National River Ecosystem Accounts for South Africa

Discussion Document

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Preface

South Africa is one of seven pilot countries involved in a global initiative called Advancing SEEA Experimental Ecosystem Accounting,[1] led by the United Nations Statistics Division (UNSD) in partnership with the United Nations Environment Programme (UNEP) and the Convention on Biodiversity (CBD), with funding from the Government of Norway. Within South Africa, the South African National Biodiversity Institute (SANBI) and Statistics South Africa (Stats SA) have worked in partnership with the Council for Scientific and Industrial Research (CSIR), the Department of Water and Sanitation (DWS), the Department of Environmental Affairs (DEA) and Ezemvelo KZN Wildlife, to take this project forward.

This discussion document forms part of a set of deliverables resulting from South Africa's participation in Phase 1 of Advancing SEEA Experimental Ecosystem Accounting, which took place from mid-2014 to May 2016.

Related reports

The document forms part of a set of deliverables from South Africa for the Advancing SEEA Experimental Ecosystem Accounting (AEEA) project. Related project reports include:

- Land and Ecosystem Accounting in KwaZulu-Natal, South Africa: Discussion Document
- Advancing Experimental Ecosystem Accounting in South Africa: Stakeholder Engagement Report
- National Plan for Advancing Environmental-Economic Accounting: South Africa

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[1] Also referred to in some of the global project documents as Advancing Natural Capital Accounting or ANCA.

Acknowledgements

We gratefully acknowledge the support of the UNSD, UNEP and the CBD Secretariat through the Advancing SEEA Experimental Ecosystem Accounting project, as well as funding from the Government of Norway. In particular we thank the UNSD for their enthusiastic support for South Africa's emerging programme of work on ecosystem accounting.

The work presented here builds on data collation and exploratory work on river condition indices in South Africa, funded by SwedBio and led by the UNEP World Conservation Monitoring Centre and the CSIR.

Stats SA has been a key partner in this work and a champion of ecosystem accounting, building on their existing work on environmental accounting. In particular we thank Joe de Beer, Gerhardt Bouwer, Riaan Grobler, Ester Koch, Robert Parry, Thembalihle Ndlovu and Brenda Mphakane for their active advice and involvement.

We thank the Department of Water and Sanitation (DWS) for their strong commitment and collaborative approach to this work. In particular we thank Ndileka Mohapi for her active engagement and championship, and Neels Kleynhans for his help with interpreting national data on present ecological state used in the river condition accounts. We also thank those who participated in a series of technical workshops that were held to review the approach and draft results reported here. These included a workshop on 22 July 2014 in Pretoria, at which the proposed data and methods to develop national river ecosystem accounts for South Africa were presented, together with initial draft results. About 25 people participated, including government officials, consultants and other relevant experts from the freshwater ecosystem sector. On 12 May 2015 we held a workshop to discuss the draft accounts and results in detail, involving mainly officials from DWS. Regular reports on the development of river ecosystem accounts were provided at meetings of the Inter-departmental Committee on Inland Water Ecosystems, which is convened approximately twice a year by DWS and aims to enable and strengthen co-operative governance between national departments and their agencies involved in managing and conserving inland water ecosystems.

The work benefited from the input of South Africa's Strategic Advisory Committee on Ecosystem Accounting. For a list of members and further information about stakeholder engagement linked to the project please see the Stakeholder Engagement Report for the project as a whole.

We especially thank Lindie Smith-Adao (CSIR) for her careful attention to detail in formatting all the tables in this document, as well as Neels Kleynhans (DWS), Wietsche Roets (DWS), Michael Bordt (consultant to the UNSD) and Carol Poole (SANBI) for their helpful comments on the approach and on a draft of this document.

Acronyms

AEEA	Advancing SEEA Experimental Ecosystem Accounting
ANCA	Advancing Natural Capital Accounting
CBD	Convention on Biological Diversity
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
GDP	Gross Domestic Product
GIS	Geographic Information Systems
KZN	KwaZulu-Natal
LCEU	Land cover ecosystem functional unit
NFEPA	National Freshwater Ecosystem Priority Areas project
SANBI	South African National Biodiversity Institute
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
Stats SA	Statistics South Africa
UNEP	United Nations Environment Programme
UN	United Nations
UNSD	United Nations Statistics Division
WMA	Water Management Area

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Executive summary

This discussion document presents the results of South Africa's first pilot set of national river ecosystem accounts, undertaken as part of a global project on Advancing SEEA Experimental Ecosystem Accounting. The purpose of the document includes highlighting key trends in the extent and condition of the country's river ecosystems, informing further ecosystem accounting work in South Africa, and contributing to the global research agenda on ecosystem accounting.

Rivers were selected as a pilot class of ecosystem assets for national ecosystem accounts owing to the availability of relatively comprehensive national datasets developed over more than a decade by the Department of Water and Sanitation (DWS) and consolidated through the National Freshwater Ecosystem Priority Areas project (NFEPA) (Nel et al 2011).

The accounts are set out as follows:

- Ecosystem extent account for rivers,
- Ecosystem condition account for rivers, presented in three different ways:
    - Using four ecological condition indicators,
    - Using an aggregated ecological condition category,
    - Using an Ecological Condition Index.

In future work, our intention is to extend this set of accounts to include the full set of physical ecosystem accounts for rivers, including ecosystem service generation and use accounts.

Throughout the accounts, a distinction is made between main rivers and tributaries. Main rivers are defined as rivers that span more than one quaternary (fourth-order) catchment, while tributaries are defined as rivers that are contained within a single quaternary catchment, and usually feed into main rivers. Main rivers and tributaries are collectively referred to as 'all rivers'.

Ecosystem extent account

The extent of river ecosystems can be measured in terms of the length of the river network, the area of river channels and their banks, or the volume of flow (e.g. naturalised, non-cumulative volume of water at a sub-catchment scale). For the accounts presented here we measured extent in terms of length in kilometres.

Table A (or Table 7 in the main report) shows the extent of main rivers, tributaries and all rivers, based on the standard river network GIS layer used for national water resource management, which is mapped at approximately 1:500 000 scale. The period 1999 to 2011 was used to correspond with the ecosystem condition accounts shown below. There was no change in extent over this period, reflecting the fact that river length is generally quite stable at the time scales used in accounting. South Africa's total river length of approximately 160 000 km is divided roughly equally between main rivers and tributaries.

Table A: Ecosystem extent account for rivers in South Africa, showing length of main rivers, tributaries and all rivers

Kilometres	Main rivers	Tributaries	All rivers
Opening stock 1999	76 310	87 223	163 533
Opening stock as % of total river length	47	53	100
Additions/reductions			
Additions/reductions as a % opening stock			
Opening stock 2011	76 310	87 223	163 533
Opening stock as % of total river length	47	53	100

The extent of rivers can be summarised to a range of reporting units, including administrative units and biophysical units. Table B (or Table 8 in the main report) shows extent of rivers by the nine Water Management Areas (WMAs) in South Africa (see Figure 9 in the main report for a map of WMAs), which are important administrative units for management of water resources. The larger WMAs tend to have a higher proportion of river length. Table C (or Table 9 in the main report) shows extent of rivers by four longitudinal zones that are associated with different ecological characteristics of rivers – from mountain streams through to lowland rivers. The majority of South Africa's rivers are upper or lower foothill rivers, with a moderate gradient and little to no floodplain. Lowland rivers with distinct floodplains make up only 9% of total river length, making them relatively rare, especially compared to many northern hemisphere countries. The fertile floodplains of these lowland rivers are in high demand for intensive cultivation. It is also possible to show the extent account by South Africa's 31 river ecoregions (see Table 10 in main report, and Figure 7 for a map of river ecoregions).

Table B: Ecosystem extent account for rivers by Water Management Area

Kilometres	Main rivers	Tributaries	All rivers	% total river length
Berg-Olifants	4 166	6 078	10 243	6
Breede-Gouritz	5 313	7 129	12 441	8
Inkomati-Usuthu	3 808	2 289	6 097	4
Limpopo	6 117	5 625	11 742	7
Mzimvubu-Tsitsikamma	16 000	17 317	33 317	20
Olifants	6 242	4 722	10 964	7
Orange	13 104	23 580	36 684	22
Pongola-Mzimkulu	10 613	7 272	17 884	11
Vaal	10 948	13 212	24 160	15
Total	**76 310**	**87 233**	**163 533**	**100**

* Percentage is based on the total length of all rivers in South Africa

Table C: Ecosystem extent account for rivers by longitudinal zone

Kilometres	Main rivers	Tributaries	All rivers	% total river length*
Mountain stream	1 609	5 145	6 754	4
Upper foothill stream	21 566	52 592	74 158	45
Lower foothill stream	38 893	27 553	66 445	41
Lowland river	14 243	1 008	15 251	9
No Data	0	926	926	1
Total	**76 310**	**87 223**	**163 533**	**100**

* Percentage is based on the total length of all rivers in South Africa

Ecosystem condition account

Data for the condition accounts for rivers came from two comprehensive national assessments of the ecological condition of South Africa's rivers undertaken by DWS, the first in 1999 and the second in 2011. In each assessment, an aggregated ecological condition category (called Present Ecological State in South Africa) was developed based on a set of underlying indicators of ecological condition, for river reaches at the quaternary (fourth-order) or quinary (fifth-order) scale.

Figure A (or Figure 10 in the main report) provides a summary of the three different ways in which the ecosystem condition accounts are presented: using indicators of ecological condition and the aggregated ecological condition category from the two national assessments undertaken by DWS, and building on these to develop an Ecological Condition Index.

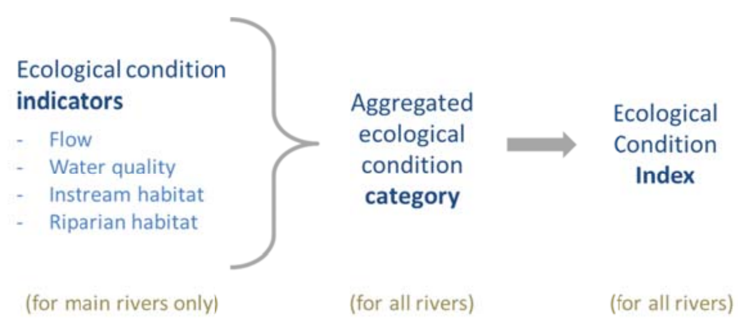

Figure A: Schematic showing the three sets of ecosystem condition accounts for rivers
Condition accounts based on the ecological condition indicators were developed for main rivers only due to lack for tributaries in 1999 data.

Condition account using four ecological condition indicators

Table D (or Table 11 in the main report) shows the ecosystem condition account for main rivers using four ecological condition indicators: flow, water quality, instream habitat and stream bank/riparian habitat. For each indicator, the degree of modification relative to a reference condition of natural is shown as none/small, moderate, large or serious/critical. The account sums the river length at each degree of modification, and shows the change in this length between 1999 and 2011 in absolute and proportional terms. The results are summarised graphically in Figure B (or Figure 11 in the main report).

The account highlights that there were large declines between 1999 and 2011 in the proportion river length with no/small modification for the indicators flow and instream habitat, reflected in steep declines in the blue line for these indicators in Figure B. Changes in the degree of modification to stream bank/riparian habitat were not large overall, but this indicator already reflected extensive modification in 1999.

Table D: Ecosystem condition account for main rivers using four ecological condition indicators, 1999 – 2011

Kilometres	Degree of modification from natural					Total
	None/ small	Moderate	Large	Serious/ Critical	No Data	
FLOW						
Opening stock 1999	**34 084**	**22 814**	**10 328**	**5 447**	**3 637**	**76 310**
Opening stock as a % total river length	45	30	14	7	5	100
Increase/decreases	-10 546	-2 316	6 017	5 129	1 715	
Increases/decreases as % opening stock	-31	-10	58	94	47	
Opening stock 2011	**23 538**	**20 499**	**16 345**	**10 576**	**5 352**	**76 310**
Opening stock as a % total river length	31	27	21	14	7	100
WATER QUALITY						
Opening stock 1999	**40 579**	**24 634**	**5 518**	**1 943**	**3 637**	**76 310**
Opening stock as a % total river length	53	32	7	3	5	100
Increase/decreases	-5 769	-3 591	6 149	1 496	1 715	
Increases/decreases as % opening stock	-14	-15	111	77	47	
Opening stock 2011	**34 810**	**21 043**	**11 667**	**3 439**	**5 352**	**76 310**
Opening stock as a % total river length	46	28	15	5	7	100
STREAM BANK/RIPARIAN HABITAT						
Opening stock 1999	**22 469**	**32 951**	**14 164**	**3 088**	**3 639**	**76 310**
Opening stock as a % total river length	29	43	19	4	5	100
Increase/decreases	-50	-3 612	1 255	1 667	740	
Increases/decreases as % opening stock		-11	9	54	20	
Opening stock 2011	**22 418**	**29 339**	**15 420**	**4 755**	**4 379**	**76 310**
Opening stock as a % total river length	29	38	20	6	6	100
INSTREAM HABITAT						
Opening stock 1999	**39 736**	**26 188**	**5 446**	**1 301**	**3 639**	**76 310**
Opening stock as a % total river length	52	34	7	2	5	100
Increase/decreases	-11 245	426	8 180	1 898	740	
Increases/decreases as % opening stock	-28	2	150	146	6 840	
Opening stock 2011	**28 491**	**26 615**	**13 626**	**3 200**	**4 379**	**76 310**
Opening stock as a % total river length	37	35	18	4	6	100

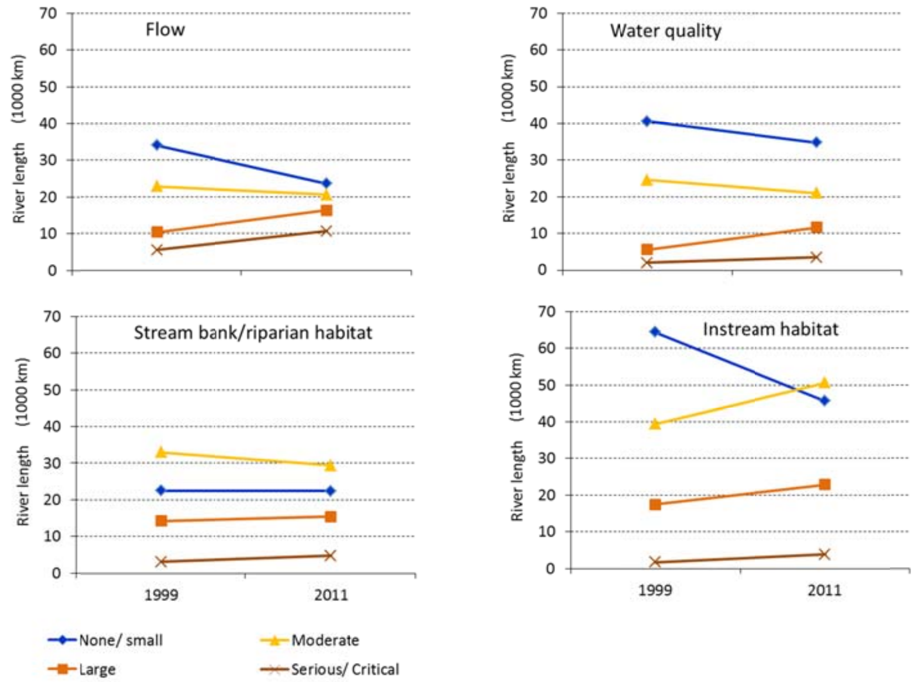

Figure B: Change in degree of modification in main rivers for each ecological condition indicator, 1999 – 2011

Condition account using aggregated ecological condition category

Table E (or Table 12 in the main report) shows the ecosystem condition account for main rivers and tributaries using the aggregated ecological condition category based on the ecological condition indicators discussed above. The four aggregated condition categories are natural (which includes near-natural), moderately modified, heavily modified and unacceptably modified (see Table 6 in the main report for descriptions of these). The results are summarised graphically in Figure C (or Figure 13 in the main report) and shown spatially in Figure D (or Figure 14 in the main report).

The account shows that there was a 47% decrease in extent of river length in natural condition between 1999 and 2000 (from 86 835 km to 45 673 km), accompanied by increases in extent of river length in all three of the other categories, including a 368% increase in river length in heavily modified condition. The absolute extent of rivers in an unacceptably modified condition in 2011 was still relatively small at 3 776 km or 2% of total river length, but had increased by 179% since 1999. The maps in Figure D suggest that the decrease in the extent of river length in natural condition was particularly pronounced along the north-eastern coast of South Africa in KwaZulu-Natal province. Rivers in the south-western part of the country (Western Cape province) and far north (Limpopo province) also showed marked deterioration in condition.

Table E: Ecosystem condition account for rivers based on the aggregated ecological condition category, for main rivers, tributaries and all rivers

Kilometres	Degree of modification from natural					Total
	Natural	Moderately modified	Heavily modified	Unaccept-ably modified	No Data	
MAIN RIVERS						
Opening stock 1999	**46 541**	**22 315**	**2 791**	**1 026**	**3 637**	**76 310**
Opening stock as a % total river length	61	29	4	1	5	100
Increase/decreases	-24 100	9 467	13 168	1 465		
Increases/decreases as % opening stock	-52	42	472	143		
Opening stock 2011	**22 441**	**31 782**	**15 960**	**2 492**	**3 637**	**76 310**
Opening stock as a % total river length	29	42	21	3	5	100
TRIBUTARIES						
Opening stock 1999	**40 294**	**7 470**	**2 084**	**328**	**37 047**	**87 223**
Opening stock as a % total river length	46	9	2		42	100
Increase/decreases	-17 062	11 339	4 766	957		
Increases/decreases as % opening stock	-42	152	229	292		
Opening stock 2011	**23 232**	**18 809**	**6 850**	**1 285**	**37 047**	**87 223**
Opening stock as a % total river length	27	22	8	1	42	100
ALL RIVERS						
Opening stock 1999	**86 835**	**29 784**	**4 875**	**1 354**	**40 684**	**163 533**
Opening stock as a % total river length	53	18	3	1	25	100
Increase/decreases	-41 163	20 806	17 935	2 422		
Increases/decreases as % opening stock	-47	70	368	179		
Opening stock 2011	**45 673**	**50 591**	**22 810**	**3 776**	**40 684**	**163 533**
Opening stock as a % total river length	28	31	14	2	25	100

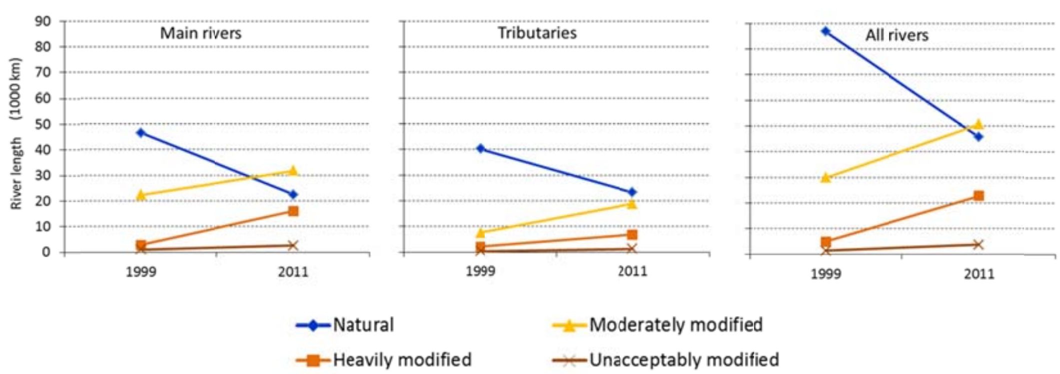

Figure C: Change in the extent of river length in each aggregated ecological condition category, for main rivers, tributaries and all rivers, 1999 – 2011

