permanently open estuaries in the Fish-to-Tsitsikamma Water Management Area are in a "Good" condition, according to Whitfield (2000), whilst the remaining estuaries are rated in a "Fair" state (Figure 15). Nine of the 17 temporarily open estuaries are in a ""Excellent" or "Good" state, three are in a "Fair" state and the remaining five are in a "Poor" state. The ecological state of estuaries selected for inclusion in the conservation plan should be given attention to ensure that biodiversity within these estuaries is maintained.

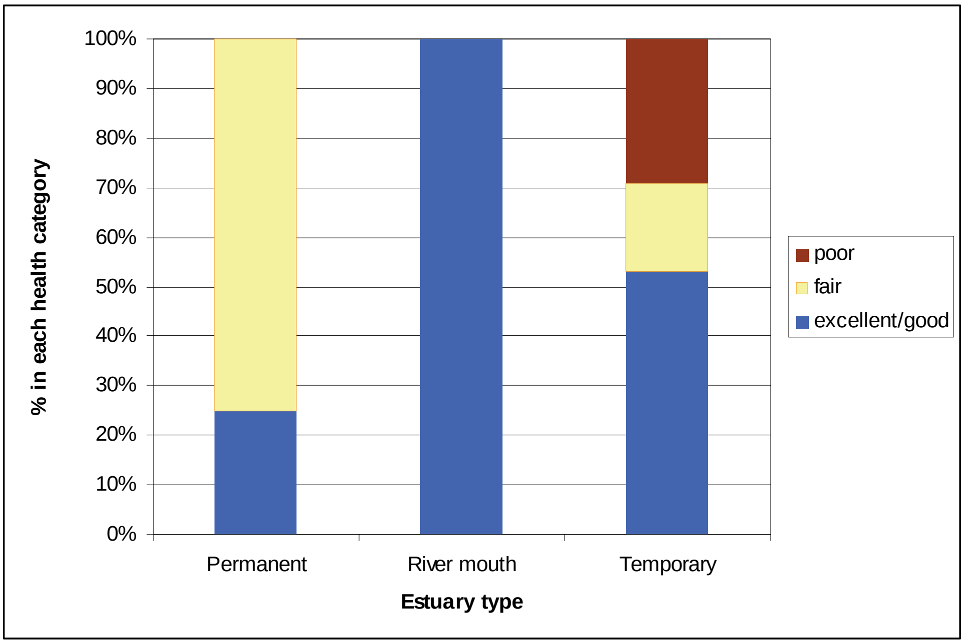


Figure 15: Ecological integrity of estuaries (after Whitfield 2000)

7.4 Current protection status

The current status of protection was classified from Whitfield (2000). Nine of the Fish-to-Tsitsikamma estuaries receive some sort of protection status already (Table 15): all five river mouths qualify as Estuarine Protected Areas, there is one temporary estuary (the Tsitsikamma) that qualifies as an Estuarine Conservation Area, and the remaining three are co-managed as Estuarine Management Areas. There are no permanent estuaries that receive Estuarine Protection or Conservation status (although the Gamtoos receives Estuarine Management status).

Thus, the protection status currently afforded to estuaries in the Fish-to-Tsitsikamma Water Management Area is biased, and the conservation plan should aim to correct this bias. Current protection status was also taken into account, in terms of feasibility for protection, in the selection of estuaries for inclusion in the conservation plan.

7.5 Setting quantitative biodiversity targets for estuaries

Estuary targets were set based on methods used in the assessment of estuaries on the Wild Coast (Turpie and Van Niekerk 2004), in which the targets used were:

- Estuarine Protected Areas: 20% of estuaries
- Estuarine Conservation Areas: 30% of estuaries

These targets appear to be high, but are fully defensible. The 20% as Estuarine Protected Areas corresponds to the target of 20% recommended for inland water biodiversity conservation in South Africa (Roux *et al.* 2006). The additional protection afforded by Estuarine Conservation Areas is justifiable on the basis of the important links between estuarine conservation, the biodiversity processes that support both marine and freshwater ecosystems, and the natural-resource based economy of the area. The minimum biodiversity targets required for estuaries in the Fish-to-Tsitsikamma Water Management Area are shown in Table 17.

Table 17: Biodiversity targets for Fish-to-Tsitsikamma estuaries

Estuary type	Number EPA	Number ECA
Permanently open	2	3
Temporarily open	4	5
River mouth	1	1

7.6 Selecting estuaries for inclusion in the conservation plan

The following selection protocol was used for choosing each estuary type (permanent, temporary, river mouth) to satisfy the biodiversity targets (Table 17):

(i) Estuaries in “Excellent”, “Good” or “Fair” condition were deemed suitable for selection. Estuaries in “Poor” condition were excluded from selection options.

(ii) Estuaries that already have high protection status (Estuarine Protected Areas) were chosen first to satisfy targets. Estuaries with lower protection status (Estuarine Conservation Areas or Estuarine Management Areas) were favoured, but not necessarily chosen over other more suitable estuaries.

(iii) Spatial distribution was then taken into account, making sure that estuaries are evenly dispersed along the coast. This is an iterative step as estuaries of other types and status are selected.

(iv) National importance rating was used to decide between estuaries of the same type and condition located no more than 200 km apart (most were often less than this).

(v) The selection of Estuarine Protected Areas was selected governed by the feasibility of pure protection. In cases where high protection is not considered feasible, but where the estuary qualified on the above criteria, the estuary was assigned to Estuarine Conservation Area status. This feasibility assessment included criteria such as:

    - Current levels of terrestrial and coastal protection in the area. Areas in close proximity to existing protected areas were favoured.
    - Current socio-economic activities associated with the estuary.

- Quality of river flowing into the river. Rivers with an ecological integrity of A, B or C were favoured over rivers with a lower ecological integrity (D, E or F).

Table 18 and Figure 16 show the estuaries that were selected for inclusion into the conservation plan for the Fish-to-Tsitsikamma Water Management Area using this selection protocol.

Table 18: Estuaries selected to satisfy estuarine biodiversity targets
EPA and ECA refer to Estuarine Protected Areas and Estuarine Conservation Areas respectively (refer to text for definitions).

Estuary type	Selection notes
Permanently open Estuary EPAs	
Gamtoos	Selection based on its medium protection status and feasibility for stronger protection (banks are very steep, which can allow development more easily, as long as there is no sewerage water).
Kariega	Although the next on the EPA list of permanent estuaries should be the Great Fish (based on its condition, spatial distribution and national importance rating), strong EPA protection is probably not feasible. Also, the Gamtoos (selected already as an EPA) and Great Fish are both narrow channel-like estuaries with little salt marsh area, so it was deemed better to have one narrow channel-like estuary and one with large salt marshes.
Permanently open Estuary ECAs	
Swartkops	Selection based on its spatial distribution from other permanent estuaries and its overall national importance score. Although it is connected to a river with an ecological integrity of D, the estuary still functions because of the open mouth which maintains large productive intertidal saltmarshes. This is the third largest estuary in South Africa.
Great Fish	Selection based on its spatial distribution from other permanent estuaries and its overall national importance score.
Krom	Selection based on its spatial distribution from other permanent estuaries and its overall national importance score. This is an important estuary because of large salt marshes and benthic productivity. However, it is connected to a D river, and estuary reserve studies have placed the estuary in a D category because of reduced freshwater input, increase in water column salinity and reduced water column production. Management plans for this estuary should therefore take measures to improve the ecological integrity of both the river and estuary.
Temporary Estuary EPAs	
Tsitsikamma	Selection based on its high protection status.
Van Stadens	Selection based on its medium protection status and feasibility for stronger protection.
Kabeljous	Selection based on its national importance score and feasibility of existing terrestrial protected areas in its vicinity.
Kleinemond East	Kleinemond East and West have similar scores, but Kleinemond East was chosen because it contains an endemic pipefish.
Temporary Estuary ECAs	
Kleinemond West	All chosen on the basis of their overall spatial distribution and ecological integrity.
Riet	
Kasuka	
Boknes	
Maitland	
River Mouth EPA	
Storms	All River Mouths in the Fish-to-Tsitsikamma Water Management Area are EPAs, but this system was singled out on the basis of its excellent condition and high value as a nursery ground.
River Mouth ECA	
Elandsbos	Next most definitive river mouth in the area.