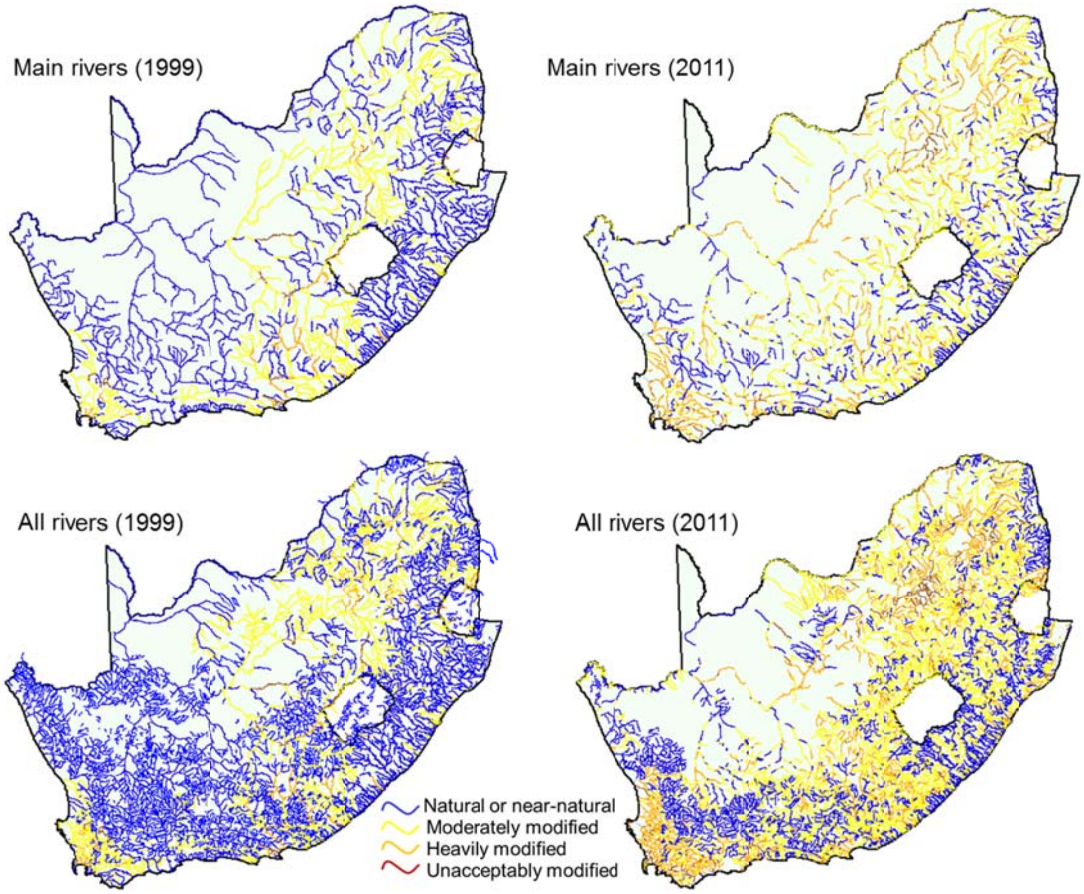

Figure D: Maps of the aggregated ecological condition category for main rivers and all rivers in South Africa, 1999 and 2011

Condition account using Ecological Condition Index

With the aim of simplifying the presentation of the condition account, we converted the aggregated ecological condition category to an Ecological Condition Index (see Figure 15 and Table 13 in the main report for more detail on the method used). The index ranges between 0 and 100, and gives an indication of the degree of modification, where 100 is the reference condition of an ecosystem in the absence of significant modification by human activity, and 0 is where ecosystem function is absent. The Ecological Condition Index is scalable in that it can be calculated for any reporting unit, from quinary (fifth-order) catchments to the national level, for administrative or biophysical units. If such an index were to be developed in a comparable way for other countries, it could be summarised at a regional, continental or global scale.

Table F and Figure E (or Table 15 and Figure 16 in the main report) show the results of this initial estimate of Ecological Condition Index for rivers in South Africa. The index for all rivers declined by 10.6% between 1999 and 2011, with a slightly lower rate of decline and better condition overall for tributaries than main rivers. Figure F (or Figure 22 in the main report) shows changes in the

Ecological Condition Index per Water Management Area between 1999 and 2011, and highlights that the index declines in all nine WMAs, with the most dramatic decline being for main rivers in the Limpopo WMA (21%, from 83.1 to 61.5). This is likely to reflect a widespread problem of poor waste water management (both in terms of failing infrastructure and poor operating capacity) and increasing development pressures from mining and agriculture. Figure G (or Figure 25 in the main report) shows changes in the Ecological Condition Index by longitudinal zone, and highlights that the value of the index is highest for mountain streams and lowest for lowland rivers, with declines experienced across all four longitudinal zones.

An analysis of the Ecological Condition Index by the 31 freshwater ecoregions (see Table 19 in the main report) shows that the ecoregions with the lowest Ecological Condition Index were the South Western Coastal Belt at 47 and the Natal Coastal Plain at 49. The Natal Coastal Plain showed the largest decline (41%) between 1999 and 2011. These two ecoregions are subject to intense urbanisation pressures around the Cape Town and Ethekwini (Durban) metropolitan centres. The Southern Coastal Belt, next lowest at 50, is in a known biodiversity hotspot (the Agulhas Plain), where the main pressures on rivers are from cultivation and invasive alien plants.

Table F: The Ecological Condition Index for 1999 and 2011 for main rivers and tributaries

	Main rivers	Tributaries	All rivers
1999	81.3	84.9	82.8
2011	70.1	75.2	72.2
Change between 1999 and 2011	-11.2	-9.7	-10.6

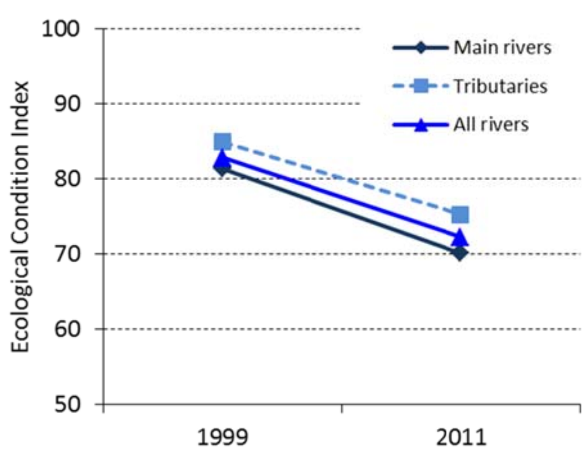

Figure E: Change in the Ecological Condition Index for main rivers, tributaries and all rivers, 1999 – 2011

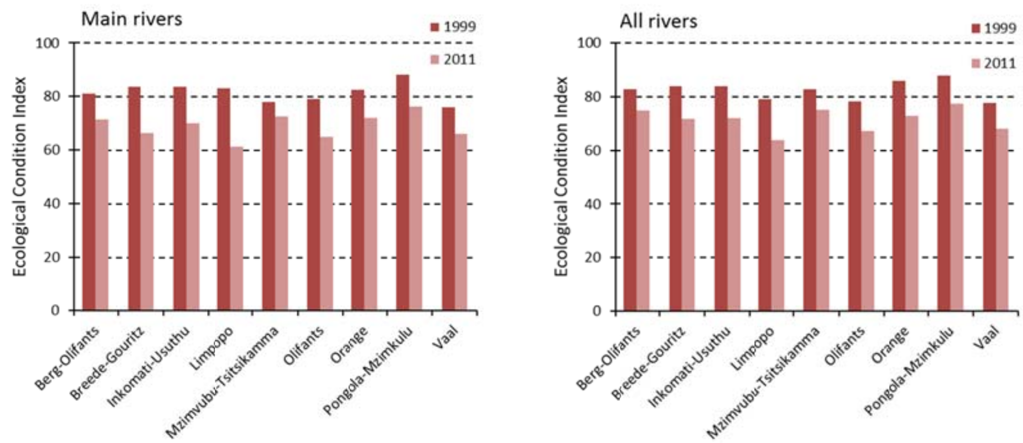

Figure F: Change in the Ecological Condition Index of each Water Management Area for main rivers and all rivers, 1999 – 2011

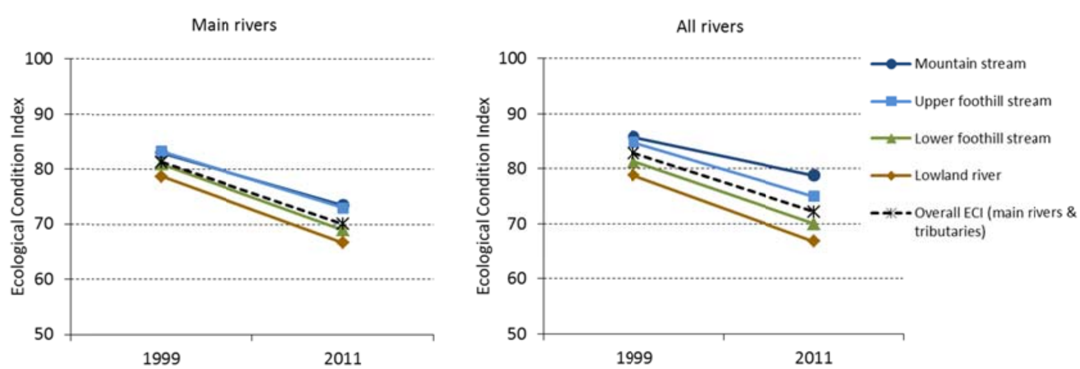

Figure G: Change in the Ecological Condition Index per longitudinal zone for main rivers and all rivers, 1999 – 2011

The national trends in the Ecological Condition Index concur with the judgement of stakeholders and experts involved in piloting this index, who felt that, based on their experience of working directly with the management of rivers and water resources, the results reflect real trends in the country's rivers. Our overall assessment, corroborated by these stakeholders, is that summarising trends into a single index is generally easier to communicate than showing inter-related trends across several aggregated ecological condition categories, especially for target audiences such as national politicians or civil society that are not experienced in river ecological condition and spatial analysis. We believe this index holds much promise for communicating the overall trends in river condition, and there has been considerable excitement amongst stakeholders about these initial results.

Recommendations for ecosystem condition accounts

Drawing on our experience in developing the accounts presented here, we propose an approach to the development of indicators of ecological condition and the structure of ecosystem condition accounts, which can be applied across terrestrial, freshwater, coastal and marine realms, building on the approach suggested in SEEA Experimental Ecosystem Accounting (see Section 2.3 in the main report).

Key points include:

- For each broad class of ecosystem assets (e.g. terrestrial, river, wetland, coastal, marine), four to six *indicators of ecological condition* should be selected, which can be measured on a scale of 0 to 1 (or 0 to 100). These are aggregated to give an *overall index of ecological condition*.
- Indicators of ecological condition should reflect a combination of:
    - *System drivers* in the class of ecosystems concerned (such as land cover/land use change in terrestrial systems, hydrological changes in freshwater systems, harvesting pressure in marine systems),
    - *Habitat attributes* (such as degree of fragmentation, instream siltation),
    - *Biological responses* of the ecosystems and associated species (such as changes in population levels of particular species, loss of species richness).
- Ecologists in the different realms (terrestrial, freshwater, marine) have done substantial thinking on this, and it is important to draw on this existing work in the process of developing the condition accounts for a particular class of assets. It is essential for ecologists to be closely involved in the selection of indicators of ecological condition, and in determining the method used for aggregating them, to ensure that the result is ecologically meaningful and sensible.
- It is not possible to devise a single set of indicators of ecological condition that applies to *all* ecosystem asset classes; however, some indicators are likely to be common across more than one asset class.
- All indicators should be assessed/quantified in relation to a reference condition for the ecosystem type concerned. Where possible, the reference condition is the natural condition in the absence of significant modification by human activity. If this is not possible, an alternative stable reference condition can be selected (e.g. condition at a particular baseline date).

Table 20 (a) to (e) in the main report provides examples of what the tables might look like for different classes of ecosystem assets, with examples of possible indicators.

Priorities for national river ecosystem accounting work

Priorities for further work to take forward national river ecosystem accounting include the following:

- Producing a full set of ecosystem accounts for rivers, including ecosystem service generation and use accounts.
- Linking the ecosystem accounts for rivers with national water accounts.
- Developing land accounts for key ecological infrastructure features that are closely linked to rivers, such as strategic water source areas, riparian zones and wetlands.

- Analysing ecosystem condition trends for rivers in relation to other socio-economic indicators, including:
  - Links to census information, especially for low-income households that rely on use of water directly from rivers,
  - Links to GDP and other aspects of the economy, especially if these can be spatially disaggregated.

Priorities for further testing related directly to the extent and condition accounts presented here include the following:

- Reporting on the extent of rivers in terms of volume of water, in addition to length.
- Testing which of the conditions accounts, graphics and maps are most useful for communicating trends to different target audiences.
- Developing a more robust Ecological Condition Index, by improving the underpinning data so that the Present Ecological State is expressed as a continuous range from 100 (reference condition) to zero in addition to categories.
- Testing how to integrate and display confidence limits and uncertainty.
- Testing the application of the ecosystem condition account in water resource planning and policy.
- Exploring options for using more quantitative, site-based ecological condition data for rivers.

Lastly, we highlight priorities for improved systems for collecting and recording time series data on ecological condition of rivers, including the spatial scale and methods for data collection. *We recommend that river extent and condition accounts be produced every five years in South Africa* – more frequent national scale assessment is not feasible given resource constraints. A major challenge in this regard is that there is currently no plan for another national assessment of the Present Ecological State of rivers. Especially if such a national assessment does not take place, we need to ensure that there is regular monitoring in a comprehensive set of sites that can be built up to a national picture, supplemented by innovative use of data gathered through remote sensing and citizen science.

1. Introduction

This discussion document presents ecosystem extent and condition accounts for South Africa's rivers (Box 1, Figure 1). Rivers were chosen as the first set of ecosystem assets for which to compile national ecosystem accounts primarily because of the availability of relatively comprehensive, relevant national datasets on river ecosystems, discussed further in Section 3. The accounts presented here build on many years of work by the Department of Water and Sanitation (DWS)[2] on mapping South Africa's rivers and assessing their ecological condition, as well as on work undertaken for the National Freshwater Ecosystem Priority Areas project (NFEPA),[3] for which much data on rivers was collated, reviewed and synthesised.

Box 1: South Africa's rivers in brief

South Africa is a semi-arid country, with an average annual rainfall of 465 mm compared to the world average of 860 mm. The climate is characterised by an uneven, poorly predictable and highly seasonal distribution of rainfall, while potential evapotranspiration rates exceed rainfall over most of the country. Droughts are common and are often followed by equally devastating floods. South Africa has very few natural lakes and the country's rivers have highly variable flows between seasons and between years. Rivers located in the wetter regions of the country, mainly in the east, tend to be perennial while those in the drier regions, mainly in the west, are seasonal (flow some time each year) or ephemeral (can go for years without flowing).

As a result of unpredictable flows, large numbers of dams and inter-basin transfer schemes have been constructed in South Africa to increase the reliability of water supply to users. Most large rivers have been impounded and 98% of the country's surface-water supply options have already been developed. There is very limited opportunity for more dams and transfer schemes. In most catchments of the country, water demand outstrips current water availability, and further water reconciliation options and strategies are being considered (e.g. water demand management, water re-use, groundwater resource development, desalinisation).

The combination of climatic and hydrological circumstances, as well as socio-economic demands, place enormous pressure on the condition and functioning of South Africa's river ecosystems. The country has a diversity of river ecosystems, ranging from sub-tropical in the north-eastern part of the country, to semi-arid and arid in the interior, and mediterranean in the south-west (see Section 3.3 for more on different river ecosystem types). Consistent with global trends, high levels of threat have been reported for river ecosystems, with over half of the country's river and wetland ecosystem types assessed as threatened in the National Biodiversity Assessment 2011 (Nel et al. 2007; Nel & Driver 2012).

[2] Known as the Department of Water Affairs (DWA) prior to July 2014.
[3] NFEPA was a three-year multi-partner project, completed in 2011. Products included an Atlas of Freshwater Ecosystem Priorities in South Africa (Nel et al 2011a), an accompanying implementation manual (Driver et al 2011) and a technical report (Nel et al 2011b). These documents and the data are available at http://bgis.sanbi.org/nfepa/NFEPAmap.asp.

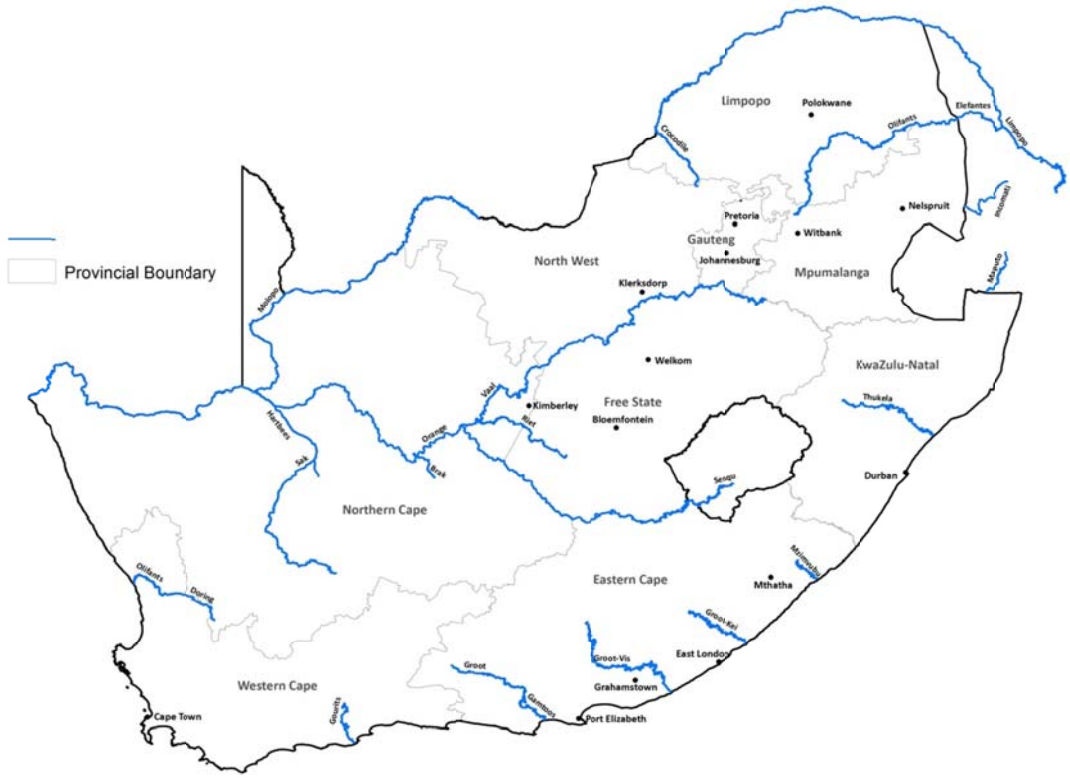

Figure 1: Major rivers in South Africa

This initial set of accounts for river ecosystems has been undertaken with a view to informing the subsequent development of national accounts for other classes of ecosystem assets in South Africa, including wetlands, marine and coastal ecosystems, and terrestrial ecosystems. In addition, we would like to motivate for the collection and recording of improved times series data for ecological condition of rivers, so that ecosystem accounts for rivers can be repeated and strengthened. In future, we hope to build on the extent and condition accounts presented here to produce the full set of physical ecosystem accounts (see Figure 2 in Section 2.1) for rivers, including ecosystem service generation and use accounts, and to link these accounts with national water accounts and land accounts. We also hope that this work will contribute to the global research agenda for the development of ecosystem accounting.[4]

The purpose of ecosystem accounts is to quantify and track changes in ecosystem assets and ecosystem services over time. This is intended to inform a range of policy, planning and decision-making processes relating to the management of ecosystems and the use of ecosystem services, and to enable links to be made between the measurement of ecosystems and the measurement of the economy. Ecosystem accounts can support strategic decision making about natural resource management and about trade-offs between different ecosystem services, for example in relation to

[4] The global research agenda is set out in SEEA Experimental Ecosystem Accounting (UN 2014b). This work contributes particularly to the area of research on physical ecosystem accounting (p147-148).

the food-water-energy nexus. They can also provide a powerful set of information and indicators for measuring and reporting on sustainable development.

Ecosystem accounts form part of the System of Environmental-Economic Accounting (SEEA), developed by the United Nations as a counterpart to the System of National Accounts (SNA). The SNA focuses on how much is produced, consumed and invested in a country's economy, providing a range of information and indicators to inform macro-economic policy, the most well-known of which is Gross Domestic Product (GDP). The SEEA focuses on interactions between the environment and the economy, providing a set of complementary accounts to the SNA. The SEEA includes a Central Framework, which was adopted by the United Nations Statistical Commission as an international standard in 2012 (UN 2014a), as well as a more recently developed volume on Experimental Ecosystem Accounting (UN 2014b). The SEEA Central Framework focuses on accounting for individual environmental assets, such as timber, water, minerals and fish, while SEEA Experimental Ecosystem Accounting focuses on accounting for ecosystem assets and ecosystem services. Relevant aspects of SEEA Experimental Ecosystem Accounting for river ecosystem accounts are outlined further in Section 2.

The 'national accounting approach' has several distinguishing characteristics, described in the technical guidelines for ecosystem accounting which were in draft form at the time of writing (UN 2015). It implies that measurement efforts are guided by an accounting framework in which concepts are consistently and coherently defined, thereby allowing the pragmatic integration of multiple data sources and methods to develop metrics that provide the best possible estimates of the concept(s) being measured. There is full recognition that data and methods are seldom perfect and change over time, and that as data and methods change and improve, revisions of previously published results will be required. A national accounting approach also implies a focus beyond the local level or an individual sector – the aim is to develop a broad picture that covers the full scope and territory of the concepts concerned.

Importantly, accounting does not necessarily imply quantification or valuation in monetary terms. In both the SEEA Central Framework and SEEA Experimental Ecosystem Accounting, the starting point is to account in physical terms. As explained in SEEA Experimental Ecosystem Accounting, "A key feature of the SEEA lies in the fact that the organisation of information in physical terms facilitates comparison with economic data even without monetary valuation and thus contributes to analysis from both economic and environmental perspectives" (UN 2014b, p4). Monetary accounts that build on the physical accounts may be appropriate and useful in some instances.

The accounting approach provides a systematic way of gathering and synthesising large amounts of data that can then be used in multiple applications by a variety of sectors. Accounts in themselves do not constitute policy advice or policy recommendations – they describe a series of stocks and flows, and how these have changed over time. Because of the consistency and coherence of the accounting approach, accounts can be used to provide indicators, aggregates and other information that may help to identify key policy issues and inform policy responses. The multi-purpose nature of accounts is key – they are not aimed at one particular use or sector but should be able to be used in a range of different contexts. Once-off accounts can be useful, but the real power lies in accounts that are produced regularly to provide consistent information over several accounting periods.

The focus of the accounts presented here is on physical accounts of the extent and condition of rivers throughout South Africa, not on ecosystem services generated by or used from rivers or on monetary accounts for rivers. The purpose of this document is four-fold:

- To present the extent and condition accounts for rivers for three different sets of reporting units, highlighting key results,
- To pilot an ecological condition index that shows trends in the ecological condition of rivers in a single figure that is simple to communicate, and which can potentially be developed for other classes of ecosystem assets,
- To highlight some limitations of the underlying data on ecological condition of rivers and suggest how these might be addressed in order to strengthen monitoring of river ecosystems going forward, whether for ecosystem accounts or other purposes,
- To contribute to the global research agenda on ecosystem accounting, especially in relation to the measurement of ecosystem extent and condition.

The document is structured as follows:

- Section 2 summarises key content from SEEA Experimental Ecosystem Accounting on ecosystem extent and condition accounts,
- Section 3 gives background on national river-related data in South Africa,
- Section 4 presents ecosystem extent accounts for rivers,
- Section 5 presents ecosystem condition accounts for rivers, summarised at the national level,
- Section 6 presents ecosystem condition accounts for rivers by Water Management Area (WMA),
- Section 7 presents ecosystem condition accounts for rivers by longitudinal zone,
- Section 8 presents ecosystem condition accounts for rivers by ecoregion,
- Section 9 discusses recommendations, including a proposed approach for identifying indicators of ecological condition across different realms, and priorities for further work.

The intended users of this document include:

- Those involved in national development planning who need to consider synergies and trade-offs across multiple sectors,
- Those involved in management of the country's river ecosystems, including but not limited to DWS, Catchment Management Agencies, provincial environmental affairs departments, conservation authorities and municipalities,
- Those involved in collecting and collating data for monitoring the condition of rivers, including through government programmes and citizen science initiatives,
- Those who have an interest in ecosystem accounting, especially organisations or individuals involved in experimental ecosystem accounting work, in South Africa or elsewhere,
- Those involved in developing national water accounts, which were being revitalised in South Africa at the time of writing,
- Those involved in developing national accounts and other official statistics, especially those with an interest in strengthening the integration between geospatial and statistical information.

2. Ecosystem extent and condition accounts in SEEA Experimental Ecosystem Accounting

SEEA Experimental Ecosystem Accounting sets out a framework for ecosystem accounting that includes ecosystem asset accounts and ecosystem service accounts. This section summarises the content of SEEA Experimental Ecosystem Accounting that is most directly relevant to ecosystem extent and condition accounts, which are both components of ecosystem asset accounts. The section includes content relating to:

- The structure of ecosystem accounts,
- Spatial units for ecosystem accounting,
- Guidance specifically on ecosystem extent and condition accounts.

Some of the key challenges for ecosystem accounting that remain unresolved include which spatial units to use to represent ecosystem assets, at what scale to map ecosystems, and which factors to use to measure ecosystem condition. These are issues with which we have grappled in producing national river ecosystem accounts, as reflected in the discussion below as well as in the rest of this document.

2.1 Structure of ecosystem accounts

Ecosystem assets are defined in SEEA Experimental Ecosystem Accounting as "spatial areas comprising a combination of biotic and abiotic components and characteristics that function together" (UN 2014b, p22). Ecosystem asset accounts have three main elements according to SEEA Experimental Ecosystem Accounting: ecosystem extent accounts, ecosystem condition accounts, and the expected future flow of ecosystem services (which relates to the capacity of ecosystems to provide services).

A technical guideline document that complements SEEA Experimental Ecosystem Accounting was in draft form at the time of writing and provides more detail, including a diagram showing the suggested full set of ecosystem accounts, reproduced here in Figure 2 (UN 2015). The intention is that ecosystem accounts could be approached in a modular way, with different possible entry points, represented by the different blocks in the diagram. For example, a country might start with ecosystem service generation accounts rather than necessarily having to start with ecosystem extent accounts. However, ultimately the aim would be to have the full set of accounts. In South Africa, we have decided to start with ecosystem extent and condition accounts, as our available data is best suited to this entry point.

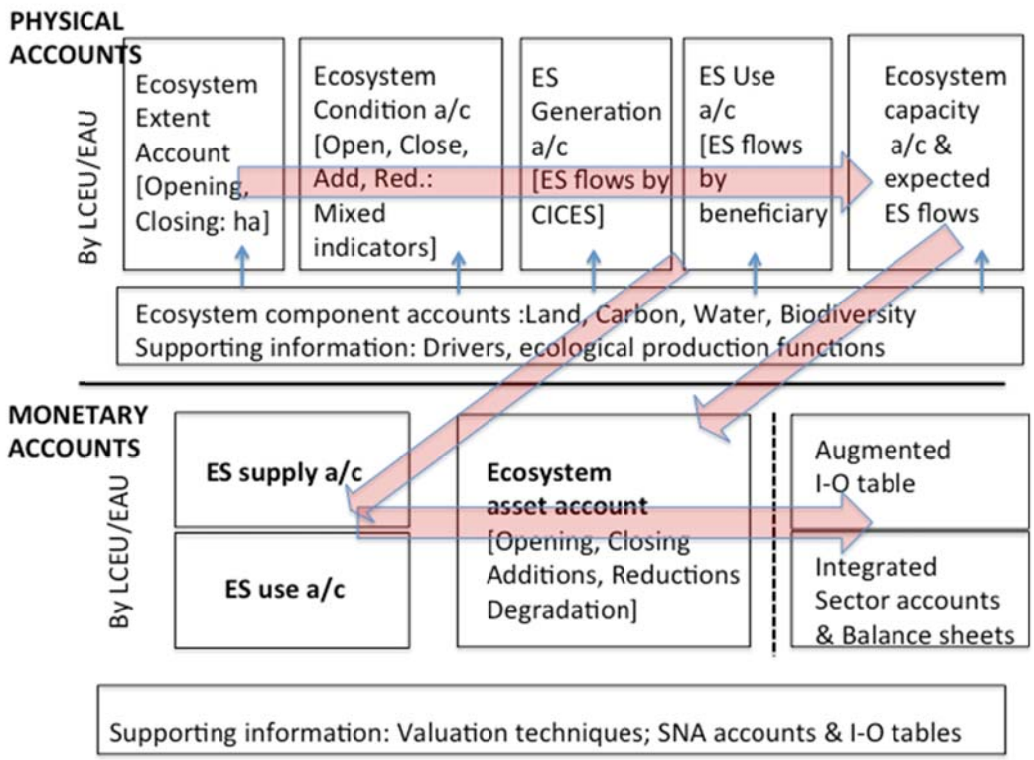

Figure 2: Steps in the compilation of ecosystem accounts (draft)
(Source: UN 2015, p33)

2.2 Spatial units for ecosystem accounting

Ecosystem accounts are inherently spatial, as they deal with ecosystem assets that are represented by spatial areas. SEEA Experimental Ecosystem Accounting sets out three types of spatial units for ecosystem accounting:

- Basic spatial units (BSUs) – usually envisaged as a grid of pixels (e.g. 100m by 100m),
- Land cover ecosystem functional units (LCEUs) – these are intended to represent ecosystem assets,
- Ecosystem accounting units (EAUs) – these are essentially reporting units to which results are aggregated, and may be administrative units (such as municipalities) or biophysical units (such as ecoregions).

SEEA Experimental Ecosystem Accounting recognises that linear features such as rivers may need special treatment, but does not provide specific guidance on how rivers should be delineated or mapped for the purposes of ecosystem accounting. Under the sub-heading "Units for the atmosphere, marine areas and linear features, including rivers", SEEA Experimental Ecosystem Accounting says: "Particular care should be taken in (a) determining the treatment of coastal ecosystems that straddle terrestrial and marine areas; (b) *delineating areas related to rivers, such as flood plains; (c) considering other linear features*; and (d) defining aquatic ecosystems such as wetlands" (UN 2014b, paragraph 2.81, p30, emphasis added).

As discussed in Section 3 below, rivers in South Africa are currently mapped as lines, and for these accounts we have therefore measured their extent in terms of length. In future we would ideally like to map river channels as areas and to embed them in a national vegetation map, creating an integrated national map of ecosystem types across the terrestrial and freshwater realms. If this is achieved, the extent of rivers could be measured in terms of either length or area, or both. A third option may be to measure the extent of rivers in terms of naturalised volume of water. It is already possible to report on the volumetric extent of all rivers assessed in this report using currently available data on mean annual runoff in South Africa. We have chosen not to pursue this option for now, but have noted it as something to explore in future work (see Section 9).

Subsequent to the publication of SEEA Experimental Ecosystem Accounting there has been ongoing discussion globally about how to delineate spatial units for ecosystem accounting and what to call them. At the Forum of Experts on Ecosystem Accounting convened by the UNSD in April 2015, a proposal was made to rename LCEUs as 'ecosystem units'. We support this proposal for reasons discussed in the companion discussion document to this one (Land and Ecosystem Accounting in KwaZulu-Natal), which relate to the need to separate the identification of ecosystem types from the identification of land cover classes. An additional reason is that land cover datasets are generally poor at identifying natural inland water features other than large permanent bodies of open water – most rivers and seasonal wetlands are not picked up well in land cover datasets, and land cover data thus provides a poor starting point for delineating most freshwater ecosystems. Rivers in South Africa have been mapped at the national level as a river network, independently of land cover data or land cover classes. For these accounts, 'ecosystem units' representing river ecosystem assets are defined as river reaches at the fifth-order sub-catchment scale, as explained in more detail in Section 3.

The interim high-level land cover classes suggested in SEEA Experimental Ecosystem Accounting include 'inland water bodies' and 'regularly flooded areas', which are intended to include rivers and their floodplains. Using land cover to identify these features does not provide a comprehensive spatial picture of the location of rivers and wetlands, and can thus be misleading for ecosystem extent accounts. We suggest that a linear river network dataset is a better starting point for extent accounts for rivers, recognising the limitations associated with treating rivers as lines rather than features that also have area and volume. In the absence of a fully integrated national map of ecosystem types across terrestrial and freshwater realms, with river channels included as areas, the measurement of rivers by length has the advantage of avoiding any double-counting of area between extent accounts for terrestrial ecosystems and river ecosystems.

2.3 Guidance on ecosystem extent and condition accounts

In SEEA Experimental Ecosystem Accounting, ecosystem extent refers to the size of an ecosystem asset. Extent is usually measured in terms of surface area, for example in hectares, but it is recognised that this may be less straightforward for aquatic ecosystems. No specific guidance is given in SEEA Experimental Ecosystem Accounting on the structure of tables for ecosystem extent accounts, but in the draft technical guidelines referred to above (UN 2015), an example of an extent account is given, reproduced here as Table 1. It records opening stock, additions to or reductions in stock, and closing stock for each LCEU.

Somewhat more detail is given in SEEA Experimental Ecosystem Accounting on ecosystem condition accounts. The relevant section is reproduced in Box 2. We are building on key points given in the SEEA Experimental Ecosystem Accounting guidelines, including:

- Ecosystem condition is assessed based on characteristics of an ecosystem asset.
- Assessment of condition involves several steps:
    - Identifying or selecting relevant *characteristics* that meaningfully reflect the functioning, resilience and integrity of the ecosystem asset,
    - Identifying *indicators* associated with those characteristics,
    - Assessing each indicator relative to a common *reference condition* or benchmark.

Box 2: Excerpt on ecosystem condition and extent from SEEA Experimental Ecosystem Accounting

Ecosystem condition and ecosystem extent

2.35 ***Ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics***. The assessment of ecosystem condition involves two distinct stages of measurement with reference to both the quantity and the quality aspects of the characteristics of the ecosystem asset. In the first stage, it is necessary to select appropriate characteristics and associated indicators of changes in those characteristics. The selection of characteristics and associated indicators should be carried out on a scientific basis so that there is an assessment of the ongoing functioning, resilience and integrity of the ecosystem asset. Thus, movements of the indicators should be responsive to changes in the functioning and integrity of the ecosystem as a whole.
2.36 Measures of ecosystem condition may be compiled in relation to key ecosystem characteristics (e.g., water, soil, carbon, vegetation, biodiversity) and the choice of characteristics will generally vary depending on the type of ecosystem asset. … Usually, there will not be a single indicator for assessing the quality of a single characteristic. Both the selection and measurement of characteristics and associated indicators are likely to present measurement challenges.
2.37 In the second stage, the indicators are related to a common reference condition or benchmark. … . The use of a common reference condition relative to all indicators for an ecosystem asset may allow an overall assessment of the condition of the asset.
2.38 ***Ecosystem extent refers to the size of an ecosystem asset***. For ecosystem assets, the concept of extent is generally measured in terms of surface area, for example, hectares of a land-cover type.[21]

[21] Land cover is most easily associated with terrestrial ecosystems (e.g., forest, grassland, tundra). Aquatic ecosystems may be classified by type of water cover (e.g., inland water bodies, coastal water bodies, open wetlands) but also through aquatic ecosystem mapping systems which distinguish between marine, estuarine, riverine, palustrine and lacustrine environments…. These mapping systems may consider different aquatic habitats (e.g., reefs and seagrass) and factors such as depth and light availability.

(Source: UN 2014b, p22-23, italics and bold in the original)

There is an explicit recognition that "the choice of characteristics [for measuring ecosystem condition] will generally vary depending on the type of ecosystem asset" and also that "selection of characteristics and associated indicators should be carried out on a scientific basis" (UN 2014b, p23). SEEA Experimental Ecosystem Accounting uses a standard set of characteristics of ecosystem condition in all the examples given. These are: vegetation, biodiversity, soil, water, carbon, as shown in Table 2 reproduced here. Water, carbon and soil accounts are also referred to as 'basic resource accounts', and are assumed to provide information relevant for the measurement of ecosystem condition. In other documentation on Experimental Ecosystem Accounting, the proposed characteristics of ecosystem condition are often further simplified to: land, water, carbon, biodiversity; and are often referred to 'ecosystem component accounts' as, for example, in Figure 2.

Table 1: Example of an ecosystem extent account, from draft technical guidelines for SEEA Experimental Ecosystem Accounting

Cover	Urban and associated		Rainfed herbaceous cropland		Forest tree cover		Inland water bodies		Open wetlands	Total
Use	Infrastructure	Residential	Permanent crops	Maintenance	Forestry	Protected	Infrastructure	Aquaculture	Maintenance	
Ownership	Government	Private	Private	Private	Private	Government	Government	Private	Government	
Units	hectares									
Opening Stock										
Additions to stock										
Managed expansion										
Natural expansion										
Reductions to stock										
Managed regression										
Natural regression										
Closing stock										

(Source: UN 2015, Table 4.2, p35)

Table 2: Example of an ecosystem condition account, from SEEA Experimental Ecosystem Accounting

	Characteristics of ecosystem condition				
	Vegetation	Biodiversity	Soil	Water	Carbon
	Examples of indicators				
	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Opening condition					
Improvements in condition					
Improvements due to natural regeneration (net of normal natural losses)					
Improvements due to human activity					
Reductions in condition					
Reductions due to extraction and harvest of resources					
Reductions due to ongoing human activity					
Catastrophic losses due to human activity					
Catastrophic losses due to natural events					
Closing condition					

(Source: UN 2014b, Table 4.4, p83)

Table 3: Example of an ecosystem condition account, from draft technical guidelines for SEEA Experimental Ecosystem Accounting

Ecosystem type	Ecosystem extent	Ecosystem condition					
	Area	Vegetation	Biodiversity	Soil	Water	Carbon	Index
	hectares						
Urban and associated							
Rainfed herbaceous cropland							
Forest tree cover							
Inland water bodies							
Open wetlands							

(Source: UN 2015, Table 4.3, p36)

Our view is that the standard examples of water, carbon, soil and biodiversity as characteristics of ecosystem condition are unlikely to be suitable for all classes of ecosystem assets. For example, river condition monitoring in South Africa – which is guided by over 30 years of river research and application – distinguishes between physical drivers of river systems (which encompass physico-chemical attributes, geomorphology and hydrology), habitat attributes (which include instream and riparian habitat), and biological responses (which include fish, macro-invertebrates and riparian vegetation). The relationship between these is summarised in Figure 3. In the accounts presented here, the characteristics used to measure the condition of river ecosystem assets in South Africa include flow, water quality, instream habitat condition, and stream bank/riparian condition, as discussed at some length in Sections 3 and 9 below. Flow and water quality could be called 'driver-related' indicators, while instream habitat condition and stream bank/riparian condition could be called 'habitat-related' indicators.