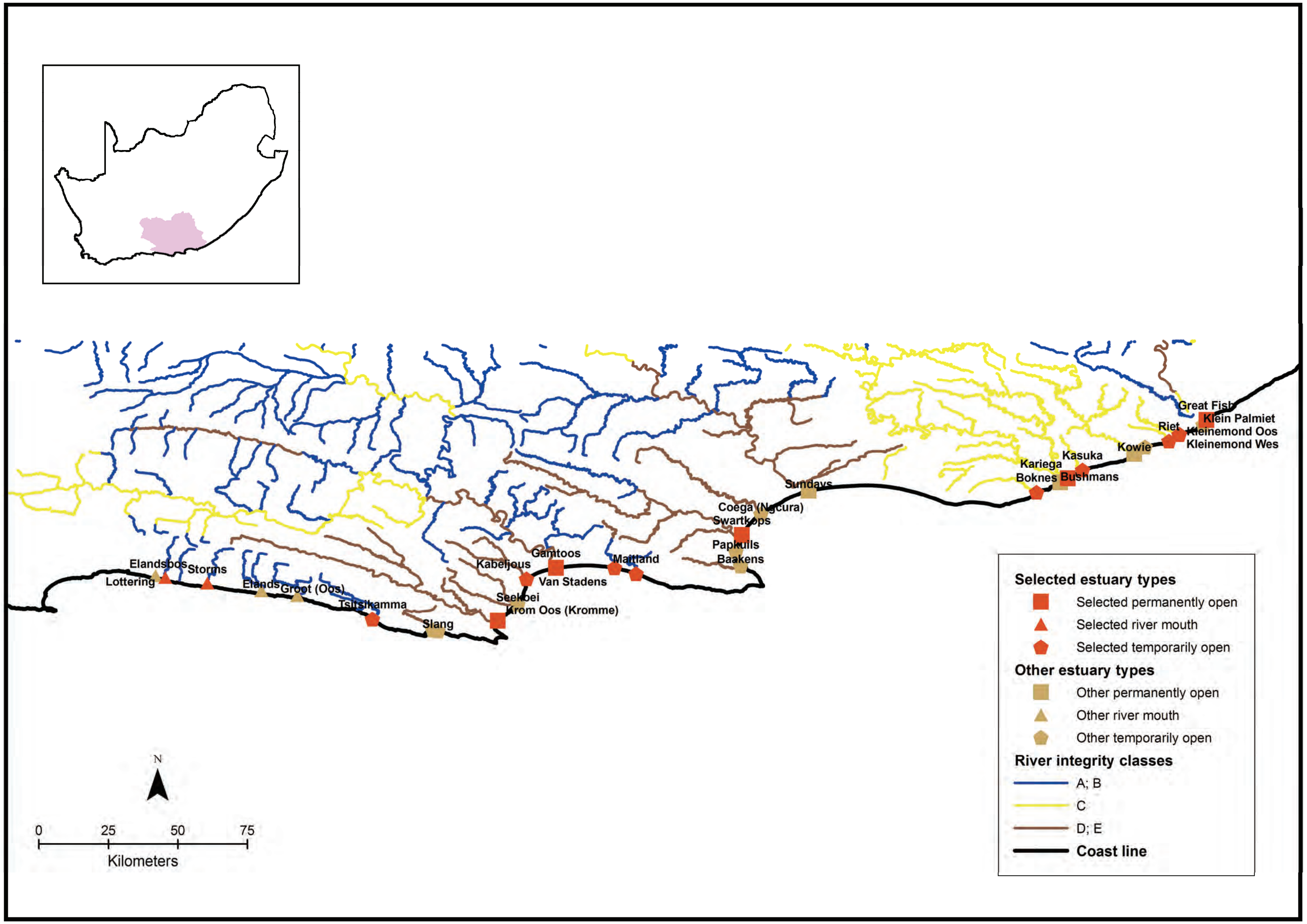


Figure 16: Estuaries selected for inclusion into the Fish-to-Tsitsikamma conservation plan

8 CONSERVATION DESIGN FOR RIVERS, QUATERNARY CATCHMENTS AND ESTUARIES

8.1 Introduction

The aim of this stage in the conservation planning process is to locate a set of catchments and estuaries that will achieve riverine and estuarine biodiversity targets. A selection protocol for rivers was developed with stakeholders, and used to select those quaternary catchments and river reaches that would best to conserve the biodiversity of the region. This section outlines the selection protocol, the testing of conservation planning decision support software, and the preliminary outputs of the conservation plan. It should be noted that conservation planning should be viewed as a process of iterative improvement – ground truthing should be undertaken in selected catchments to verify 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.

8.2 Planning units

In order to select areas to achieve biodiversity targets, the units of selection, or planning units, need to be defined. In this project, quaternary catchments were used as planning units. Rivers containing the biodiversity features that contribute towards achieving targets within each selected quaternary were also recorded, and depicted on the conservation plan. Using quaternary catchments as planning units has the advantage of building in a significant degree of connectivity. Rivers highlighted within quaternaries need a recommended level of protection, and in order to achieve this, the entire quaternary catchment should be managed appropriately.

8.3 Selection protocol for rivers

The following steps were used, in the order listed below, to select rivers and quaternary catchments for inclusion in the Fish-to-Tsitsikamma conservation plan:

1. Use conservation planning decision support software to help with the derivation of an initial plan that takes into account the following multiple criteria:
   - Complementarity and efficiency in achieving biodiversity targets;
   - Building in longitudinal connectivity; and
   - Where there are choices between quaternary catchments with similar biodiversity components, in order of appearance below:
     - Choose rivers near/flowing through terrestrial protected areas; and
     - Choose rivers adjacent to quaternary catchments that have been flagged for river rehabilitation.

2. Add in additional quaternary catchments needed for rehabilitation;
3. Add in additional quaternary catchments required for large-scale migration;
4. Build in large-scale connectivity where it is still needed;
5. Remove short stretches of river reach deemed too small to be viable; and

6. Investigate removal of marginal quaternary catchments, defined as those quaternary catchments whose percentage length of A or B class rivers is very low compared to the total length of river in that catchment.

An outline of each of these steps is provided below.

8.4 Step 1: Using decision support software for initial outputs

The process of using decision 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 utility in aiding decision-making for inland water conservation plans. A recent marine conservation planning software (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), that 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 in 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 6), which help to ensure that the issues in Step 1 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:

  Choosing rivers near/flowing through terrestrial protected areas.

Using the cost parameters outlined in Information Box 6, we ran[5] MARXAN/CLUZ to achieve targets for Level 3 river types.

8.5 Step 2: Adding additional quaternary catchments needed for rehabilitation

From the assessment of rehabilitation quaternary catchments Q94F, Q92E, Q92G, P40C, P40B, P40D, Q92F, L82G (Section 6.3, Appendix 2) were added to the plan. Specific rivers within these catchments (see Appendix 2 for details) need to be rehabilitated to an ecological integrity class of A or B in order to achieve the biodiversity targets for the Fish-to-Tsitsikamma Water Management Area.

[5] 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

8.6 Step 3: Adding additional quaternary catchments for large-scale migration

At this stage, many of the quaternary catchments required for the migration of freshwater eels and mullet (Figure 8) had already been selected for achievement of biodiversity targets. Any additional quaternary catchments required, that had not yet been selected for target achievement, were included – these additional catchments need not necessarily be in an A or B ecological integrity class, but they must be in a class that facilitates migration of the relevant species, usually not lower than a C state.

Information Box 6: MARXAN portfolio costs and costs applied for the Fish-to-Tsitsikamma conservation plan

The MARXAN portfolio cost consists of three parts, which are explained below in terms of the costs applied to the Fish-to-Tsitsikamma 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 Fish-to-Tsitsikamma quaternary catchments were assigned a basic cost of 100, but those which had ≥10 % of their area under Type 1 protected areas[6] were discounted to 50. Where there are choices between two quaternary catchments with similar biodiversity components, this discounting encourages MARXAN to select quaternary 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 Fish-to-Tsitsikamma 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 Fish-to-Tsitsikamma conservation plan, BLM=0.4.

3) Target penalty factor (or species penalty cost)

MARXAN calculates whether the target for each biodiversity feature is met by a portfolio and includes a cost for any target that has not been met. In the Fish-to-Tsitsikamma 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

[6] 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.

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

Using MARXAN/CLUZ and the quaternary catchments as planning units facilitates 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. It was decided to leave some isolated headwater reaches as isolated if they were sufficiently large (≥ 1 km) – i.e. downstream connectivity in these cases was not taken into account UNLESS flagged as very high migration value (it should be noted that most of these isolated headwaters were removed in Step 5 and 6). In essence, incorporating downstream connectivity had already been largely accomplished by including quaternary catchments that are nationally important for migration. Thus, this step focused mainly on upstream connectivity. Six additional quaternary catchments (M10A, L11A, L12B, L12D, L30C, and L50B) were selected for maintaining upstream connectivity in the conservation design. Rivers playing a connecting role in these catchments are not necessarily required in an A or B ecological integrity class, but rather they should be maintained in a condition that facilitates longitudinal connectivity.

8.8 Steps 5 and 6: Investigating size and marginal quaternary catchments

Final steps in the conservation plan were to examine the costs and benefits of including marginal quaternary catchments into the conservation plan. Marginal catchments are those catchments where the percentage length of A or B class rivers is very low compared to the total length of river in that catchment (i.e. the benefit of conserving these A or B river reaches may not outweigh the cost of managing an additional quaternary catchment). These were often the catchments which contained selected river reaches of a size deemed too small to be viable. The effect on target achievement of removing catchments whose A or B river lengths fell below a certain threshold percentage of the total river length in that catchment was examined:

- Where the percentage A or B length ≤ 25, the impact on the targets was too great (11 additional Level 3 River types would not meet their targets with the exclusion of these catchments);
- A threshold of percentage A or B length ≤ 17 was deemed a good compromise (5 Level 3 River types cannot meet their targets, but all except one can meet at least 16% of its target; the remaining one can meet 10% of its target).

Based on this assessment, a marginal quaternary catchment was defined as having an A or B length ≤ 17% of its total length, and these catchments were removed from the plan (catchments L82D, Q50B, N22B and N30A).

8.9 Selected rivers and quaternary catchments

This analysis produced a river conservation design (Figure 17), containing quaternary catchments and rivers that are required for:

(i) Target achievement. Any river selected should maintain a present ecological integrity class of A or B;

(ii) Rehabilitation to an A or B ecological integrity class is required to help achieve biodiversity targets;

(iii) Large-scale migration routes. Catchments selected must be managed in an ecological integrity class that supports connectivity, preferably no lower that a C class; and

(iv) Upstream connectivity of river reaches. Catchments need not be in an A or B ecological integrity class, but they need to be managed to facilitate connectivity, preferably no lower than a C class.

The conservation plan requires 55 (27%) quaternary catchments in the Fish-to-Tsitsikamma Water Management Area to achieve the biodiversity targets for Level 3 river types. This translates to 29% of the total river length in the water management area. A further 27 (13%) of the quaternary catchments in the area (translating to an additional 13% of the total river length in the area) are required to maintain upstream and downstream connectivity. These catchments need not be in an A or B ecological integrity class, but will need to be maintained in a state that permits connectivity, ideally no lower than a C state.

Table 19: Percentage quaternary catchments and river lengths in the conservation plan Percentages are calculated as the proportion required to the total number of catchments, or river length respectively. "Target" refers to catchments/rivers required to meet biodiversity targets (i.e. that need to be maintained in an A or B ecological integrity); "Connectivity" refers to catchments/rivers needed to maintain upstream and downstream connectivity and "Rehabilitation" refers to those catchments/rivers that need to be rehabilitated to a ecological integrity class of A or B to achieve biodiversity targets.

Required for:	% Quaternary catchments required	% river length required
Target	27	29
Connectivity	13	13
Rehabilitation	3	5
TOTAL	43	47

8.10 Assessment of targets achieved

The proposed river selections would achieve the biodiversity targets of 76 (67%) river types in the Fish-to-Tsitsikamma Water Management Area (Table 20). If the proposed quaternary catchments and rivers are rehabilitated (see Sections 6.3 and 8.5, as well as Appendix 2), then 13 (12%) additional river types will meet their biodiversity targets. Thus, with feasible rehabilitation, 80% of the river types can meet their targets in the Fish-to-Tsitsikamma Water Management Area. It is not possible to meet biodiversity targets of the remaining 24 river types (or 21%), as rehabilitation of examples of these river types in the area is not feasible. See Section 6.3 and Appendix 2 for a detailed assessment on the consequences of not conserving the 37 river types that cannot meet their targets.

Table 20: Achievement of biodiversity targets for river types
Number of river types that can meet targets without and with rehabilitation, and number that cannot meet targets in the planning domain (i.e. those where rehabilitation is not feasible). Numbers in brackets represent % of total number of river types.