At the time of writing, work was underway in South Africa as part of the National Biodiversity Assessment 2018 to further develop and refine approaches and methods for assessing ecological condition in the terrestrial and marine realms, in which different sets of characteristics and indicators of ecosystem condition are required than for rivers. Some initial thinking around relevant characteristics for terrestrial, freshwater and marine realms is provided in Section 9.1. The challenge is not simply to identify the relevant set of characteristics of ecosystem condition, but also to define appropriate indicators for each characteristic, ensuring that those indicators add up to a meaningful overall picture of ecosystem condition for that particular ecosystem asset.

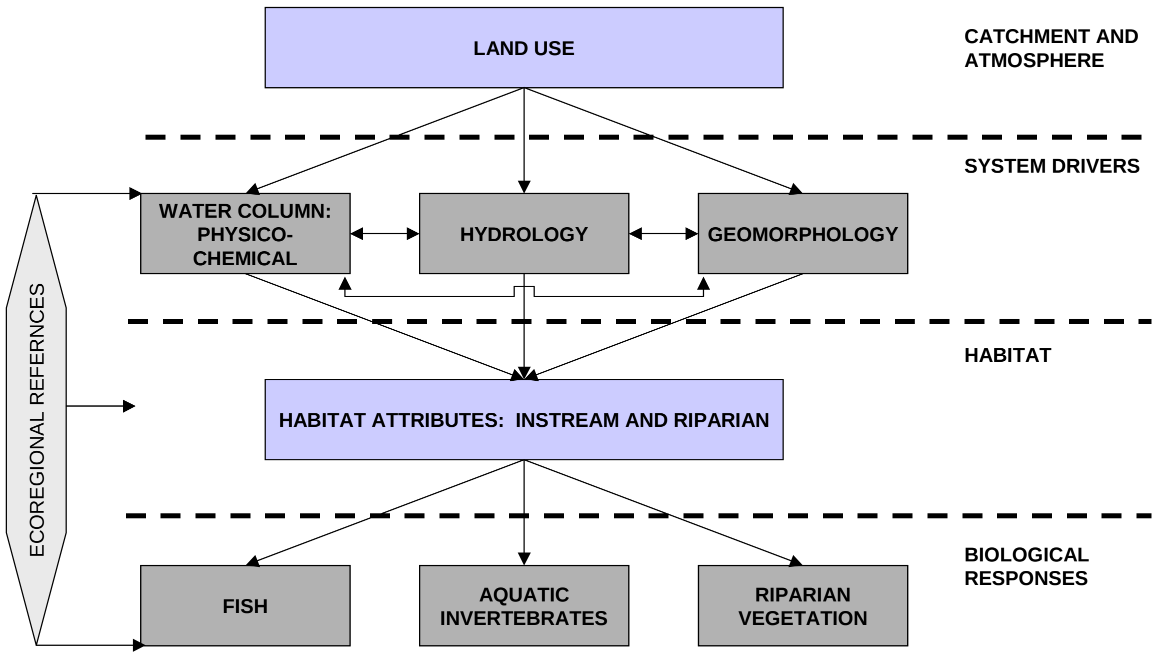

Figure 3: The conceptual framework used to guide assessments of ecological condition of rivers in South Africa

Indicators of ecological condition should ideally reflect a combination of system drivers, habitat attributes and biological responses. Habitat and species indicators are considered 'response indicators' that are influenced by system drivers. Source: Kleynhans and Louw 2007.

3. National river-related data in South Africa

This section summarises the data that were used to construct the ecosystem extent and condition accounts presented in this document, namely:

- Nested hierarchical system of catchments
- River network
- Ecological condition of rivers
- River ecoregions and longitudinal zones
- Water Management Areas

More comprehensive technical information on these datasets is available elsewhere, as reflected in the references of this section.

3.1 Catchments and river network data

Key points

- South Africa uses a **nested hierarchy of hydrological catchments**, from primary (first-order) catchments through to quinary (fifth-order) catchments.
- **Rivers can be mapped at different scales**, with finer-scale mapping likely to pick up a more extensive network of smaller rivers and streams than broad-scale mapping. These accounts are based on DWS's 1:500 000 river network layer.
- A distinction is made between **main rivers and tributaries**. Main rivers are defined as rivers that span more than one quaternary (fourth-order) catchment, while tributaries are defined as rivers that are contained within a single quaternary catchment. Tributaries usually feed into main rivers. Main rivers and tributaries are **collectively referred to as 'all rivers'** in this document.
- For these accounts, **ecosystem units** are defined as river reaches at the quinary (fifth-order) catchment scale. Some of them are main rivers and others are tributaries.

Catchments in South Africa are divided hierarchically into nested hydrological units, from primary (first-order) catchments, through to secondary, tertiary, quaternary and quinary (fifth-order) catchments.[5] The quaternary catchment is used as the basic unit for national water resource management (mean size 650 km^2; Figure 4), and each contains hydrological data (gauged or simulated) that is updated from time to time. More recently, a quinary hydrological subdivision has been delineated, which splits quaternary catchments into roughly one fifth of their size (mean size of

[5] Standard national data layers with boundaries for primary, secondary, tertiary and quaternary catchments have been developed and endorsed by DWS. A standard national set of quinary catchment boundaries has yet to be agreed on, partly because different quinary catchment boundaries are useful for different purposes. For example, quinary catchments based on altitudinal subdivisions of quaternary catchments are useful for climate change modelling, while quinary catchments based on drainage units within quaternary catchments are useful for hydrological modelling. For these accounts, we use hydrological quinaries based on the 1:500 000 river network drainage units, not altitudinal quinaries. *This distinction is important for South African readers, many of whom will know the hydrological quinaries used here as 'sub-quaternaries'*. We have decided to avoid the term 'sub-quaternaries' in this document as it is less likely to be understood beyond South Africa.

120 km^2; Figure 4). Data on ecological condition of rivers is available at the quaternary and quinary catchment scale, as discussed further in Section 3.2.

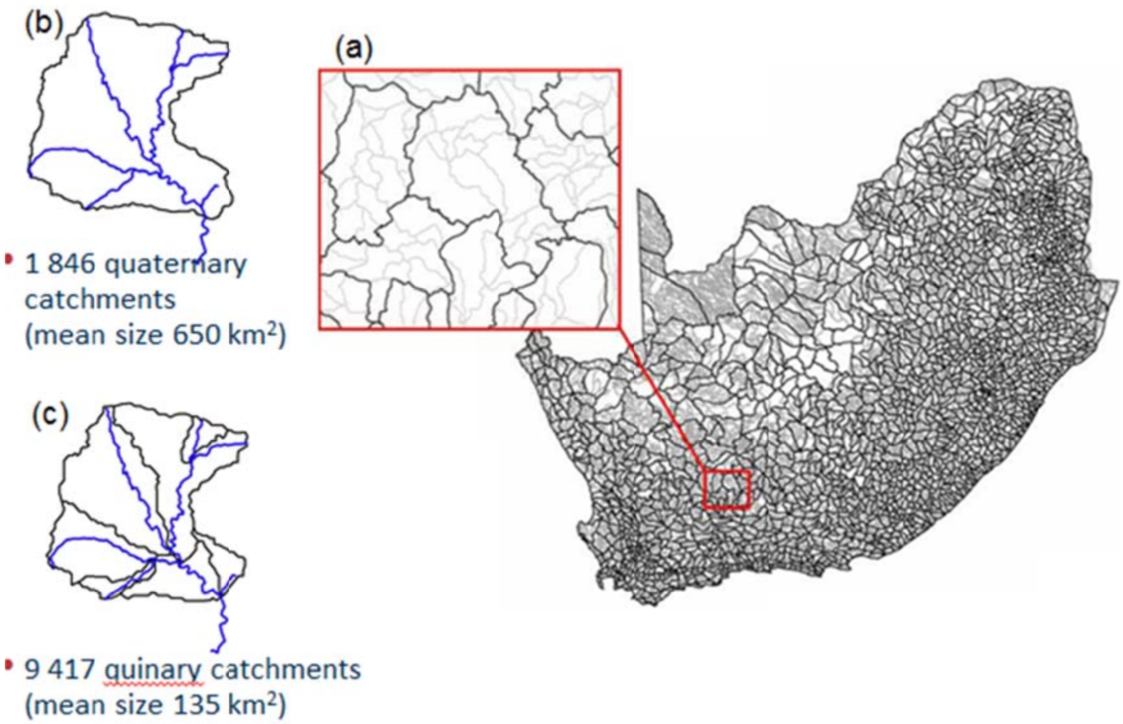

Figure 4: Hydrological units (catchments) at the quaternary (fourth-order) and quinary (fifth-order) scale
(a) shows the relationship between quaternary catchments (black outline) and quinary catchments (grey outline); (b) shows the relationship between quaternary catchments and the 1:500 000 river network with the main river passing through the quaternary catchment and the tributaries nested within the quaternary catchment; and (c) shows the relationship between quinary catchments and the 1:500 000 river network, where a quinary catchment has been delineated around each tributary.

The extent of rivers depends on the scale at which the rivers are mapped. For example, if rivers are mapped at a 1:1 000 000 scale, only major rivers will be included in the dataset, and the total length of rivers will be less than if rivers were mapped at a 1:50 000 scale, with smaller rivers and streams also included in the dataset. We used the 1:500 000 river network of DWS, which is the standard GIS layer for national water resource management, as the basis for generating river accounts.[6] . Rivers that span more than one quaternary catchment are considered to be **main rivers**; while **tributaries** are rivers that are completely contained within single quaternary catchments (Figure 5). Figure 6a shows the network of main rivers in South Africa, while Figure 6b shows the network of main rivers and tributaries, collectively referred to as '**all rivers**' in this document. The network of tiny streams that feed into tributaries is not reflected in the 1:500 000 river network. Our view is that the 1:500 000 river network provides an appropriate level of detail for national river ecosystem accounts. For more detailed planning and assessment at a sub-national level, it may be appropriate to use a river network mapped at a finer scale.

[6] Available at http://www.dwaf.gov.za/iwqs/gis_data/river/rivs500k.html

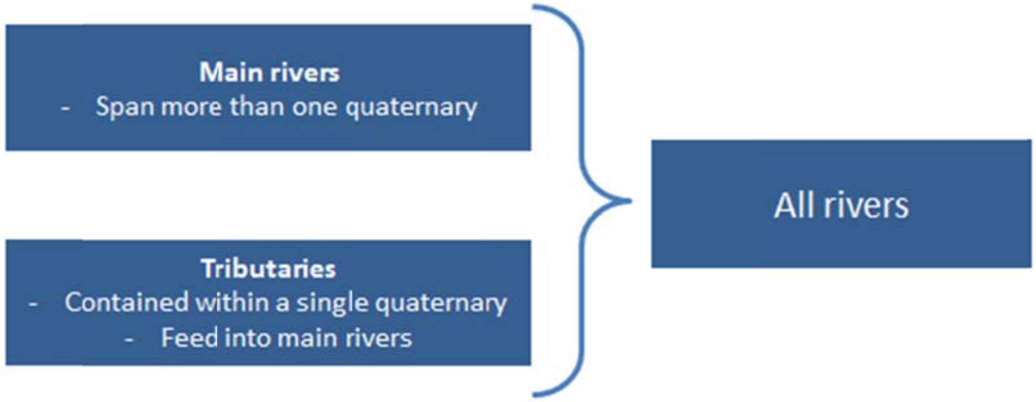

Figure 5: Diagram showing the distinction between main rivers, tributaries and all rivers

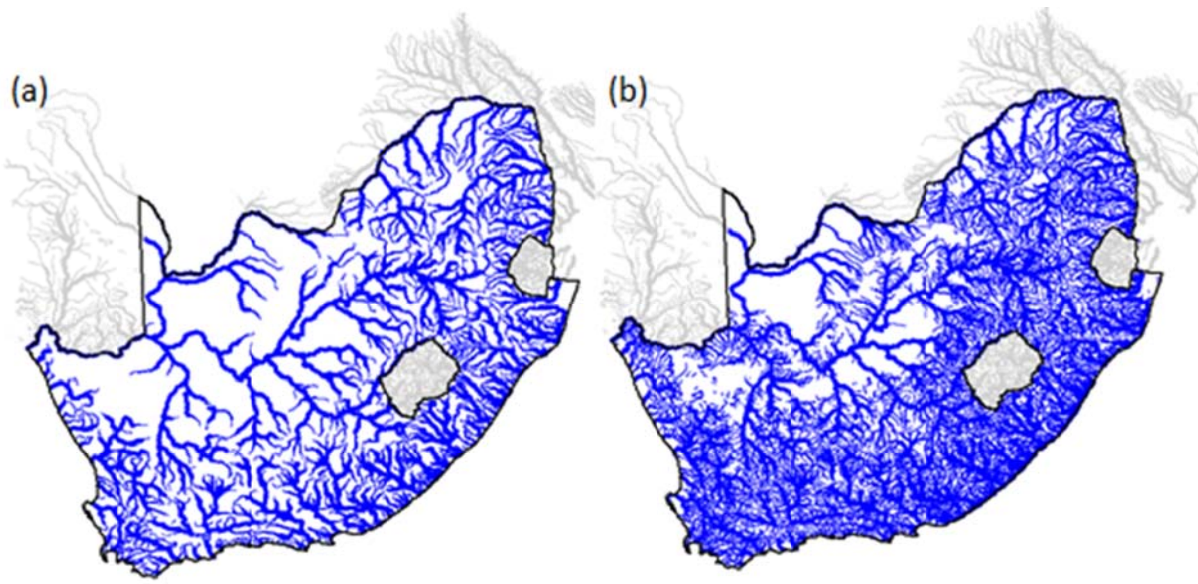

Figure 6: South Africa's 1:500 000 river network showing (a) main rivers, and (b) main rivers and their tributaries.
Rivers in grey are shared rivers in neighbouring countries and were not included in the accounts. Rivers forming the border with other countries were included.

3.2 Data on ecological condition of rivers

Key points

- Two comprehensive national assessments of the ecological condition of South Africa's rivers have been undertaken by DWS, the first in 1999 and the second in 2011.
- In each case, an **aggregated ecological condition category**, called Present Ecological State, was developed based on a set of six underlying indicators of ecological condition. The aggregated ecological condition category reflects the degree of modification from a reference condition of natural. We have summarised DWS's six Present Ecological State categories (A through to F) to four aggregated ecological condition categories for the purposes of these accounts: Natural (A and B), Moderately modified (C), Heavily modified (D), Unacceptably modified (E and F)[7].
- Four of the six underlying **ecological condition indicators** were consistent across the 1999 and 2011 assessments: These were:
    - Flow
    - Instream habitat condition
    - Stream bank/riparian condition
    - Water quality
- The assessment in **1999** was undertaken at quaternary catchment scale, for **main rivers only**, i.e. each main river reach in each quaternary catchment was scored based on the ecological condition indicators and assigned an aggregated ecological condition category. Tributaries were not assessed.
- The assessment in **2011** was undertaken at quinary catchment scale, for **main rivers and tributaries**, i.e. each main river reach or tributary in each quinary catchment was scored based on the ecological condition indicators and assigned an aggregated ecological condition category. Both main rivers and tributaries were included in the assessment.
- In order to enable time series comparison of the ecological condition of both main rivers and tributaries, the ecological condition of tributaries in 1999 has been retrospectively estimated, based on modelling and expert review. We have used these **estimates of the condition of tributaries in 1999** in the accounts presented here, recognising the limitations of the data, partly to demonstrate the importance of including tributaries in any future assessments of ecological condition of rivers.

DWS has the mandate to monitor the ecological condition of South Africa's rivers, and has invested considerable effort in this task, including two comprehensive national assessments of the Present Ecological State of rivers, the first in 1999 and the second in 2011 (Kleynhans et al. 2000; DWS 2014). The Present Ecological State data describe the extent to which a river has been modified from its reference condition, where reference condition is the ecological condition that existed before major human modifications to the water resource (the river) and surrounding landscape. In both the 1999 and 2011 assessments, modification was described according to six indicators of ecological condition (Table 4), which were assessed by aquatic ecologists with local knowledge using available data such as existing bioassessment data at site level, presence of dams and water transfer schemes, and surrounding land cover at 30 m resolution. Modification was scored from 0 (no or small

[7] We have used the term "unacceptably modified" in accordance to DWS policy that states that no river should intentionally be managed or left in this ecological condition.

modification) to 5 (critical modification) (Table 5), and confidence levels were assigned to each rating based on the data available for informing the assessment. An aggregated ecological condition category was also calculated from the median of the modification ratings of the six indicators, which then underwent further expert review. This median value was converted into six categories of ecological condition ranging from A (natural) to F (unacceptably modified), which we grouped into four ecological condition categories for the national river accounts: natural (A and B); moderately modified (C); heavily modified (D); unacceptably modified (E and F) (Table 6).

Table 4: Ecological condition indicators used in the 1999 and 2011 assessments of ecological condition of rivers

* Four of the indicators, marked with asterisks, were comparable across the 1999 and 2011 assessments.

Ecological condition indicator	**Description**
* Flow	Relative deviation from the expected natural flow and flood regimes, based on land cover/land use information (urban areas, inter basin transfers), presence of weirs, dams, water abstraction, agricultural return flows, sewage releases.
* Water quality	Water quality modification based on activities such as mining, cultivation, irrigation (i.e. agricultural return flows), sewage works, urban areas and industries, as well as algal growth and macrophyte data.
* Instream habitat	Modification of stream bed habitat caused by disturbances such as sedimentation, covering by excessive algal growth related to eutrophication. Includes consideration of the functioning of instream habitats and processes, as well as habitat for instream biota.
* Stream bank/riparian habitat	Riparian or stream bank condition as indicated by physical disturbances such as removal of vegetation, invasive vegetation and erosion.
Introduced instream biota	The impact of invasive alien species on native biota in the form of impact on physical habitat, competition and predation. This was assessed separately in 1999, but incorporated into assessment of habitat modification in 2011.
Connectivity	Alteration of connectivity along the longitudinal or lateral dimension (instream habitat and riparian/wetland zone respectively), and the possible fragmentation effect on biological populations and communities. Longitudinal and lateral connectivity were assessed together as one indicator in 1999 (inundation), and separated into two indicators (instream connectivity and riparian/wetland connectivity) in 2011.

Table 5: Modification scores used for each of the ecological condition indicators, indicating the degree of modification relative to a reference condition of natural

Modification score*	Description
0	**None:** Reference condition. No discernible impact, or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.
1	**Small:** The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.
2	**Moderate:** The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.
3	**Large:** The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.
4	**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.
5	**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.

* In the original 1999 ecological condition dataset from DWS, the modification scores were reversed such that 5 indicated no modification and 0 indicated critical modification. We changed the 1999 order to match the 2011 order.

Table 6: Aggregated ecological condition categories used in the river condition accounts, including their relationship to the Present Ecological State categories used by DWS

Aggregated ecological condition category used in these accounts	DWS Present Ecological State category	**Description** (after Kleynhans 2000)
Natural	A or B	Unmodified, natural rivers or rivers that are largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
Moderately modified	C	Rivers where a loss and change of natural habitat and biota has occurred but the basic ecosystem functions are still predominantly unchanged.
Heavily modified	D	Rivers where a large loss of natural habitat, biota and basic ecosystem functions have occurred.
Unacceptably modified*	E or F	Includes rivers where the loss of natural habitat, biota and basic ecosystem functions is extensive, as well as rivers where modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

* DWS policy is that 'D' is the lowest acceptable Present Ecological State for any river in South Africa, and that no river should intentionally be managed or left in an E or F condition. Taking the lead from this policy objective, we have used the term 'unacceptably modified' for rivers with a Present Ecological Condition of E or F.