Targets met without rehabilitation	Targets achievable with rehabilitation	Cannot meet targets
76 (67)	14 (12)	23 (21)

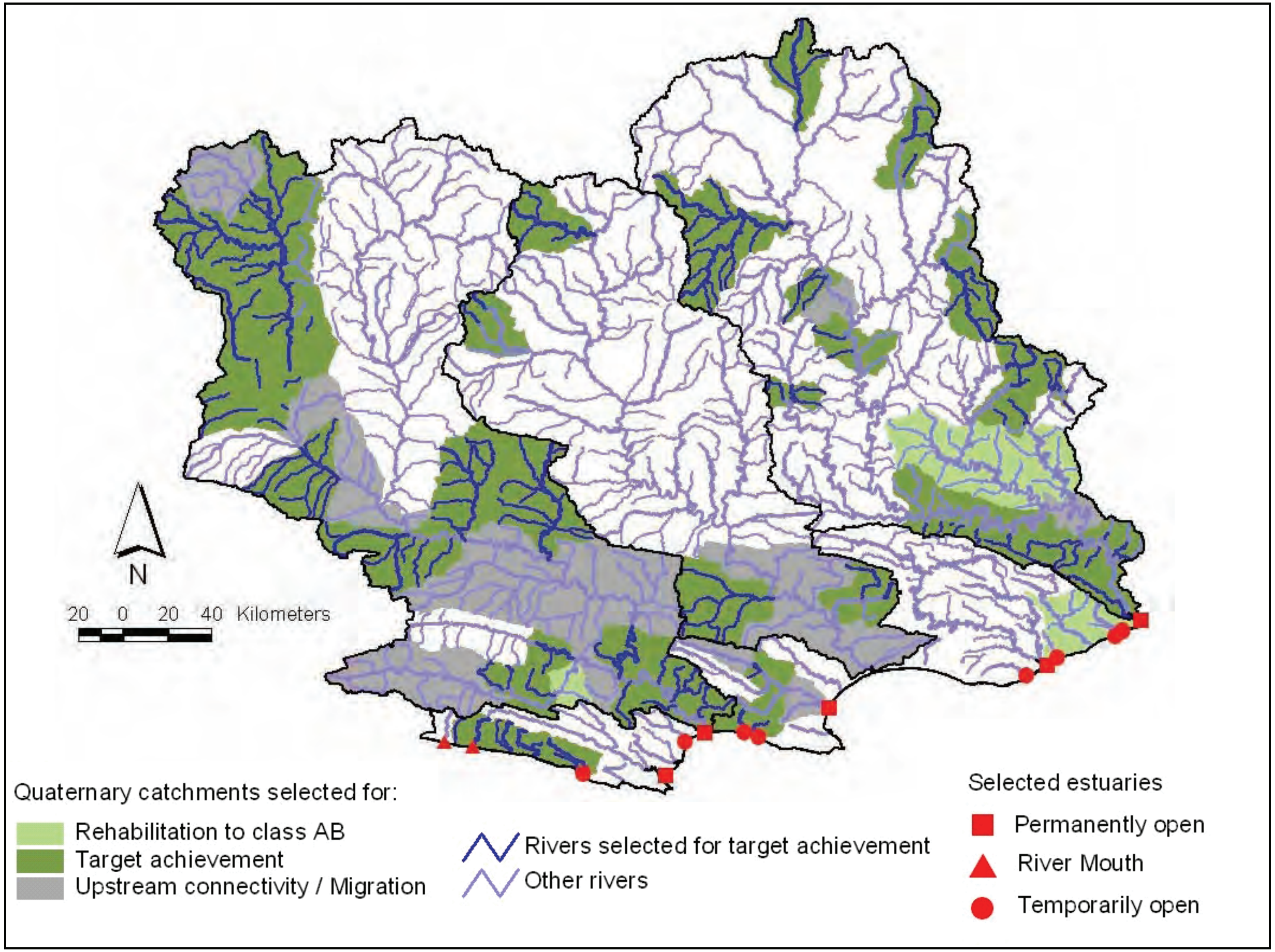


Figure 17: Selected rivers and estuaries for inclusion in the conservation plan

9 CONCLUSIONS

9.1 Lessons learnt

Conservation planning for inland waters is a new and rapidly evolving field. The Fish-to-Tsitsikamma is the first river conservation plan to be devised for a water management area in South Africa (some estuarine conservation plans have already been developed, e.g. Turpie and Van Niekerk 2004). Lessons from this planning exercise are already being applied in new conservation planning projects underway in the Crocodile (West) and Marico, and Olifants/Doorn Water Management Areas. Key lessons include:

(i) *National context*: There is a need to consider the national context within which plans at the level of the water management area are undertaken, particularly when assessing river types that cannot meet targets. A national process is underway to cascade national targets differentially across South Africa, based on a national conservation assessment of biodiversity. Currently, an assessment of national context is constrained by data limitations: the assessment requires consideration of the distribution of biodiversity at a national level, combined with the ecological integrity of this biodiversity. Level 3 river types have not yet been developed at a national level as this requires constructing longitudinal zones for at least all 1:500 000 rivers in South Africa, work that is currently being undertaken by the Department of Water Affairs and Forestry. Ecological integrity has also not yet been developed for all 1:500 000 rivers, although the Department of Water Affairs and Forestry is currently attempting to initiate a national ecostatus determination to derive these data. This is a time-consuming process and it is recommended that a suitable model be developed to predict river ecological integrity at finer scales (see Section 9.2).

(ii) *Choosing which rivers to assess*: Careful consideration needs to be given to choosing which rivers to assess in the conservation plan (i.e. which rivers data layer to use). River data layers for South Africa are available at scales of 1:500 000; 1:250 000 and 1:50 000. The 1:500 000 data layer is based on 1:500 000 topographical maps, but has been refined to include alignment of the rivers to within 50 m of 1:50 000 topographical maps. This is a marked improvement on the 1:250 000 rivers data layer which, although containing more rivers, consists simply of the blue plates from 1:250 000 topological maps that have not been cleaned or hydrologically corrected. Rivers at the 1:50 000 scale have been hydrologically corrected and coded and may seem ideal; however: (i) using 1:50 000 rivers can lead to selecting streams that are of too small a size to satisfy biodiversity targets; and (ii) constructing longitudinal zones for all 1:50 000 rivers (required for Level 3 river typing) would also be an immense task. Using the 1:500 000 rivers as a base data layer and augmenting this with any other significant river reaches from 1:50 000 (identified by regional experts) seems to be a good compromise for planning at the level of a water management area.

(iii) *Using sub-quaternary catchments*: The conservation plan for the Fish-to-Tsitsikamma Water Management Area uses quaternary catchments as the units of selection, or planning units. Modelling smaller sub-quaternary catchments would produce a more efficient conservation plan, as this would incorporate specific rivers. This lesson has been carried forward to the Crocodile (West) and Marico conservation plan with some success, and it would be ideal to develop a data layer of such sub-quaternary catchments at a national level (see Section 9.2).

(iv) *Assessing ecological integrity at the level of river reach*: Conservation plans for river biodiversity are often constrained by river ecological integrity across a planning region, particularly in areas where many rivers are in a poor condition. Two methods are commonly used in South Africa to derive ecological integrity at a landscape level; these are the present ecological status (Kleynhans 2000) or ecostatus determination (Kleynhans *et al.* 2005). Both of these methods aggregate rivers into broad-scale assessment units. All rivers in the assessment unit are then assumed to have the same generalised ecological integrity class. This ignores the possibility that, at a finer scale within the broad assessment unit, there may be some rivers that are in better condition than others, and therefore limits the options for achieving biodiversity targets. Modelling river ecological integrity at the level of each individual river reach (e.g. reaches between river confluences) would enable a better assessment of options across the landscape (see Section 9.2)

(v) *Using preliminary conservation plans to guide field verification*: Conservation plans are dependent on the data that are used to derive them. Since ecological integrity data are extremely scarce in the Fish-to-Tsitsikamma Water Management Area, a desktop ecological integrity score was derived using ecostatus determination techniques (Kleynhans *et al.* 2005). There was a need to undertake field verification in order to test the accuracy of these data before using them in the conservation planning exercise. Field sites were chosen mainly in areas where expert knowledge was lacking to obtain a more consistent coverage of the landscape. However, in retrospect, to utilize resources effectively it would have been better to undertake a desktop conservation plan with preliminary data and then to visit the priority areas identified in this process to verify that they do, in reality, contain the biodiversity components for which they were selected. Initially, this was not done so as not to bias the conservation plan.