The Present Ecological State data were originally collated to inform catchment-scale water resource management decisions and water simulation models, and have not previously been used in an accounting context or for other time series comparisons. Using the data for accounting or monitoring presents challenges related to the comparability of data over time and the scale of the two assessments. In terms of comparability, only four of the six ecological condition indicators were comparable across the 1999 and 2011 time periods (Table 4). In generating the river condition accounts, we were therefore able to use only the four comparable indicators: flow, water quality, instream habitat, and stream bank/riparian habitat.

In terms of scale, the assessment of Present Ecological State in 1999 was done for main rivers only, compared to the 2011 assessment that also included tributaries. To allow for a less accurate, but nevertheless indicative, assessment of tributaries in South Africa over the two time periods, we supplemented the 1999 data for main rivers with estimates of the aggregated ecological condition for tributaries derived for the National Freshwater Ecosystem Priority Areas project (Nel et al. 2011a and 2011b). The ecological condition of tributaries in 1999 was modelled based on the proportion of natural land cover within a series of GIS buffers around each river reach as well as within the associated quinary catchment, and the results were reviewed by experts with local knowledge. We used only those ecological condition data for tributaries in 1999 for which there was a reasonable level of confidence, based on expert review. This amounted to 42% of tributary river length – in other words the ecological condition data for tributaries in 1999 is not comprehensive.

Notwithstanding the limitations of the data on ecological condition of tributaries in 1999, we believe that on balance it makes sense to include tributaries in the accounts. The inclusion of the tributaries provides a more complete picture of the condition of rivers in South Africa. Main rivers are generally heavily utilised to improve water security for socio-economic use, whereas tributaries are less heavily utilised on the whole. We would thus expect tributaries to be in a better condition on average than main rivers. Main rivers also rely strongly on the flushing potential of healthy tributaries for their rejuvenation – without this they are prone to deterioration in ecological condition. Inclusion of the tributaries therefore not only provides a more complete picture of the trends in South African river condition, but also alerts us to trends in the condition of tributaries that may impact negatively on the condition of main rivers.

3.3 River ecoregions and longitudinal zones

Key points

- National river ecosystem types in South Africa are based on three factors: river ecoregions, broad categories of flow variability, and longitudinal zones. These factors influence the ecological characteristics of a river, and together provide a hierarchical classification of 223 river ecosystem types.
- **River ecoregions and longitudinal zones provide useful biophysical reporting units** for river ecosystem accounts, helping to highlight patterns that relate to ecological characteristics of different river ecosystem types.

In a similar way that South Africa has a national vegetation map that delineates and classifies different terrestrial ecosystem types across the country, different river ecosystem types have been identified and classified. The classification and mapping of ecosystem types forms part of the National Ecosystem Classification System (SANBI 2013a), and is guided by two key principles: that ecosystems of the same type share similar ecological characteristics, and that ecosystems are identified and mapped based on their characteristics and extent prior to major human modification.

A river can be characterised broadly according to the landscape through which it flows, its flow regime or hydrology, and its position in the landscape (e.g. slope vs. lowland plain). Spatial information on **river ecoregions** (Kleynhans et al. 2005), broad **flow variability**, and river channel slope categories or **longitudinal zones** (Rowntree and Wadeson 1999) have been combined to identify 223 national river ecosystem types across South Africa. These river types were formalised for the first time in the Atlas of Freshwater Ecosystem Priority Areas in South Africa (Nel et al. 2011a). In these accounts, the national river ecosystem types are not used directly, but two of the three factors that were used to identify them – river ecoregions and longitudinal zones – are used for summarising the accounts. They are effectively **biophysical reporting units**, and are useful for highlighting patterns in the extent and condition accounts that relate to ecological characteristics of different river ecosystem types.

River ecoregions classify rivers according to similarities based on a top-down nested hierarchy. South Africa's river ecoregions classify the landscape into 31 regions based on topography, altitude, slope, rainfall, temperature, geology and potential natural vegetation (Kleynhans et al. 2005, Figure 7)[8]. The ecoregions broadly characterise the landscape through which a river flows, such that rivers in the same ecoregion share similar broad ecological characteristics compared to those in different ecoregions. For example, the Highveld (ecoregion 11 in Figure 7) is characterised by extensive flat plains with gentle meandering rivers, compared to rivers in the Eastern Coastal Belt (ecoregion 17 in Figure 7), which are often in steeply incised and confined valleys.

[8] These 31 river ecoregions are Level 1 ecoregions. There is also a more detailed set of approximately 120 Level 2 ecoregions, which may be useful for classifying river ecosystem types at a sub-national scale but have not been used in the classification of national river ecosystem types.

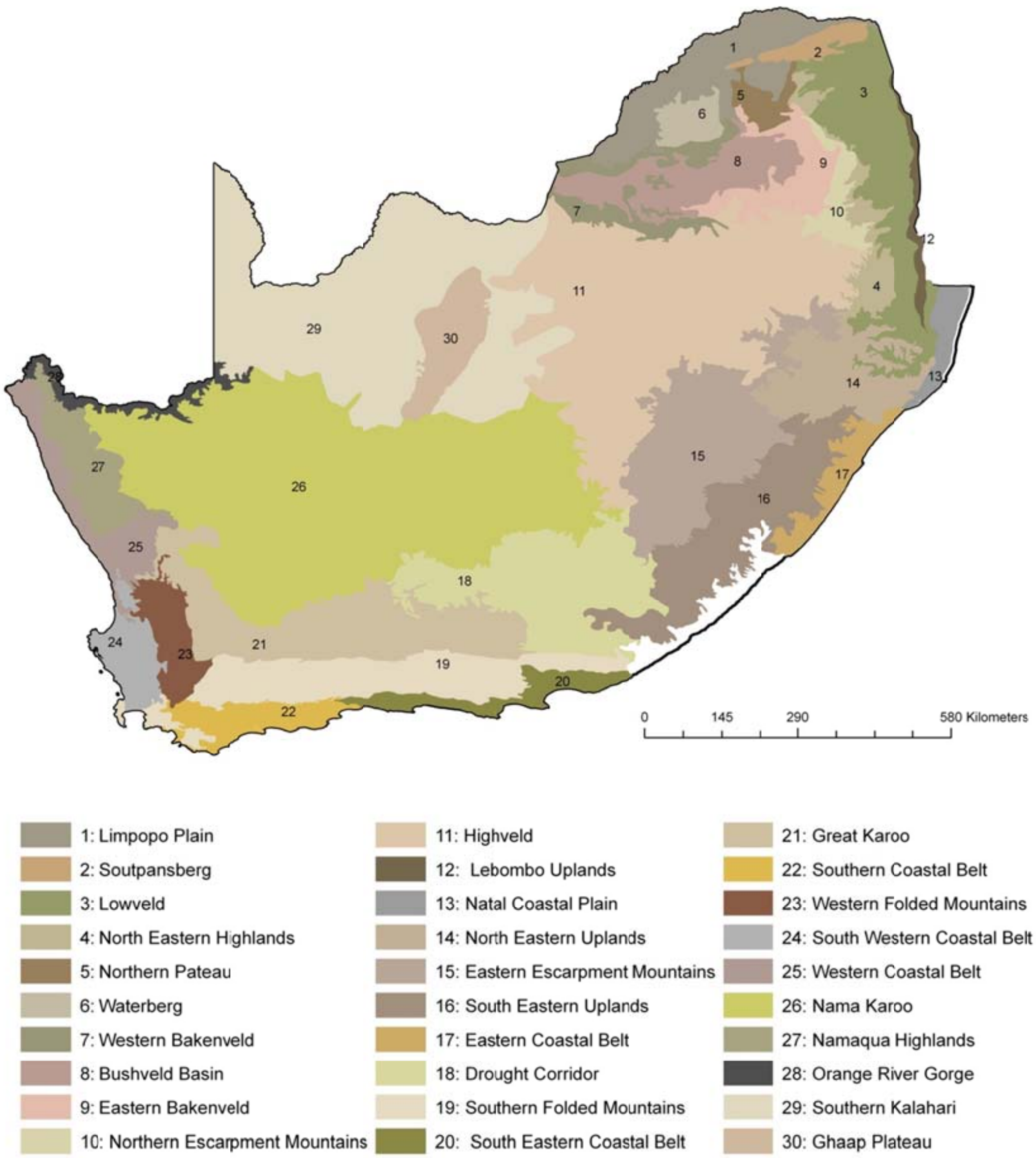

Figure 7: River ecoregions of South Africa
(Source: After Kleynhans et al. 2005)

Geomorphological or longitudinal river zones characterise the ability of river reaches to store or transport sediment (Rowntree and Wadeson 1999). South Africa's 1:500 000 river network has been stratified into slope categories using GIS slope profiles (Moolman et al. 2002). For defining river ecosystem types, these are grouped these into four longitudinal zones that depict ecological characteristics at a national level: mountain streams, upper foothills, lower foothills and lowland rivers (Figure 8). Each zone represents distinct physical and hydrological characteristics, and has different vulnerabilities and responses to human impacts, which in turn impacts ecosystem service delivery. For example, mountain streams generally tend to be less impacted by human activities, and also contain many endemic and specialised species that are likely to be less resilient to human impacts. Upper foothill rivers present some of the best opportunities for placement of dams, where rivers emerge from mountains with water quality that is often minimally impacted. They also often contain sensitive endemic species. Lower foothill and lowland rivers are often heavily impacted by agriculture or urban development. The maintenance of healthy natural vegetation along river banks is particularly important in lowland rivers as it provides filtering capacity for pollutants in runoff.

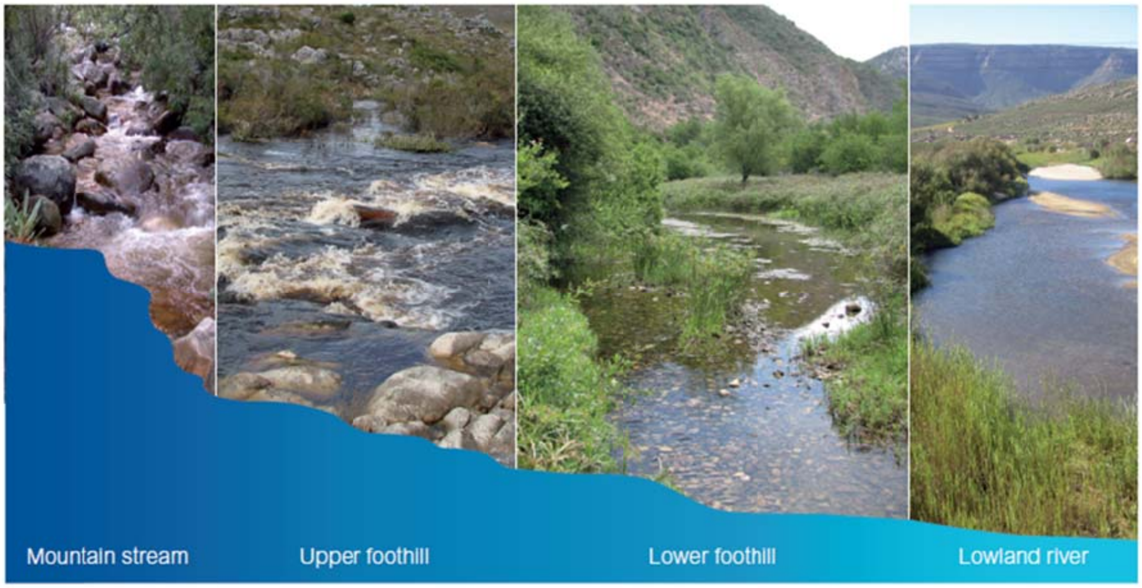

Figure 8: Schematic of four longitudinal zones for rivers, each of which has different ecological characteristics
(Source: SANBI 2013b, p21)

3.4 Water Management Areas

South Africa has nine Water Management Areas that are used as administrative and management units for implementing water policy and legislation. Catchment Management Agencies are in the process of being established for Water Management Areas or groups of Water Management Areas. Water Management Areas are delineated using catchment boundaries and do not align with provincial or municipal boundaries (Figure 9). We have used Water Management Areas as an example of **administrative reporting units** in these accounts.

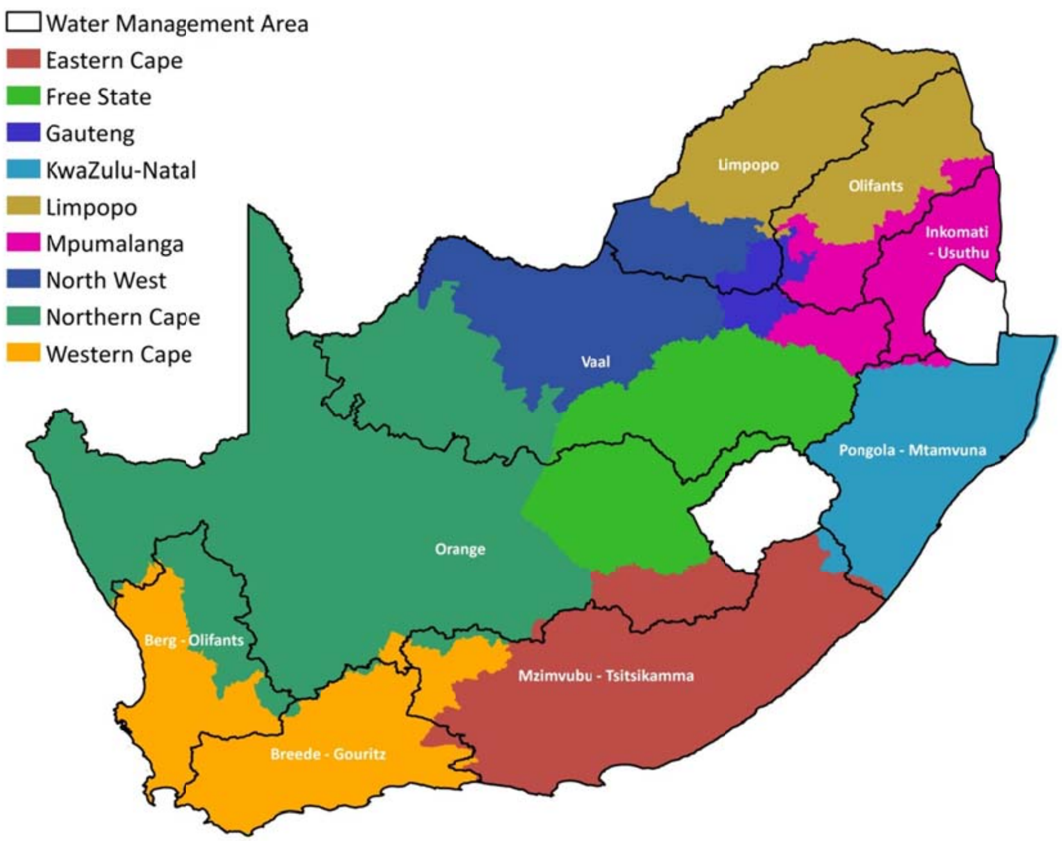

Figure 9: Map of South Africa showing boundaries of Water Management Areas in relation to provinces

4. Ecosystem extent account for rivers

In this section we present extent accounts for rivers in South Africa, distinguishing between the extent of main rivers, tributaries and all rivers. We base the extent account on river length (km), which avoids area overlaps with terrestrial or wetland ecosystems. The extent account can be summarised according to administrative or biophysical reporting units, and we demonstrate this by presenting extent accounts for rivers summarised by Water Management Area, longitudinal zone and river ecoregion.

4.1 Extent account for rivers in South Africa

An extent account tracks how the extent of an ecosystem unit changes over time. Table 7 shows the extent accounts for rivers of South Africa, calculated based on the length of main rivers and tributaries in the 1:500 000 river network in 1999 and 2011 – the same time period as that used for the ecosystem condition accounts that follow in later sections. In a 'classic' ecosystem extent account, additions to stock are divided into managed expansion, natural expansion and upward reappraisals, and reductions in stock are divided into managed regression, natural regression and downward reappraisals. We have not shown these subdivisions as the values for each are zero in this case, as discussed further below. We have added a row showing opening stock as a percentage of total river length, as this provides useful information about the proportion of main rivers and tributaries in relation to all rivers.

Table 7: Ecosystem extent account for rivers in South Africa, showing length of main rivers, tributaries and all rivers

Kilometres	Main rivers	Tributaries	All rivers
Opening stock 1999	76 310	87 223	163 533
Opening stock as % of total river length	47	53	100
Additions/reductions			
Additions/reductions as a % opening stock			
Opening stock 2011	76 310	87 223	163 533
Opening stock as % of total river length	47	53	100

No changes were recorded in the length of main rivers and tributaries between 1999 and 2011. When reported on in terms of length, river extent is quite stable compared to land cover or areal extent – river channels experience most change over geological time scales rather than the human time scales used in accounting, unless through relatively large human engineering schemes. Most of the expected changes to length would therefore occur as a result of updating the river network data, and would be recorded in the extent account as reappraisals. While ecosystem extent in terms of length generally remains relatively stable for rivers, ecological condition of rivers can change rapidly and substantially, as shown in the sections that follow.

We would have expected more change in extent had the extent account been reported in terms of area of the river channel and its banks (e.g. owing to changes in riparian vegetation and channel braiding). However, a high confidence map of river channels and riparian vegetation does not exist in South Africa (or in most countries, even those that are data-rich). We would like to emphasize that, as discussed in Section 2.2, land cover data are unreliable sources for mapping river channels and their riparian vegetation, particularly in semi-arid environments, and it is for this reason that we used a river network layer instead. In the future, deriving an integrated land-based ecosystem map that includes high confidence mapping of river channels would facilitate reporting on extent of river ecosystems in terms of area.

Further, we also propose in future to analyse the extent of river ecosystems according to the naturalised, non-cumulative volume of water (m^3) delivered by the sub-catchment representing the ecosystem unit (in this case, the quinary catchment). This may prove to be the most useful metric of extent for river ecosystem accounting as volume of water is more closely related to potential ecosystem service supply than length of river, particularly in semi-arid environments.

4.2 Extent account for rivers by Water Management Area

It is useful to summarise the data on extent of river ecosystems at a range of spatial scales for a range of reporting units (administrative or biophysical), not just at the aggregate national level. Throughout this document, we have used the Water Management Areas of South Africa to provide an example of administrative reporting units. Water Management Areas are particularly relevant for policy, decision-making and management of water resources by DWS. Other useful administrative reporting units could be provinces or municipalities, and it may be useful to explore these in future.

Table 8 shows the extent account for rivers summarised by Water Management Area. We have already made the point that the extent of main rivers and tributaries measured in terms of length did not change over the period 1999 to 2011 (Table 7), and is in general quite stable, so we have dropped the opening/closing balance between time periods in Table 8. Rivers in the Orange, Mzimvubu-Tsitsikamma and Vaal Water Management Areas make up over 50% of the total river length in South Africa. In terms of area, these are also the largest Water Management Areas in the country.

4.3 Extent account for rivers by longitudinal zone

Extent accounts can also be summarised by biophysical reporting units, such as longitudinal zones or river ecoregions. Table 9 shows the extent account for rivers summarised by longitudinal zone. As for the extent account by Water Management Area, we have not included the opening/closing balance between time periods in Table 9. The majority of South African rivers (86%) are upper or lower foothill rivers, with a moderate gradient and little to no floodplain. Lowland rivers with distinct floodplains constitute only 9% of South Africa's total river length, making them relatively rare, especially compared to many northern hemisphere countries. In a country with very little high potential arable land, the fertile floodplains of these lowland rivers are in high demand for intensive agriculture such as orchards and crops.