(vi) *Preparation of the spatial data layers*: This is a time consuming process, but it is critical that adequate time is spent making sure that these data layers are of high quality and contain no errors and data artefacts (e.g. slivers produced from spatial overlays may produce false river types).

(vii) *Hydrological index*: It is important to take care when lumping hydrological index classes without a strong rationale for doing so. Initially, it appeared that it would be easier to deal with only three levels of flow variability. However, on closer inspection of the hydrological index data with regional experts, it seemed the hydrological index classes separated out true river types.

(viii) *Best Attainable Ecological Management Class*: These data (Kleynhans 2000) are broad scale and outdated (assembled between 1996 and 1998), and should thus be applied with caution in assessing the rehabilitation potential of rivers. The available data tend to suggest that the river can be returned to a higher ecological integrity class than that which is currently deemed feasible by experts.

9.2 Future research and monitoring to support the conservation plan

The future research needs that are identified below would all feed into the development of a national biodiversity assessment and conservation strategy, which is critical to provide context for conservation planning at a sub-national level:

(i) *Collecting and verifying primary data*: Conservation planning outputs are highly dependent on biodiversity pattern and ecological integrity data layers. These data layers have their limitations (Section 3.3 and Section 5.6), and require both expert knowledge and field verification. In addition, research on how best to supplement conservation plans with species data needs to be investigated, e.g. freshwater fish distribution data. Collecting high quality primary data for a region, or nationally, is well worth the investment because experience in terrestrial conservation planning (already over a decade old in this country; Driver *et al.* 2003) suggests that the primary data have a much longer life span than the conservation plan itself.

(ii) *Developing a model to predict ecological integrity, using existing data on land cover, dams and surface run-off*: A model has been developed for Australian rivers (Stein *et al.* 2002), which could be used as a basis for use on South African rivers. This model would need to be verified, a process which could be done together with the regional ecostatus determination due to be launched in the next year. Information Box 5 in Section 6.3 provides an example of what can be done using natural vegetation alone as a predictor of ecological integrity in South Africa. Point (iv) in the section above (Section 9.1) explains why this would provide better options for conservation planning.

(iii) *Modelling sub-quaternary catchments*: Point (iii) in Section 9.1 above explains how the modelling of sub-quaternary catchments would prove far more efficient for conservation planning. Techniques have already been pioneered in the conservation plan for the Crocodile (West) and Marico Water Management Area, which is currently underway, and this would need to be extended to the entire country. Extending it to the entire country, rather than generating sub-quaternary catchments on a piece-meal basis, would facilitate synergy and alignment of the sub-catchments used. It would also facilitate efficiency in developing a national biodiversity assessment and conservation strategy.

(iv) *Incorporating wetlands*: There are a number of projects under way to promote the inventory and classification of wetlands in South Africa. These processes are highly challenging, but once the spatial products are available, wetlands could be incorporated relatively easily into biodiversity pattern targets. Challenges related to future research for wetlands with regard to conservation planning, include: deriving data for wetland condition at a landscape level (this is probably best mapped using a predictive model similar to the one described in Section 9.1, point iii); incorporating the functional importance of wetlands; and setting biodiversity targets for wetland types. Some of these aspects are being pioneered at a very basic level in the conservation plan for the Crocodile (West) and Marico Water Management Area.

(v) *Incorporating ground water*: Research is required on how best to incorporate ground water into conservation planning. Whilst many research projects currently target the management of groundwater, limited research is focussed on mapping ground water processes. Efforts that are currently being applied in the Crocodile (West) and Marico conservation plan focus on identifying rivers that are highly dependent on ground water inflows and areas that are important for ground water recharge. Although some preliminary maps of ground water dependent ecosystems are available, the areas that need managing in order to maintain these can be great distances away - maps of the actual areas that support ground water dependent ecosystems therefore need to be developed.

(vi) *Setting more ecologically meaningful targets for aquatic biodiversity*: It is recognised that the biodiversity target of 20% is somewhat arbitrary and not based on a sound scientific understanding of the limits of acceptable change and other ecological thresholds. These targets may also differ for different ecosystem types (some may require a larger proportion than others in order to enjoy an adequate level of protection). Scientific research around ecological thresholds should therefore be undertaken to inform the setting of biodiversity targets.

9.3 Way forward

9.3.1 Management actions

Maintenance of ecological integrity in selected river reaches is critical, and these should be connected within the selected quaternary catchments via rivers that facilitate upstream and downstream connectivity. Selected estuaries should be afforded appropriate levels of protection as suggested by their Estuarine Protected Area or Estuarine Conservation Area status. They should also have accompanying management plans and a comprehensive estuary reserve assessment should be undertaken and implemented. The linking of selected rivers and estuaries with the national water resource classification process is essential, as well as setting Resource Quality Objectives for all selected rivers and quaternary catchments.

Saunders *et al.* (2002) list the three primary causes of biodiversity loss in inland water systems: (i) land-use disturbances; (ii) altered hydrological regimes; and (iii) alien invasive species. This concurs with the findings of river health surveys carried out in South Africa, where the destruction of riparian zones, flow regulation and alien species (terrestrial and riparian flora as well as aquatic biota) are typically found to be main factors impacting on river health (RHP 2001a, 2001b). From these primary impacts, Roux *et al*. (2006) suggest three basic management actions that would go a long way to conserving inland water biodiversity. These are outlined below, with specific recommendations regarding the Fish-to-Tsitsikamma Water Management Area:

(i) *Negate effects of deleterious land-use activities*:
This would include:

- Conserving whole catchments if this is at all feasible. Where this is not possible, catchment zoning, in which the most deleterious activities for the resource are relegated to the part of the catchment furthest away from the river, should be used as a management option. Where the former options are not available, intact riparian buffer strips may be used to reduce the effects of deleterious land-use practices. Widths of 10-50 m have been found to be effective in maintaining ambient stream temperatures and retaining sediments and nutrients. The effective width of a riparian buffer strip should be determined on a site-specific basis, considering factors such as varying vegetation types and slope.

- Improving or re-instating extension in agricultural landscapes.
- Avoiding road crossings in selected rivers. Where they are necessary, ensure that their impacts are minimized. For example, bridges are better than causeways – where causeways have to be built, build a reasonable number of culverts into the causeway so that it allows water to flow freely in the active channel; build retaining walls for roads next to rivers (especially gravel roads).

(ii) <u>*Retain natural flow regimes*</u>:

This would include:

- Understanding the in-stream flow requirements of rivers.
- Managing the primary drivers of in-stream ecological integrity, i.e. in-stream water abstraction, flow modification, bed modification, channel modification, water quality and inundation (Table 9).
- Developing a water release plan for dammed rivers that is suited to maintaining the river in the desired ecological integrity (A or B class for rivers required to meet targets; preferably a C class for rivers required for maintaining connectivity).
- Building fishways in rivers that are required for connectivity. NOTE: alien infestations may need to be managed before this is done.
- Removing non-functional weirs, a common occurrence in the Fish-to-Tsitsikamma Water Management Area, particularly in the more arid inland areas of the region. NOTE: alien infestations may need to be managed before this is done.

(iii) <u>*Exclude alien species:*</u>

All selected catchments should have an alien organism management plan, which includes a monitoring component.

9.3.2 Identify a champion institution to coordinate implementation of this plan

Implementation of this conservation plan will require an effective integrated management approach where water resource management, land-use management, and biodiversity conservation are managed in a coordinated manner that aims to achieve ecological and socio-economic sustainability. To achieve this coordination, it is important to identify a regional champion institution to drive this plan forward. Conservation of inland water biodiversity is a cross-sectoral responsibility. The two departments with the most direct line responsibility are the departments of Water Affairs and Forestry, and Environmental Affairs and Tourism. However, to make cooperative implementation work in practice, one of these departments should take the lead.

The most appropriate framework within which to operate would be the Catchment Management Agencies under the auspices of the Department of Water Affairs and Forestry; however, it may take several years before these agencies are fully functional. In the interim, the most appropriated champion institution is the Resource Directed Measures and Water Resources Planning Directorates of the regional and national offices of the Department of Water Affairs and Forestry. This department should develop an implementation strategy and action plan with significant involvement of the provincial offices of the Department of Economic Affairs, Environment and Tourism, and the Bioregional Coordination Unit (under the auspices of the South African National Biodiversity Institute). Other key stakeholders in the region that should be included in the implementation process are presented in Table 2, but this list should be extended to include local and district municipalities and the agricultural sector.

The implementation strategy and action plan should give due attention to the various roles and responsibilities in this complex cross-sector environment. Aspects that should receive close attention in the implementation strategy include:

- Development of a cooperative governance framework which would form the building block for the implementation of the conservation plan for the region;
- Capacity (skills and knowledge) required to implement conservation action and to "do the right thing";
- Financial resource requirements;
- Providing clear definition of roles and responsibilities, and possibly of required institutional and functional design aspects that may currently be lacking;
- Problem-solving, negotiation and conflict management skills (this is an inevitable requirement where overlapping responsibilities and conflicting of interests are realities); and
- Developing a monitoring and evaluation system, not only for achievement and revision of ecological and conservation targets or objectives, but also for institutional and individual performance measurements.

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Appendix 1: Level 3 river types

River type name comprises the name of the geomorphic province, followed by a number from 1 to 8 representing the hydrological Index class, and a letter corresponding to the longitudinal zone (S = source zone, A = mountain headwaters/mountain headwater streams, C = transitional zones, D = upper foothills, E = lower foothills, F = lowland rivers and R = rejuvenated zones). Length FTT is the total length of each river type in the Fish-to-Tsitsikamma Water Management Area, Length A or B is the length of the river type in ecological integrity class A or B, Target is calculated as 20% of Length FTT. River types where Rehab = 1 cannot achieve the target in rivers with an ecological integrity class A or B, and need to be investigated for rehabilitation (see Appendix 2 for a detailed assessment of the rehabilitation potential for these river types).

River type	Length FTT (km)	Length AB (km)	Target (km)	Rehab
Central Cape Fold Mountains 1 A	19.3	19.3	3.9	0
Central Cape Fold Mountains 1 C	27.1	27.1	5.4	0
Central Cape Fold Mountains 1 D	15.5	15.5	3.1	0
Central Cape Fold Mountains 1 R	0.2	0.2	0.0	0
Central Cape Fold Mountains 2 A	4.6	1.3	0.9	0
Central Cape Fold Mountains 2 C	3.1	0.5	0.6	0
Central Cape Fold Mountains 2 D	11.6	0.0	2.3	1
Central Cape Fold Mountains 2 E	40.5	0.0	8.1	1
Central Cape Fold Mountains 5 A	85.1	53.0	17.0	0
Central Cape Fold Mountains 5 C	143.7	101.7	28.7	0
Central Cape Fold Mountains 5 D	261.0	88.9	52.2	0
Central Cape Fold Mountains 5 E	13.9	0.0	2.8	1
Central Cape Fold Mountains 5 R	238.0	13.0	47.6	1
Central Cape Fold Mountains 6 A	44.3	44.3	8.9	0
Central Cape Fold Mountains 6 C	62.1	62.1	12.4	0
Central Cape Fold Mountains 6 D	121.4	121.4	24.3	0
Central Cape Fold Mountains 6 E	53.6	29.7	10.7	0
East London Coastal Hinterland 3 A	0.7	0.0	0.1	1
East London Coastal Hinterland 3 C	13.5	0.0	2.7	1
East London Coastal Hinterland 3 D	66.8	0.0	13.4	1
East London Coastal Hinterland 3 E	97.9	0.0	19.6	1
East London Coastal Hinterland 5 A	16.8	0.0	3.4	1
East London Coastal Hinterland 5 C	39.3	0.0	7.9	1
East London Coastal Hinterland 5 D	283.4	26.3	56.7	1
East London Coastal Hinterland 5 E	499.1	70.9	99.8	1
East London Coastal Hinterland 6 A	52.4	3.1	10.5	1
East London Coastal Hinterland 6 C	130.9	1.8	26.2	1
East London Coastal Hinterland 6 D	760.7	21.7	152.1	1
East London Coastal Hinterland 6 E	953.0	6.1	190.6	1
East London Coastal Hinterland 6 S	5.7	0.0	1.1	1
Eastern Cape Fold Mountains 5 A	62.2	50.9	12.4	0
Eastern Cape Fold Mountains 5 C	112.1	89.7	22.4	0
Eastern Cape Fold Mountains 5 D	322.2	138.8	64.4	0