Table 8: Ecosystem extent account for rivers by Water Management Area

Kilometres	Main rivers	Tributaries	All rivers	% total river length
Berg-Olifants	4 166	6 078	10 243	6
Breede-Gouritz	5 313	7 129	12 441	8
Inkomati-Usuthu	3 808	2 289	6 097	4
Limpopo	6 117	5 625	11 742	7
Mzimvubu-Tsitsikamma	16 000	17 317	33 317	20
Olifants	6 242	4 722	10 964	7
Orange	13 104	23 580	36 684	22
Pongola-Mzimkulu	10 613	7 272	17 884	11
Vaal	10 948	13 212	24 160	15
Total	**76 310**	**87 233**	**163 533**	**100**

* Percentage is based on the total length of all rivers in South Africa

Table 9: Ecosystem extent account for rivers by longitudinal zone

Kilometres	Main rivers	Tributaries	All rivers	% total river length*
Mountain stream	1 609	5 145	6 754	4
Upper foothill stream	21 566	52 592	74 158	45
Lower foothill stream	38 893	27 553	66 445	41
Lowland river	14 243	1 008	15 251	9
No Data	0	926	926	1
Total	**76 310**	**87 223**	**163 533**	**100**

* Percentage is based on the total length of all rivers in South Africa

4.4 Extent account for rivers by river ecoregion

Ecoregions present another biophysical reporting unit for ecosystem extent accounts, as presented in Table 10. The Highveld and Nama Karoo ecoregions have the most extensive river networks, mainly because of their large size (Figure 7) and not necessarily because of their drainage density. In the Nama Karoo ecoregion, many of the rivers are ephemeral and may go for several years without flowing.

Table 10: Ecosystem extent account for rivers by river ecoregion

Code	Kilometres Ecoregion	Main rivers	Tributaries	All rivers	% total river length*
1	Limpopo Plain	2 156	1 183	3 339	2
2	Soutpansberg	516	304	820	1
3	Lowveld	5 019	2 995	8 014	5
4	North Eastern Highlands	1 242	336	1 577	1
5	Northern Plateau	407	336	744	0
6	Waterberg	404	754	1 158	1
7	Western Bankenveld	1 224	1 246	2 470	2
8	Bushveld Basin	2 114	2 192	4 306	3
9	Eastern Bankenveld	1 613	1 475	3 088	2
10	Northern Escarpment Mountains	998	561	1 558	1
11	Highveld	10 183	11 826	22 009	13
12	Lebombo Uplands	138	465	602	0
13	Natal Coastal Plain	393	355	748	0
14	North Eastern Uplands	3 850	2 677	6 527	4
15	Eastern Escarpment Mountains	3 471	3 247	6 718	4
16	South Eastern Uplands	6 059	5 475	11 534	7
17	Eastern Coastal Belt	2 062	1 328	3 390	2
18	Drought Corridor	4 969	6 264	11 233	7
19	Southern Folded Mountains	3 544	5 366	8 910	5
20	South Eastern Coastal Belt	1 602	988	2 590	2
21	Great Karoo	4 053	6 991	11 044	7
22	Southern Coastal Belt	1 168	1 407	2 575	2
23	Western Folded Mountains	1 453	1 200	2 652	2
24	South Western Coastal Belt	847	1 199	2 046	1
25	Western Coastal Belt	1 142	1 143	2 284	1
26	Nama Karoo	7 522	16 380	23 901	15
27	Namaqua Highlands	1 035	2 046	3 081	2
28	Orange River Gorge	657	987	1 644	1
29	Southern Kalahari	4 027	3 545	7 572	5
30	Ghaap Plateau	63	1 606	1 668	1
31	Eastern Coastal Belt	2 372	1 326	3 698	2
999	No Data	10	22	32	0
	Total	**76 310**	**87 223**	**163 533**	**100**

* Percentage is based on the total length of all rivers in South Africa

5. Ecosystem condition account for rivers

As explained in Section 3.2, national data on ecological condition of rivers in 1999 and 2011 exist in the form of indicators of ecological condition as well as an aggregated ecological condition category derived from these indicators. In this section, we present three sets of ecosystem condition accounts for rivers – the first using the *ecological condition indicators*, the second using the *aggregated ecological condition category*, and the third using an *ecological condition index* that we have derived based on the existing condition data (Figure 10). Our primary purpose in presenting the third set of accounts using an ecological condition index is to demonstrate the usefulness of this approach, which allows for simpler presentation of the information on ecosystem condition than is possible in the first two sets of accounts.

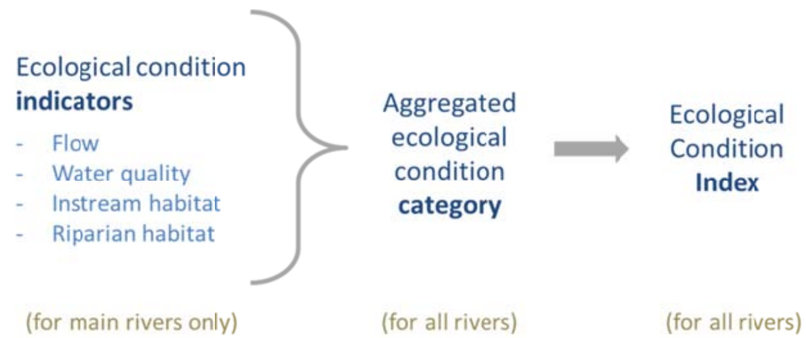

Figure 10: Schematic showing the three sets of ecosystem condition accounts for rivers
Condition accounts based on the ecological condition indicators were developed for main rivers only due to lack of condition data for tributaries in 1999.

5.1 Condition account for main rivers, based on ecological condition indicators

We have generated condition accounts using ecological condition indicators for main rivers only, because, as discussed in Section 3.2, the 1999 data did not include ecological condition indicators for tributaries. The 2011 data include tributaries, demonstrating that it may be possible in future to generate condition accounts using ecological condition indicators for both main rivers and tributaries.

Table 11 shows the ecosystem condition account for main rivers using four ecological condition indicators, showing the degree of modification to flow, water quality, instream habitat and stream bank/riparian habitat. The degree of modification is shown as none/small, moderate, large or serious/critical, relative to a reference condition of natural, and the condition account sums the river length at each of these levels of modification. The change between 1999 and 2011 is shown in absolute terms (increases/decreases in km), as well as in proportional terms. Two proportional measures are provided in the table:

- a metric showing the opening stock for each level of modification as a percentage of the total length of all rivers, which provides information on how the total length of rivers is distributed across the different levels of modification;

- a metric showing increases/decreases as a percentage of opening stock within each level of modification, which is useful for understanding proportional changes over the time period. Even if the absolute river length at a particular level of modification is small, the proportion of river length at this level of modification may nevertheless have undergone large increases or decreases.

For example, there was a 150% increase in main rivers with a large degree of instream habitat modification between 1999 and 2011, and these rivers constituted 18% of South Africa's main rivers by 2011 (Table 11).

Table 11: Ecosystem condition account for main rivers using four ecological condition indicators, 1999 – 2011

	Degree of modification from natural					
Kilometres	None/ small	Moderate	Large	Serious/ Critical	No Data	Total
FLOW						
Opening stock 1999	**34 084**	**22 814**	**10 328**	**5 447**	**3 637**	**76 310**
Opening stock as a % total river length	45	30	14	7	5	100
Increase/decreases	-10 546	-2 316	6 017	5 129	1 715	
Increases/decreases as % opening stock	-31	-10	58	94	47	
Opening stock 2011	**23 538**	**20 499**	**16 345**	**10 576**	**5 352**	**76 310**
Opening stock as a % total river length	31	27	21	14	7	100
WATER QUALITY						
Opening stock 1999	**40 579**	**24 634**	**5 518**	**1 943**	**3 637**	**76 310**
Opening stock as a % total river length	53	32	7	3	5	100
Increase/decreases	-5 769	-3 591	6 149	1 496	1 715	
Increases/decreases as % opening stock	-14	-15	111	77	47	
Opening stock 2011	**34 810**	**21 043**	**11 667**	**3 439**	**5 352**	**76 310**
Opening stock as a % total river length	46	28	15	5	7	100
STREAM BANK/RIPARIAN HABITAT						
Opening stock 1999	**22 469**	**32 951**	**14 164**	**3 088**	**3 639**	**76 310**
Opening stock as a % total river length	29	43	19	4	5	100
Increase/decreases	-50	-3 612	1 255	1 667	740	
Increases/decreases as % opening stock		-11	9	54	20	
Opening stock 2011	**22 418**	**29 339**	**15 420**	**4 755**	**4 379**	**76 310**
Opening stock as a % total river length	29	38	20	6	6	100
INSTREAM HABITAT						
Opening stock 1999	**39 736**	**26 188**	**5 446**	**1 301**	**3 639**	**76 310**
Opening stock as a % total river length	52	34	7	2	5	100
Increase/decreases	-11 245	426	8 180	1 898	740	
Increases/decreases as % opening stock	-28	2	150	146	6 840	
Opening stock 2011	**28 491**	**26 615**	**13 626**	**3 200**	**4 379**	**76 310**
Opening stock as a % total river length	37	35	18	4	6	100

The ecosystem condition account in Table 11 highlights that:

- The proportion of main river length with no/small modification declined across all four indicators from 1999 to 2011, but most notably for flow and instream habitat, which experienced a decline of 31% and 28% respectively in no/small modification relative to the opening stock.
- The extent of main river length in which flow is seriously/critically modified doubled between 1999 and 2011, and by 2011 constituted 14% of the total length of main rivers. Moderate or large modification of flow is often indicative of water schemes (including dams and other water supply infrastructure such as pipelines and canals), while serious/critical modification can be indicative of severe over-abstraction of water, or poor management of environmental flow releases from dams. Maintaining dammed rivers in a moderately modified ecological condition is possible through environmental flow releases from dams and good management of surrounding land.
- The extent of main river length with a large or serious/critical degree of modification to instream habitat more than doubled from 1999 to 2011 (from 9 to 22%), and in 2011 constituted 22% of the river length. This is indicative of alteration of habitat as a result of processes such as sedimentation and eutrophication, which affect the ability of river ecosystems to provide continued ecosystem services, and can cause regime shifts in downstream dams and lakes.
- The extent of main river length with a large degree of modification to water quality more than doubled, adding 6 149 km to this category between 1999 and 2011. This is consistent with rising evidence of failing waste-water treatment infrastructure, increasing pollutant loads from intensive land uses such as agriculture, and increasing instances of acid mine drainage from old unused mines.
- Changes in the degree of modification to stream bank/riparian habitat were not large overall, but it is worth noting that of the four indicators this one already reflected the most extensive modification in 1999, and that there was a substantial (54%) increase in the proportion of river length with a serious/critical degree of modification to stream bank/riparian habitat between 1999 and 2011.

Figure 11 summarises the change in the extent of river length at different levels of modification for each ecological condition indicator, presenting the information in Table 11 graphically. It confirms the findings discussed above, showing that most change (reflected by the steepest lines on the graphs) occurred in the flow and instream habitat indicators, as well as in the extent of river length with a large degree of modification to water quality. The information is shown spatially in Figure 12. The increasing degree of modification of flow and instream habitat is evident in these maps, especially in the south western and north eastern parts of the country, as well as the increasing degree of modification of water quality in parts of the interior of the country. These spatial trends are discussed again in Section 6, which presents the condition accounts per Water Management Area.

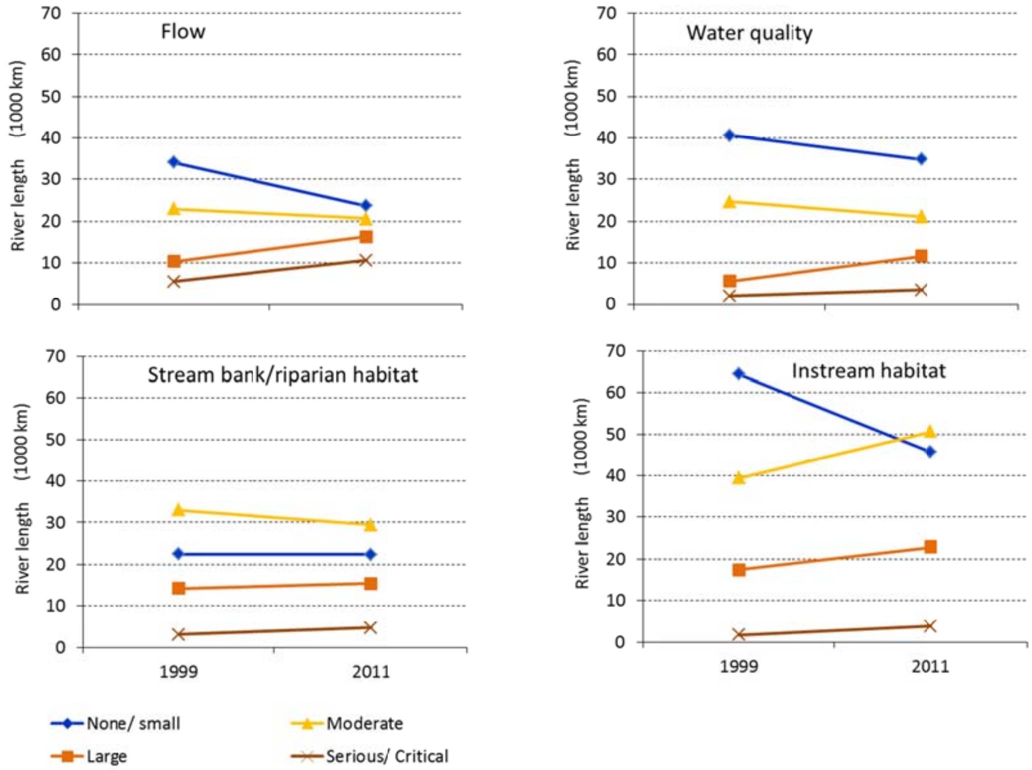

Figure 11: Change in degree of modification in main rivers for each of the four ecological condition indicators, 1999 – 2011

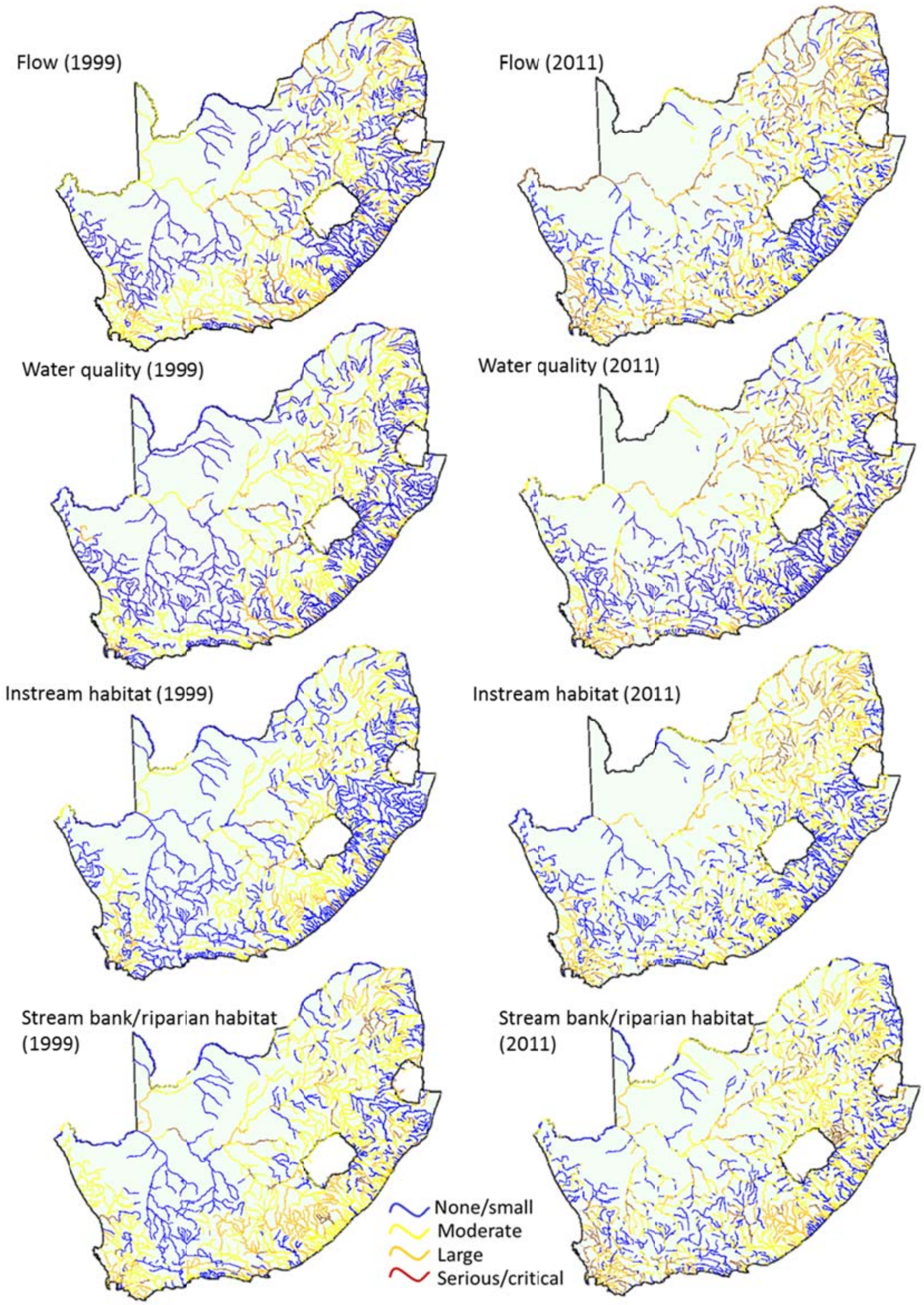

Figure 12: Maps of the four ecological condition indicators for main rivers, showing the degree of modification from natural, 1999 and 2011

5.2 Condition account for main rivers and tributaries, based on aggregated ecological condition category

As explained in Section 3.2, the individual ecological condition indicators reported on in Section 5.1 were used by DWS to assess the Present Ecological State of rivers in 1999 and again in 2011, giving an overall picture of the degree to which a river has been modified from a reference condition of natural. For these accounts, we have grouped the six Present Ecological State categories into four aggregated ecological condition categories: natural, moderately modified, heavily modified, and unacceptably modified. Even though the 1999 Present Ecological State assessment lacked data for tributaries, we were able to use data for aggregated ecological condition of tributaries for 1999 from Nel et al. (2011a). Table 12 therefore shows condition accounts based on the aggregated ecological condition categories for both main rivers and tributaries.

Table 12: Ecosystem condition account for rivers based on the aggregated ecological condition category, for main rivers, tributaries and all rivers

	Degree of modification from natural					
Kilometres	Natural	Moderately modified	Heavily modified	Unacceptably modified	No Data	Total
MAIN RIVERS						
Opening stock 1999	**46 541**	**22 315**	**2 791**	**1 026**	**3 637**	**76 310**
Opening stock as a % total river length	61	29	4	1	5	100
Increase/decreases	-24 100	9 467	13 168	1 465		
Increases/decreases as % opening stock	-52	42	472	143		
Opening stock 2011	**22 441**	**31 782**	**15 960**	**2 492**	**3 637**	**76 310**
Opening stock as a % total river length	29	42	21	3	5	100
TRIBUTARIES						
Opening stock 1999	**40 294**	**7 470**	**2 084**	**328**	**37 047***	**87 223**
Opening stock as a % total river length	46	9	2		42*	100
Increase/decreases	-17 062	11 339	4 766	957		
Increases/decreases as % opening stock	-42	152	229	292		
Opening stock 2011	**23 232**	**18 809**	**6 850**	**1 285**	**37 047***	**87 223**
Opening stock as a % total river length	27	22	8	1	42*	100
ALL RIVERS						
Opening stock 1999	**86 835**	**29 784**	**4 875**	**1 354**	**40 684**	**163 533**
Opening stock as a % total river length	53	18	3	1	25	100
Increase/decreases	-41 163	20 806	17 935	2 422		
Increases/decreases as % opening stock	-47	70	368	179		
Opening stock 2011	**45 673**	**50 591**	**22 810**	**3 776**	**40 684**	**163 533**
Opening stock as a % total river length	28	31	14	2	25	100

* See the second last paragraph of Section 3.2 for an explanation of this high No Data value.