River type	Length FTT (km)	Length AB (km)	Target (km)	Rehab
Eastern Cape Fold Mountains 5 E	84.3	5.9	16.9	1
Eastern Cape Fold Mountains 5 R	10.1	0.0	2.0	1
Eastern Cape Fold Mountains 6 A	97.9	85.3	19.6	0
Eastern Cape Fold Mountains 6 C	176.5	137.5	35.3	0
Eastern Cape Fold Mountains 6 D	1032.9	907.5	206.6	0
Eastern Cape Fold Mountains 6 E	629.0	236.9	125.8	0
Great Escarpment 5 A	112.3	94.2	22.5	0
Great Escarpment 5 C	163.2	145.7	32.6	0
Great Escarpment 5 D	609.5	516.4	121.9	0
Great Escarpment 5 E	5.9	1.9	1.2	0
Great Escarpment 6 A	189.0	138.5	37.8	0
Great Escarpment 6 C	213.4	146.9	42.7	0
Great Escarpment 6 D	753.0	476.2	150.6	0
Great Escarpment 6 E	266.6	140.4	53.3	0
Great Escarpment 6 S	7.3	3.5	1.5	0
Queenstown Basin 5 A	3.7	0.0	0.7	1
Queenstown Basin 5 C	13.5	9.2	2.7	0
Queenstown Basin 5 D	212.3	105.4	42.5	0
Queenstown Basin 5 E	122.8	19.7	24.6	0
Queenstown Basin 6 A	5.7	5.7	1.1	0
Queenstown Basin 6 C	24.6	23.4	4.9	0
Queenstown Basin 6 D	358.3	273.6	71.7	0
Queenstown Basin 6 E	394.8	137.7	79.0	0
Southeastern Coastal Hinterland 3 A	59.3	56.3	11.9	0
Southeastern Coastal Hinterland 3 C	53.3	44.9	10.7	0
Southeastern Coastal Hinterland 3 D	154.1	80.1	30.8	0
Southeastern Coastal Hinterland 3 E	46.9	8.1	9.4	0
Southeastern Coastal Hinterland 4 A	27.2	5.3	5.4	0
Southeastern Coastal Hinterland 4 C	27.1	2.5	5.4	1
Southeastern Coastal Hinterland 4 D	114.4	13.8	22.9	1
Southeastern Coastal Hinterland 4 E	13.8	0.0	2.8	1
Southeastern Coastal Hinterland 4 S	0.8	0.0	0.2	1
Southeastern Coastal Hinterland 5 A	55.2	23.9	11.0	0
Southeastern Coastal Hinterland 5 C	76.0	42.0	15.2	0
Southeastern Coastal Hinterland 5 D	255.6	135.6	51.1	0
Southeastern Coastal Hinterland 5 E	40.2	0.0	8.0	1
Southeastern Coastal Hinterland 5 S	9.6	2.1	1.9	0
Southeastern Coastal Hinterland 6 A	83.0	22.1	16.6	0
Southeastern Coastal Hinterland 6 C	101.1	22.9	20.2	0
Southeastern Coastal Hinterland 6 D	414.1	109.4	82.8	0
Southeastern Coastal Hinterland 6 E	292.4	20.9	58.5	1
Southeastern Coastal Hinterland 6 S	4.1	4.1	0.8	0
Southern Coastal Lowlands 2 D	10.2	0.0	2.0	1
Southern Coastal Lowlands 2 E	10.1	0.0	2.0	1
Southern Coastal Lowlands 5 A	2.5	1.9	0.5	0
Southern Coastal Lowlands 5 C	12.6	9.0	2.5	0
Southern Coastal Lowlands 5 D	112.0	37.3	22.4	0
Southern Coastal Lowlands 5 E	80.8	32.1	16.2	0
Southern Coastal Lowlands 5 F	13.4	0.0	2.7	1

River type	Length FTT (km)	Length AB (km)	Target (km)	Rehab
Southern Coastal Lowlands 5 R	3.1	3.1	0.6	0
Southern Coastal Lowlands 6 A	5.3	0.0	1.1	1
Southern Coastal Lowlands 6 D	193.8	24.2	38.8	1
Southern Coastal Lowlands 6 E	216.9	85.3	43.4	0
Southern Coastal Lowlands 6 F	90.6	0.0	18.1	1
Southern Coastal Platform 1 A	1.3	1.3	0.3	0
Southern Coastal Platform 1 C	10.0	10.0	2.0	0
Southern Coastal Platform 1 D	61.2	61.2	12.2	0
Southern Coastal Platform 1 E	3.3	3.3	0.7	0
Southern Coastal Platform 1 R	3.9	3.9	0.8	0
Southern Coastal Platform 2 C	0.7	0.7	0.1	0
Southern Coastal Platform 2 D	51.3	46.2	10.3	0
Southern Coastal Platform 5 A	2.3	0.0	0.5	1
Southern Coastal Platform 5 C	1.5	0.1	0.3	1
Southern Coastal Platform 5 D	97.6	12.4	19.5	1
Southern Coastal Platform 5 E	121.1	10.1	24.2	1
Southern Coastal Platform 5 F	51.1	0.1	10.2	1
Southern Karoo 6 A	29.1	14.9	5.8	0
Southern Karoo 6 C	74.5	34.6	14.9	0
Southern Karoo 6 D	1400.0	496.5	280.0	0
Southern Karoo 6 E	1872.1	890.5	374.4	0
Southern Karoo 7 C	3.0	3.0	0.6	0
Southern Karoo 7 D	278.0	278.0	55.6	0
Southern Karoo 7 E	348.5	348.5	69.7	0
Upper Karoo 5 A	34.7	23.2	6.9	0
Upper Karoo 5 C	43.5	34.8	8.7	0
Upper Karoo 5 D	203.8	130.8	40.8	0
Upper Karoo 6 A	8.7	8.7	1.7	0
Upper Karoo 6 C	23.7	23.5	4.7	0
Upper Karoo 6 D	221.5	192.4	44.3	0
Upper Karoo 6 E	108.2	108.2	21.6	0

Appendix 2: Assessment of rehabilitation potential

Rehabilitation potential for the 37 Level 3 river types that cannot achieve their 20% targets was examined. The table below shows Level 3 river types nested within Level 2 river using table shading. "AB" is total length of each river type in an A or B ecological integrity class, "Total" is the total length irrespective of ecological integrity class, "Target" is the target expressed as 20% of the total length. The extent of the Level 2 river type national range within the study area 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 (see Information Box 5 in Section 6.3).

Level 3 River type	AB (km)	Total (km)	Target (km)	% National	Rehabilitation assessment	Notes
Central Cape Fold Mountains 2 D	0	11	2.3	13	Best conserved elsewhere	Best conserved elsewhere on the rivers in the Garden Route within tertiary catchments K30, K40, K50 and K60.
Central Cape Fold Mountains 2 E	0	40	8			
Central Cape Fold Mountains 5 E	0	14	3	30	Rehabilitation not feasible and conservation opportunities elsewhere also look bleak	Located on the Kouga/Gamtoos system. Best AEMC = C so rehabilitation is not feasible. Elsewhere in the country, lower reaches are located mainly on the Kammanassie/Olifants system, which confluences with the Gamtoos – these areas also show C class ecological integrity, with best AEMC = C in lower reaches. There are some small areas to the west of these containing A/B CCM5 rivers but these are likely to be upper reaches whose targets are more achievable.
Central Cape Fold Mountains 5 R	13	238	48		Rehabilitation feasible	Rehabilitation of the Kouga system, just upstream of the dam is feasible (L82G), although this area has been highlighted as a potential area for a dam.

Level 3 River type	**AB (km)**	**Total (km)**	**Target (km)**	**% National**	**Rehabilitation assessment**	**Notes**
Eastern Cape Fold Mountains 5 E	6	84	17	100	Rehabilitation not feasible and cannot be conserved elsewhere (unique to study area)	Lower foothills are entirely contained within the study area. ECM5E reaches are on located on the Gamtoos and Chatty systems and best AEMC = C, so not really feasible for rehabilitation. Consequence is that these Lower foothill type rivers are under-represented in the country, being able to achieve only a 7% target. The rejuvenated reaches of this river type are located on the Brak tributary that leads into the Chatty River. This is represented by a relatively small stretch of river (only 10km), but it appears to be a true river type (should be field-verified). As for ECM5E, this cannot feasibly be rehabilitated. Consequence is that these rejuvenated type rivers cannot meet any of its 20% target in the country.
Eastern Cape Fold Mountains 5 R	0	10	2			
East London Coastal Hinterland 3 A	0	1	0	24	Rehabilitation feasible	Rehabilitation of the Kat River System Q94F (AEMC=A or B) would achieve the targets for these river types (Kat River is a tributary of the Great Fish River). At a national level some of these targets could be achieved in the tributaries of the Keiskamma River but probably not enough to make up the national 20% target. A more thorough assessment needs to consider whether it is better to rehabilitate the Keiskamma River system to achieve targets or to go ahead and rehabilitate the Kat River. From a connectivity viewpoint it also needs to be investigated if it is better to rehabilitation the Keiskamma if it is in a better state than the Great Fish into which the Kat feeds. However, both the Kat and the adjacent Koonap river systems contain good remaining populations of the endangered Eastern Cape Rocky, *Sandelia bainsii.*
East London Coastal Hinterland 3 C	0	13	3			
East London Coastal Hinterland 3 D	0	67	13			
East London Coastal Hinterland 3 E	0	98	20			