The condition account in Table 12 shows that:

- There was a substantial decrease in the extent of river length in the natural category for both main rivers and tributaries.
- For main rivers, the decrease in extent of river length in the natural category was accompanied by a large increase in the extent of river length in the heavily modified category, which increased by 13 168 km (almost 500%) between 1999 and 2011. This suggests that there was substantial deterioration in the ecological condition of main rivers.
- For tributaries, the decrease in extent of river length in the natural category was accompanied by a substantial increase in the moderately modified category (4 766 km; 229%).
- Although unacceptably modified rivers comprise a minor proportion of the total river length (2% in 2011), this category experienced a large proportional increase for both main rivers and tributaries.

Figure 13 shows the timeline trends from the condition account in Table 12 in graphical form. It supports the findings highlighted above, showing steep declines in the extent of river length in the natural category, and steep inclines in the moderately modified and heavily modified categories. Figure 14 shows national maps of the aggregated ecological condition category for main rivers and all rivers in 1999 and 2011. The decrease in the extent of river length in the natural category is particularly pronounced along the north-eastern coast of South Africa in KwaZulu-Natal Province. Rivers in the south-western portion of the country (Western Cape Province) and the far north (Limpopo province) also show marked deterioration in condition.

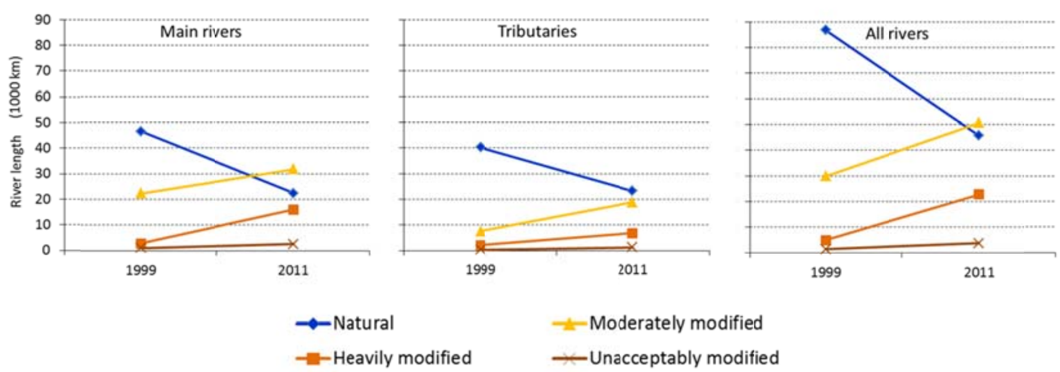

Figure 13: Change in the extent of river length in each aggregated ecological condition category, for main rivers, tributaries and all rivers, 1999 – 2011

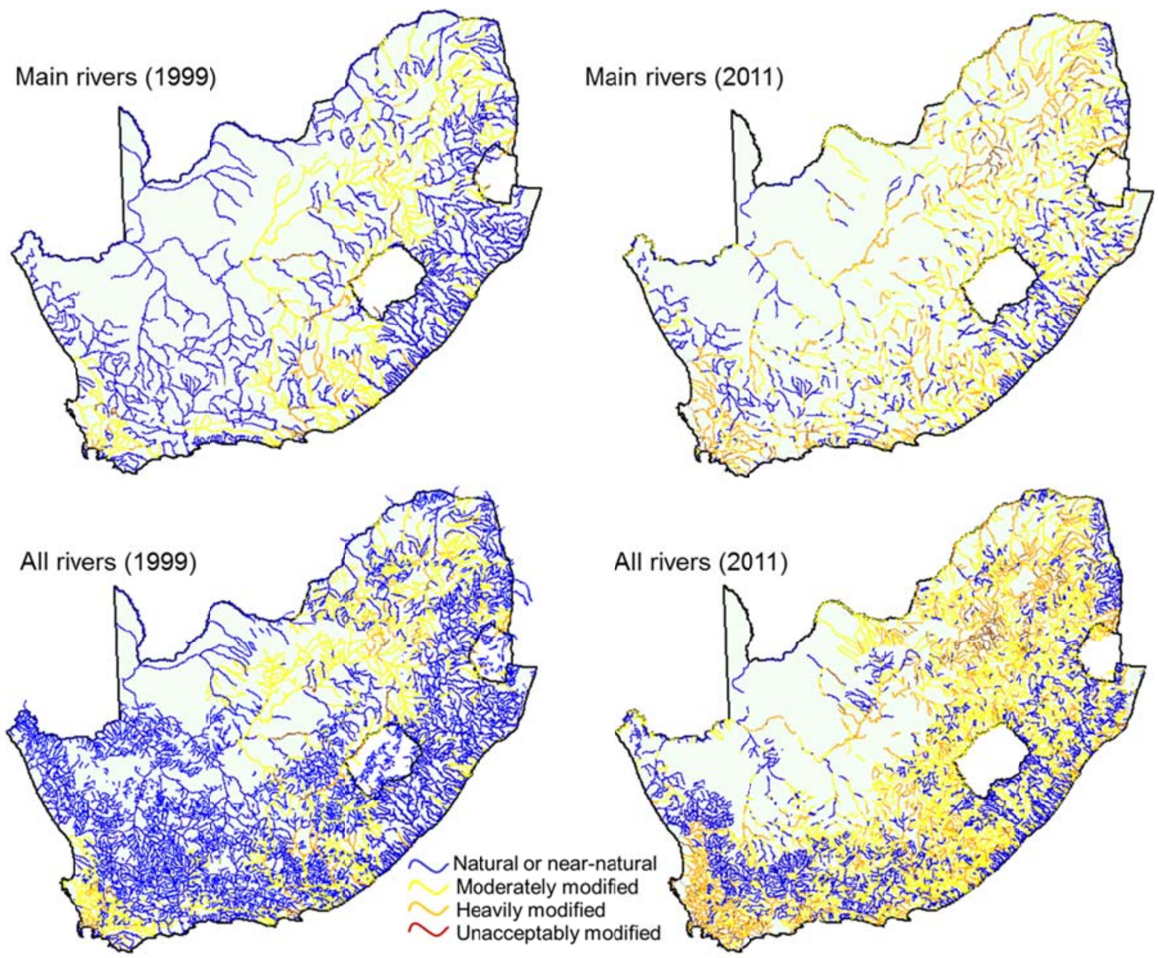

Figure 14: Maps of the aggregated ecological condition category for main rivers and all rivers in South Africa, 1999 and 2011

5.3 Condition account for main rivers and tributaries, based on the Ecological Condition Index

The aggregated ecological condition category used in Section 5.2 above is useful for providing an overall picture of the state of river ecosystems, but is still relatively complicated to communicate. In an attempt to provide a simple overall picture in a single number, we developed an Ecological Condition Index based on the aggregated ecological condition data. The Ecological Condition Index summarises the trends in the aggregated ecological condition categories into a single, scalable index. It is scalable in the sense that it can be calculated for any reporting unit, from quinary (fifth-order) catchments (Section 3.1) to the national level, for administrative or biophysical reporting units. If such an index were to be developed in a comparable way in other countries, it could be summarised at a regional, continental or global scale. The index ranges between 0 and 100, and gives an indication of the degree of modification from reference condition, where 100 is the reference condition of an ecosystem as it would be without human modification, and 0 is where ecosystem function is absent.

We developed and piloted the Ecological Condition Index with stakeholders who have many years of experience in river health and water resource management. Our overall assessment, corroborated by these stakeholders, is that summarising trends into a single index is generally easier to communicate than showing inter-related trends across several aggregated ecological condition categories. The latter approach is more difficult to communicate when the target audience – such as national politicians or civil society – is not experienced in river ecological condition and spatial analysis. We believe this index holds much promise for communicating the overall trends in river condition, and there has been considerable excitement amongst stakeholders about these initial results.

We would like to stress that our purpose here is primarily to demonstrate the usefulness of an Ecological Condition Index. We recognise that we have pushed the limits of the available data in producing the results shown below, in ways that are not ideal. Our hope is that having demonstrated the usefulness of such an index, it may be possible to refine systems for collecting and recording the underlying ecological condition data, involving all key stakeholders collectively, to allow for the construction of a more statistically robust index in future.

The steps we used to derive the Ecological Condition Index are summarised in Figure 15, and an example of how we calculated the Ecological Condition Index for main rivers in 1999 is provided in Table 13. We used the percentile ranges endorsed by DWS (Kleynhans and Louw 2007; Table 14) to express the aggregated ecological condition category as a number. Ideally, the numbers for the aggregated ecological condition should be continuous between 0 and 100. A limitation of the national dataset we used was that the aggregated ecological condition was categorical (although where site-level river condition data exist, continuous data between 0 and 100 would most likely have originally been available). To convert the aggregated ecological condition category to a number, we assigned the midpoint of this percentile range such that the natural, moderately modified, heavily modified and unacceptably modified categories were assigned a midpoint of 90, 70, 50 and 20 respectively (Table 13). The proportion river length in each aggregated ecological condition category is based on the same data used for the condition account shown in Table 12 in Section 5.2. Multiplying the midpoint of the aggregated ecological condition category by the proportion of river length in each category provides a length-weighted score for rivers in each category (Table 13). The Ecological Condition Index is then calculated as the sum of the length-weighted scores for rivers in all aggregated ecological condition categories (Figure 15).

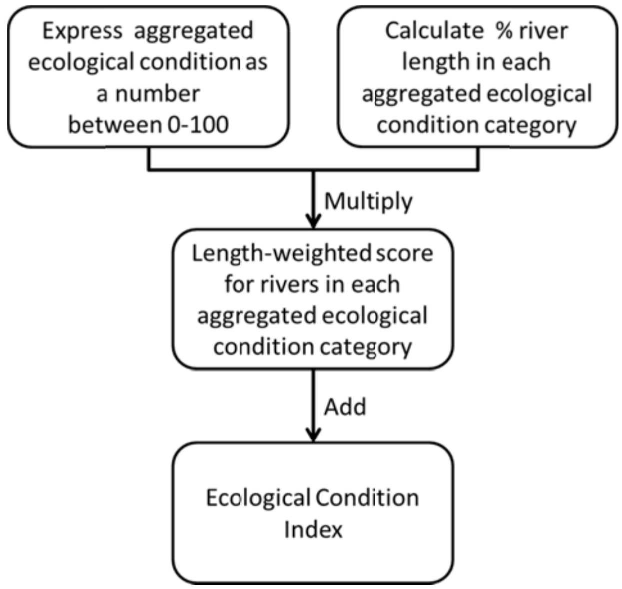

Figure 15: Four steps used to derive the Ecological Condition Index
The number between 0 and 100 that is assigned to the aggregated ecological condition category describes the modification from reference condition, where 100 is the reference condition prior to human modification, and 0 is where ecosystem function is absent.

Table 13: Example of how the Ecological Condition Index was calculated for main rivers in 1999

Aggregated ecological condition category	Percentile range	Midpoint of percentile range	Length (km)	Proportional length	Length-weighted score
Natural	80-100	90	46 541	0.640	57.6
Moderately modified	60-79	70	22 315	0.307	21.5
Heavily modified	40-59	50	2 791	0.038	1.9
Unacceptably modified	0-39	20	1 026	0.014	0.3
Total			**72 674**		**81.3**

* Percentile range is based on modification ranges used by DWS and shown in Table 14

Table 14: The aggregated ecological condition categories and their percentile scores used by DWS to describe modification from reference condition of natural, after Kleynhans and Louw (2007)

Aggregated ecological condition category	Percentile range describing deviation from reference condition
Natural	80-100
Moderately modified	60-79
Heavily modified	40-59
Unacceptably modified	0-39

The results of this initial estimate of the Ecological Condition Index for rivers in South Africa are shown in Table 15 and Figure 16. The Ecological Condition Index declined by 10.6% between 1999 and 2011. Tributaries are in slightly better condition and appear to have a slightly lower rate of decline than main rivers (9.7% vs. 11.2% respectively). These trends concur with the judgement of stakeholders and experts involved in piloting this index. Based on their experience of working directly with management of rivers and water resources, they felt that the results reflect real trends in the country's rivers over the time period concerned, notwithstanding the limitations of the underlying data.

Table 15: The Ecological Condition Index for 1999 and 2011 for main rivers and tributaries, on a scale of 0 – 100

	Main rivers	Tributaries	All rivers
1999	81.3	84.9	82.8
2011	70.1	75.2	72.2
Change between 1999 and 2011	-11.2	-9.7	-10.6

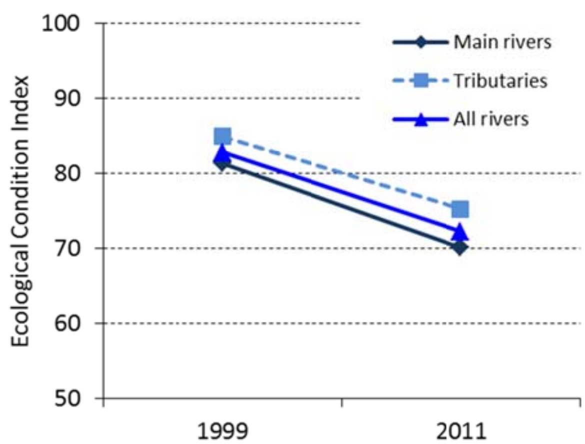

Figure 16: Change in the Ecological Condition Index for main rivers, tributaries and all rivers, 1999 – 2011

Figure 17 compares the trends in the aggregated ecological condition categories (left side graphs) to the trend in the Ecological Condition Index (right side graphs). It shows the clarity and ease of communicating a single index, rather than changes in a set of four categories. The ecological condition categories were developed primarily for planning and management purposes rather than for accounting purposes, so it is perhaps not surprising that they are not as well suited to accounts.

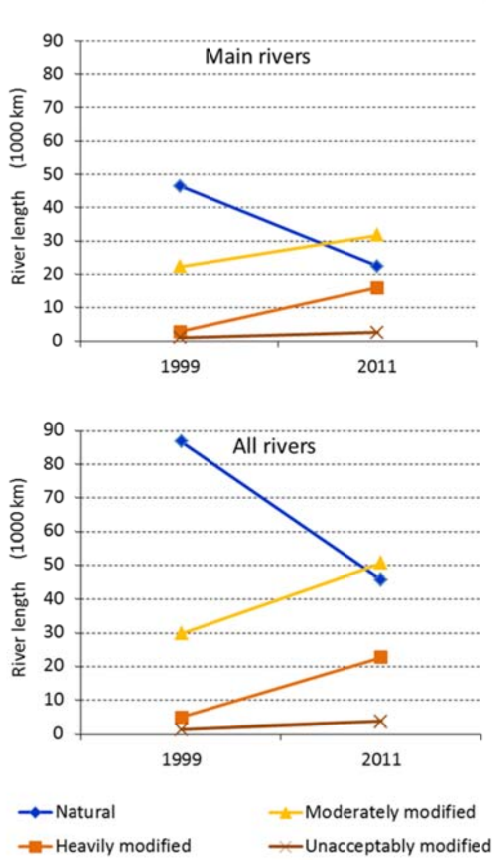

Figure 17: Comparison of trends in aggregated ecological condition categories and the Ecological Condition Index for main rivers and all rivers

6. Ecosystem condition account for rivers by Water Management Area

To understand how ecosystem condition trends differ across the country, ecosystem condition accounts can be constructed for administrative or biophysical units at the sub-national level. In this section we show how ecosystem condition accounts can be developed for Water Management Areas to examine trends between these water resource administrative units. We show examples of condition accounts for the Limpopo Water Management Area, using ecological condition indicators and the aggregated ecological condition category; use bar charts to summarise trends in the ecological condition indicators and the aggregated ecological condition category for all Water Management Areas; and then show the Ecological Condition Index for each Water Management Area. We chose the Limpopo Water Management Area as an example because it has undergone high rates of change in the last decade, both in terms of land use change and river ecological condition. It also reflects an area more typical of developing countries, with many low-income rural households that depend on untreated water drawn directly from rivers for domestic consumption.

6.1 Condition account for Water Management Areas, based on ecological condition indicators

Similar to the national-level accounts presented in Table 11, Table 16 shows the ecosystem condition account for main rivers of the Limpopo Water Management Area using the ecological condition indicators for flow, water quality, instream habitat and stream bank/riparian habitat. It shows that rivers of this area have experienced substantial modification to flow, water quality and instream habitat. Between 1999 and 2011, the proportion of river length with a critical/serious degree of modification doubled for both flow (from 34% to 66%) and water quality (from 9% to 25%), and increased seven-fold for instream habitat (from 8% to 55%). Factors influencing these large changes in the Limpopo Water Management Area include failing treatment of waste water, and pressure from growing industries of agriculture and mining. Such an account can be generated for each Water Management Area.

Figure 18 uses bar graphs to compare some of the changes to the ecological condition indicators across all nine Water Management Areas. Overall, the Limpopo and Olifants Water Management Areas stand out as the ones that are experiencing extreme levels of modification – particularly for flow, water quality and instream habitat. The key changes shown in Figure 18 include:

- Substantial increases in the proportion of river length with a critical/serious degree of flow modification for the Limpopo, Inkomati-Usuthu, Berg-Olifants and Breede-Gouritz Water Management Areas. It is also worth noting that a slight increase in the proportion of river length with no/small modification was detected in the Breede-Gouritz and Mzimvubu-Tsitsikamma Water Management Areas. This could potentially be from additional flows released from invasive alien clearing or environmental flow management, but this would need to be investigated.
- A sharp decline in water quality in the Breede-Gouritz, Olifants, Vaal, Limpopo Water Management Areas, with over 20% of the river length in these areas now being in a

critically/seriously modified state. Failing waste water infrastructure and agricultural intensification is a major driver of water quality decline across the country, with the former particularly problematic in Limpopo. In addition, the Olifants, Vaal and Limpopo Water Management Areas have water quality issues associate with mining and severe acid mine drainage problems. The water quality problems in Limpopo are particularly concerning given that there is substantial backlog in supply of water services to households in the north-eastern portion of the country combined with population demographics of many low-income rural communities that often rely on run-of-river use without water treatment (Figure 19).

- High levels of serious/critical modification to instream habitat in the Olifants and Limpopo Water Management Areas – almost 50% of the river length in these Water Management Areas has instream habitat that is now critically/seriously modified. This is most likely associated with eutrophication problems caused mainly by failing waste water infrastructure and exacerbated by agricultural intensification.
- The proportion of river length with no or small modification to stream bank or riparian habitat is generally low relative to that for flow, water quality and instream habitat, and the changes to this indicator were not as dramatic. Riparian habitat provides a very important natural filter for pollutants that would otherwise be washed into the river, and attention needs to be given to maintaining and restoring such habitat.