Level 3 River type	AB (km)	Total (km)	Target (km)	% National	Rehabilitation assessment	Notes
East London Coastal Hinterland 5 A	0	17	3	46	Rehabilitation feasible	Rehabilitation of the Koonap System, currently in a C-state (Q92E, Q92G) is better than rehabilitation in the adjacent WMA (Keiskamma-Mzimvhubu) because the area there contains many D-rivers e.g. Buffalo and Nahoon. Additionally, both the Koonap and the adjacent Kat river systems contain good remaining populations of the endangered Eastern Cape Rocky, *Sandelia bainsii.*
East London Coastal Hinterland 5 C	0	39	8			
East London Coastal Hinterland 5 D	26	283	57			
East London Coastal Hinterland 5 E	71	499	100			
East London Coastal Hinterland 6 A	3	52	10	100	Rehabilitation feasible	Rehabilitation of the Kowie (P40C and P40B) and West-Kleinemond (P40D) systems has been recommended by regional experts, rather than the Bushmans River System. It must be born in mind that the best AEMC = C, so rehabilitation of these rivers may not be feasible. To achieve these targets in totality, rehabilitation of Koonap River System (Q92F) is also necessary. May need to investigate rehabilitating either Brak (Q80F) or Voel (N30B) –Voel contains with less dams, but these add inefficiency to the conservation plan.
East London Coastal Hinterland 6 C	2	131	26			
East London Coastal Hinterland 6 D	22	761	152			
East London Coastal Hinterland 6 E	6	953	191			
East London Coastal Hinterland 6 S	0	6	1			
Queenstown Basin 5 A	0.0	3.7	0.7	80	Rehabilitation not feasible and conservation opportunities elsewhere also look bleak	Without rehabilitation this river type will be lost as a whole in the country because it does not look likely that there are headwater streams elsewhere (located on the Swart-Kei River system which is in a D class). Rehabilitation in the Fish-to-Tsitsikamma is probably not feasible as this is the area of large interbasin transfers. At a push, could investigate rehabilitation of Q42A (Elands River tributary which feeds the upper reaches of the Tarka River).
Southeastern Coastal Hinterland 4 C	2	27	5		Best conserved elsewhere	Best conserved elsewhere in tertiary catchments W21 and W22 in KwaZulu Natal – however, the extent of this river type should be examined, as rivers in the KwaZulu Natal are considered biologically different to the ones in the Eastern Cape.
Southeastern Coastal Hinterland 4 D	14	114	23			
Southeastern Coastal Hinterland 4 E	0	14	3			
Southeastern Coastal Hinterland 4 S	0	1	0			

Level 3 River type	AB (km)	Total (km)	Target (km)	% National	Rehabilitation assessment	Notes
Southeastern Coastal Hinterland 5 E	0	40	8	18	Best conserved elsewhere	Best conserved elsewhere, either in the Mzimvubu-to-Keiskamma Water Management Area, or in KwaZulu Natal around the Hluhluwe Nature Reserve – however, the extent of this river type should be examined, as rivers in the KwaZulu Natal are considered biologically different to the ones in the Eastern Cape.
Southeastern Coastal Hinterland 6 E	21	292	58	100	Rehabilitation not feasible and cannot be conserved elsewhere (unique to study area)	This is the driest western-most tip of Southeastern Coastal Hinterland. The lower foothills are made up of the Great Fish and Tarka River Systems which are not feasible to rehabilitate. Consequence is that this river type will be under-represented in the country, being able to achieve only a 7% target.
Southern Coastal Lowlands 2 D	0	10	2	11	Best conserved elsewhere	Best conserved in K40D and K40E on Goukamma and Sedgefield Rivers.
Southern Coastal Lowlands 2 E	0	10	2			
Southern Coastal Lowlands 5 F	0	13	3	67	Rehabilitation not feasible and conservation opportunities elsewhere also look bleak	The reaches on the Chatty river, which have AEMC=C and not feasible for rehabilitation. The other reaches in the country are on the lowlands of the Gouritz and Heuningnes. Gourits also has an AEMC=C. Heuningnes may not be a lowland river reach, but it is feasible to rehabilitation.
Southern Coastal Lowlands 6 A	0	5	1	100	Rehabilitation not feasible and cannot be conserved elsewhere (unique to study area)	The upper reaches of this river type, and the lowland reaches occur on the Sundays River only, which is not feasible to rehabilitate. The consequence is that these upper and lowland reaches of this river type cannot meet any of its 20% target in the country. For the upper foothills, it may be possible to rehabilitate M20A (the Bakens River running in at Port Elizabeth), but even though the AEMC for the Bakens is A or B, expert knowledge of the area remains dubious whether this system could be adequately rehabilitated. Consequence is that this river type will be under-represented in the country, being able to achieve only a 12% target.
Southern Coastal Lowlands 6 D	24	194	39			
Southern Coastal Lowlands 6 F	0	91	18			

Level 3 River type	AB (km)	Total (km)	Target (km)	% National	Rehabilitation assessment	Notes
Southern Coastal Platform 5 A	0	2	0	43	Rehabilitation not feasible and conservation opportunities elsewhere also look bleak	AEMC=B for rehabilitation of Krom at St Francis, but expert opinion remains unconvinced whether this system can be rehabilitated adequately. However, conservation options in rest of country also look bleak.
Southern Coastal Platform 5 C	0	1	0			
Southern Coastal Platform 5 D	12	88	18			
Southern Coastal Platform 5 E	10	121	24			
Southern Coastal Platform 5 F	0	38	8			

Appendix 3: Contents of Metadata CD for data used in this project

Large amounts of data were collated as part of this project. These data are provided on a Metadata CD accompanying this report. Publications are available form

Publications
Water Research Commission
Private Bag X03, GEZINA, 0031
South Africa

E-Mail: orders@wrc.org.za
http://www.wrc.org.za

The contents on this CD are as follows:

GIS shapefiles
- Fish-to-Tsitsikamma Water Management Area and sub-Water Management Areas.
- Quaternary catchments coded for migration rating, hydrological index, best attainable ecological management class, selected for incorporation into conservation plan.
- 1:500 000 rivers classified according to river type, present ecological integrity, quaternary catchment code.
- Estuaries classified according to estuary type, protection status, present ecological status, conservation importance rating, selected for incorporation into conservation plan.
- Field sites for ground verification of the desktop determination of present ecological integrity.
- Protected areas.
- Hillshade Digital Elevation Model.

Ecostatus spreadsheets
Per primary catchment containing the scores allocated to the criteria assessed in the Level 1 ecostatus determination workshop.

Field verification photos and data sheets
Scanned versions of each
An Arcview project file that hyperlinks the field sites and photographs.

CLUZ input and output files
Used for the initial decision support on which were the best quaternary catchments to choose.