Table 16: Ecosystem condition account for rivers of the Limpopo Water Management Area using ecological condition indicators, 1999 – 2011

Kilometres	Degree of modification from natural					Total
	None/ small	Moderate	Large	Serious/ Critical	No Data	
FLOW						
Opening stock 1999	**2 456**	**1 403**	**1 209**	**854**	**195**	**6 117**
Opening stock as a % total river length	40	23	20	14	3	100
Increase/decreases	-1 574	-549	336	1 785		
Increases/decreases as % opening stock	-64	-39	28	209		
Opening stock 2011	**882**	**854**	**1 545**	**2 639**	**195**	**6 115**
Opening stock as a % total river length	14	14	25	43	3	100
WATER QUALITY						
Opening stock 1999	**3 332**	**2 024**	**503**	**62**	**195**	**6 117**
Opening stock as a % total river length	54	33	8	1	3	100
Increase/decreases	-1 363	364	563	435		
Increases/decreases as % opening stock	-41	18	112	700		
Opening stock 2011	**1 969**	**2 387**	**1 066**	**497**	**195**	**6 115**
Opening stock as a % total river length	32	39	17	8	3	100
INSTREAM HABITAT						
Opening stock 1999	**3 046**	**2 372**	**503**	**0.2**	**195**	**6 117**
Opening stock as a % total river length	50	39	8	0	3	100
Increase/decreases	-2 695	-196	2 017	872		
Increases/decreases as % opening stock	-88	-8	401	383 799		
Opening stock 2011	**351**	**2 176**	**2 521**	**873**	**195**	**6 115**
Opening stock as a % total river length	6	36	41	14	3	100
STREAM BANK/RIPARIAN HABITAT						
Opening stock 1999	**2 041**	**2 803**	**1 043**	**34**	**195**	**6 117**
Opening stock as a % total river length	33	46	17	1	3	100
Increase/decreases	-1 090	653	263	172		
Increases/decreases as % opening stock	-53	23	25	500		
Opening stock 2011	**951**	**3 456**	**1 306**	**207**	**195**	**6 115**
Opening stock as a % total river length	16	57	21	3	3	100

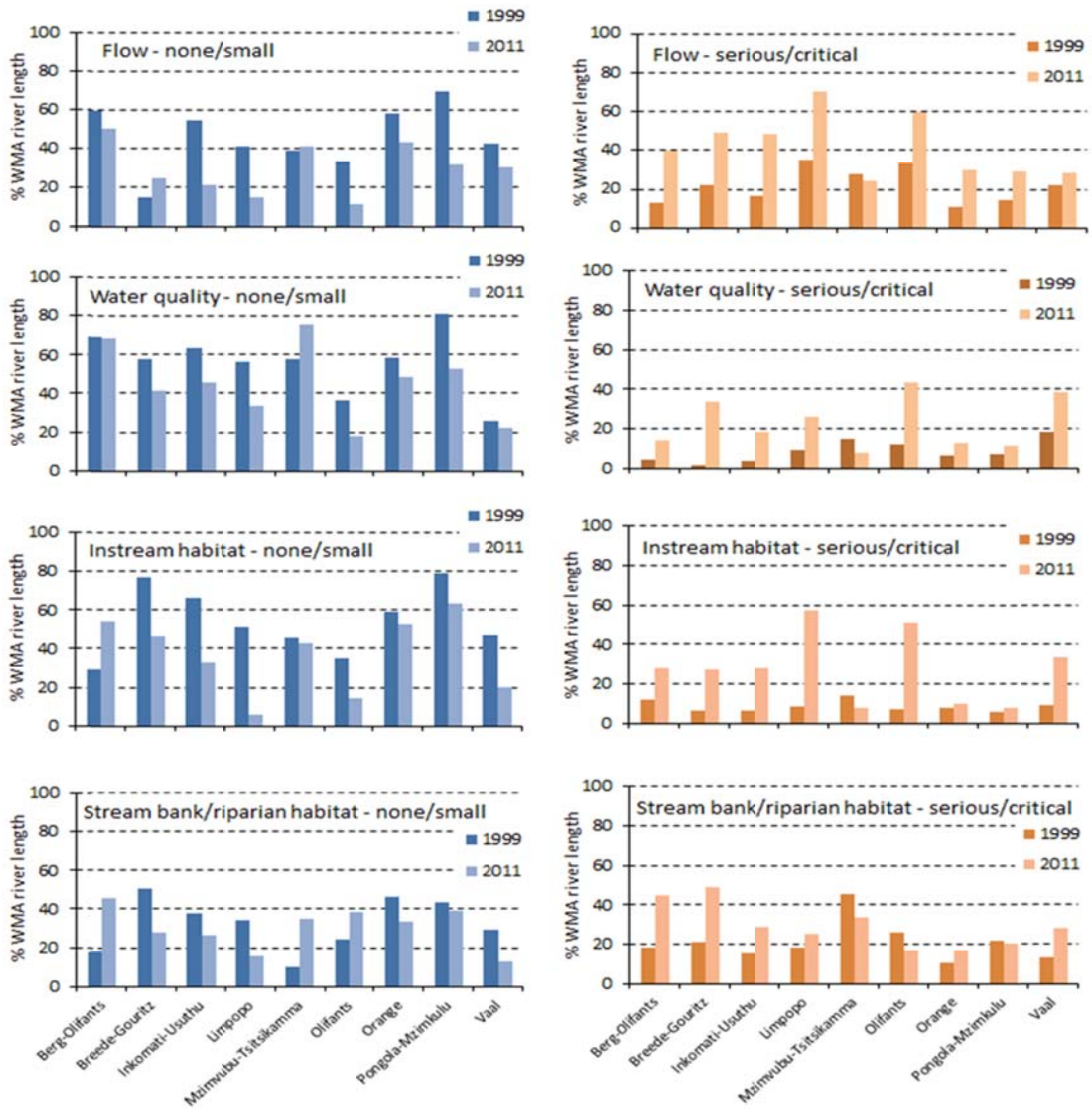

Figure 18: Change per Water Management Area in the proportion of river length with no/small modification (blue bars) and serious/critical modification (orange bars), for each of the four ecological condition indicators, 1999 – 2011

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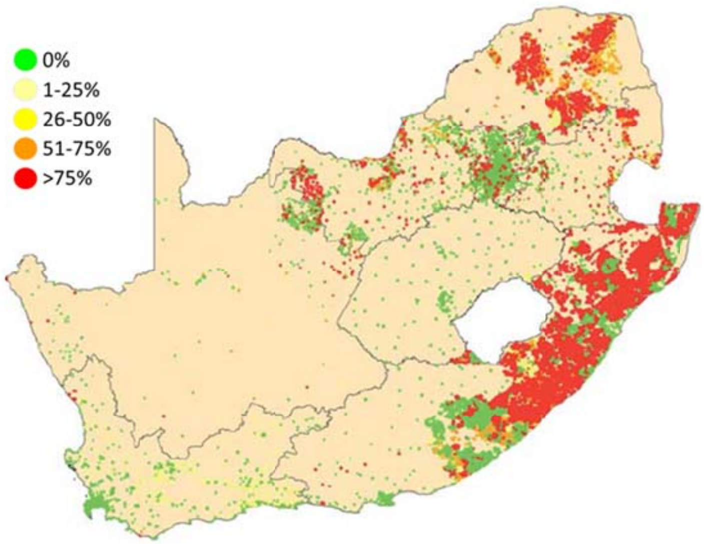

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Figure 19: Backlog in water service supply to households (DWA 2009)

6.2 Condition account for Water Management Areas, based on aggregated ecological condition category

Table 17 shows the ecosystem condition account for main rivers and tributaries of the Limpopo Water Management Area using the aggregated ecological condition category. Such an account can be generated for each Water Management Area.

The changes in the extent of river length in the natural category and the heavily and unacceptably modified categories are summarised for all Water Management Areas in Figure 20, and shown spatially in Figure 21. The trends for both main rivers and tributaries are similar and show that the extent of river length in the natural category decreased in every Water Management Area, while the extent of river length in the heavily and unacceptably modified categories increased (Figure 20). The Limpopo, Pongola-Mzimkulu and Inkomati-Usuthu Water Management Areas experienced over 40% decline in the proportion of river length in the natural category. The highest increases in the proportion of heavily and unacceptably modified river length occurred in the Limpopo, Breede-Gouritz, Olifants and Berg-Olifants Water Management Areas, all of which had more than 25% of river length either heavily or unacceptably modified in 2011.

Table 17: Ecosystem condition account for main rivers, tributaries and all rivers in the Limpopo Water Management Area using the aggregated ecological condition category

Kilometres	Degree of modification from natural					Total
	Natural	Moderately modified	Heavily modified	Unacceptably modified	No Data	
MAIN RIVERS						
Opening stock 1999	**3 966**	**1 882**	**73**		**195**	**6 117**
Opening stock as a % total river length	65	31	1		3	100
Increase/decreases	-3 363	937	2 002	423		
Increases/decreases as % opening stock	-85	50	2 743			
Opening stock 2011	**604**	**2 820**	**2 075**	**423**	**195**	**6 117**
Opening stock as a % total river length	10	46	34	7	3	100
TRIBUTARIES						
Opening stock 1999	**2 177**	**2 270**	**675**	**96**	**407**	**5 625**
Opening stock as a % total river length	39	40	12	2	7	100
Increase/decreases	-1 015	177	688	150		
Increases/decreases as % opening stock	-47	8	102	157		
Opening stock 2011	**1 163**	**2 447**	**1 363**	**246**	**407**	**5 625**
Opening stock as a % total river length	21	43	24	4	7	100
ALL RIVERS						
Opening stock 1999	6 144	4 152	748	96	603	11 742
Opening stock as a % total river length	52	35	6	1	5	100
Increase/decreases	-4 378	1 114	2 690	573		
Increases/decreases as % opening stock	-71	27	360	600		
Opening stock 2011	**1 766**	**5 267**	**3 438**	**669**	**603**	**11 742**
Opening stock as a % total river length	15	45	29	6	5	100

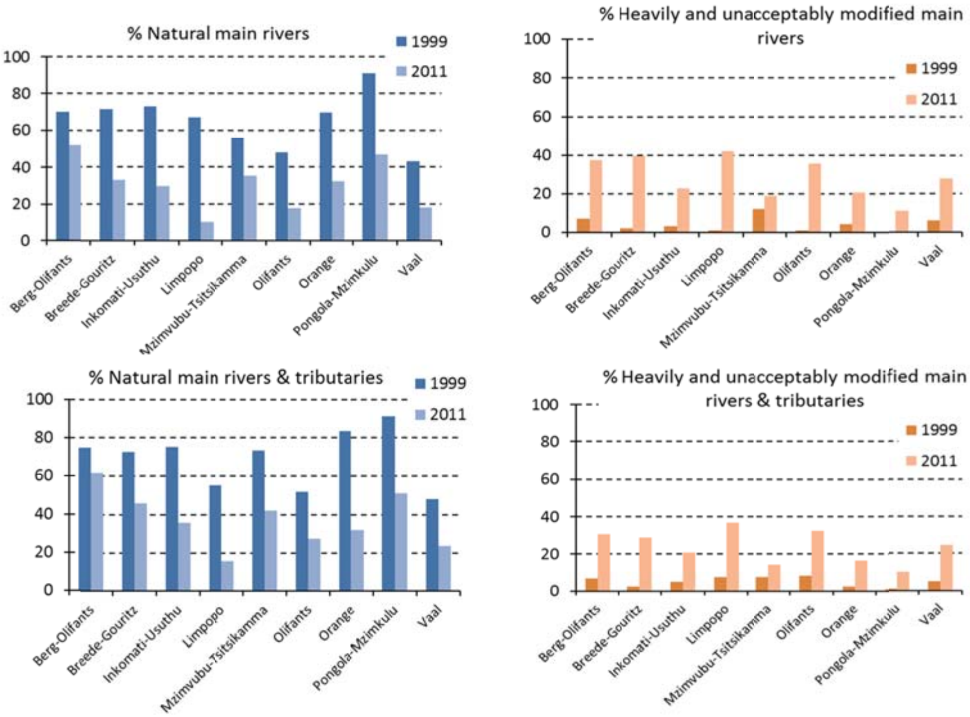

Figure 20: Change per Water Management Area in the proportion of river length in an aggregated ecological condition category of natural (blue bars), and heavily or unacceptably modified (orange bars), 1999 – 2011

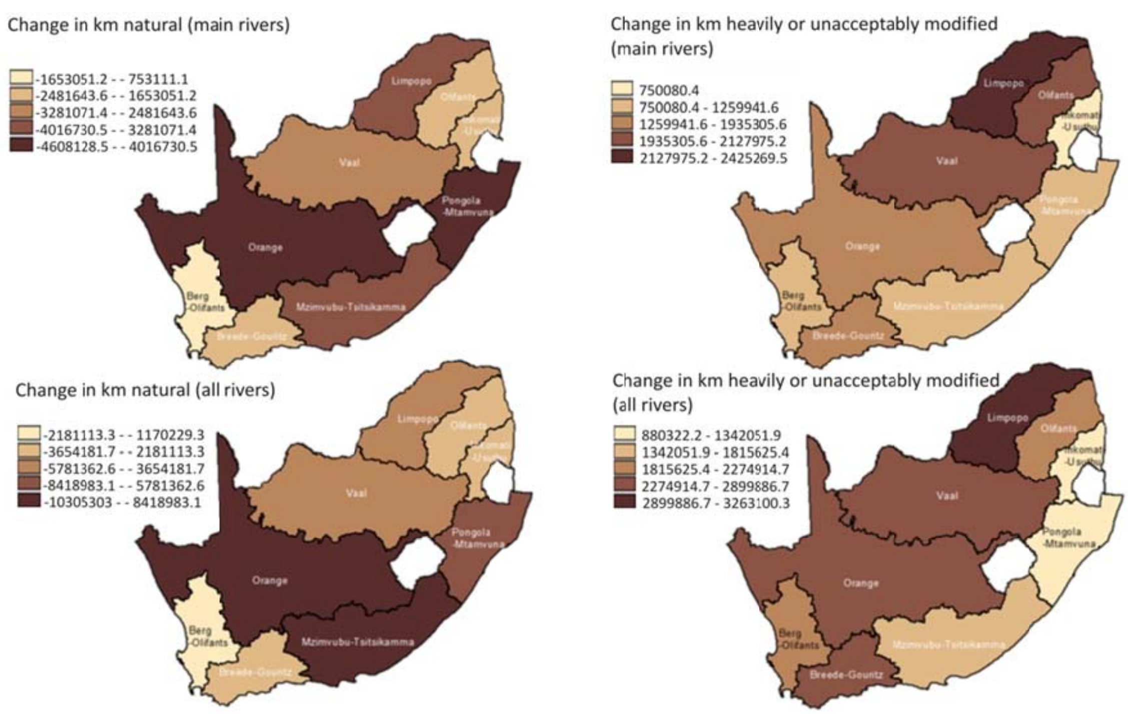

Figure 21: Maps per Water Management Area of the change in the extent of river length in an aggregated ecological condition category of natural (maps on left), and heavily or unacceptably modified (maps on right)

6.3 Condition account for Water Management Areas, based on the Ecological Condition Index

Figure 22 shows the Ecological Condition Index for each Water Management Area in 1999 and 2011, for main rivers and for all rivers. The Ecological Condition Index declined in all nine Water Management Areas between 1999 and 2011 The main rivers of the Limpopo Water Management Area experienced the most dramatic decline (22%, from 83.1 to 61.5%), most likely reflecting poor waste water management (both in terms of poor infrastructure and poor operating capacity) and increasing development pressures from mining and agriculture. The Breede-Gouritz, Olifants and Orange Water Management Areas also showed declines of over 10%, while the Mzimvubu-Tsitsikamma showed the smallest decline. These results are summarised spatially in Figure 23.

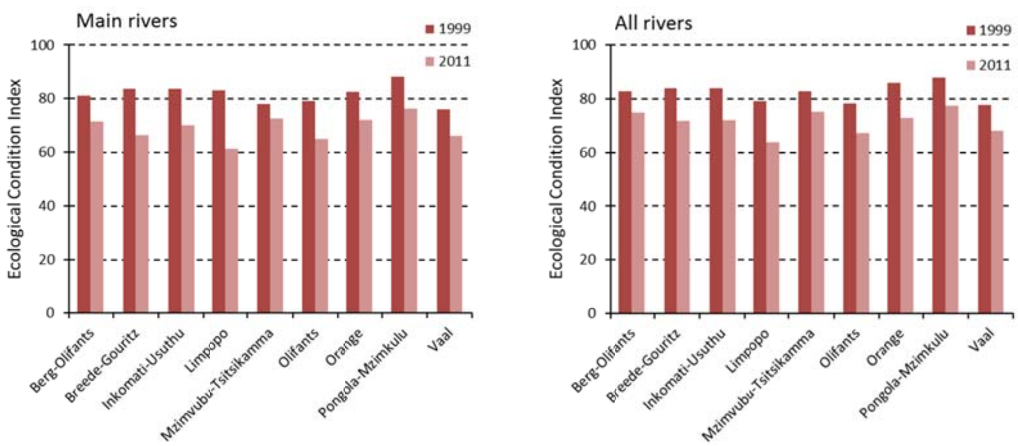

Figure 22: Change in the Ecological Condition Index of each Water Management Area for main rivers and all rivers, 1999 – 2011

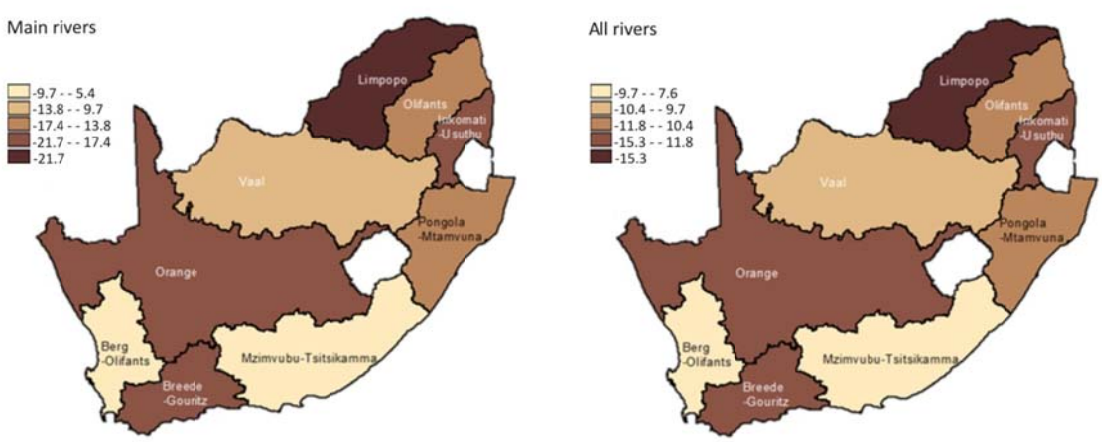

Figure 23: Maps of the change in the Ecological Condition Index of each Water Management Area for main rivers and all rivers

7. Ecosystem condition account for rivers by longitudinal zone

In this section we show the ecosystem condition accounts for the four longitudinal zones defined for rivers in South Africa (mountain streams, upper foothill streams, lower foothill streams and lowland rivers). We develop the ecosystem condition accounts using the aggregate ecological condition category, summarise the results graphically and show trends in the Ecological Condition Index for each longitudinal zone.

7.1 Condition account for longitudinal zones, based on aggregated ecological condition category

The ecosystem condition account for each longitudinal zone using the aggregated ecological condition category is provided in Table 18. This information was used to generate Figure 24, which shows how the percentage of river length in each ecological condition category changed between 1999 and 2011 within each longitudinal zone. Table 18 and Figure 24 show similar patterns of change for main rivers and all rivers, indicating that the trends in main rivers and tributaries are similar. In all longitudinal zones, the proportion of river length in the natural category showed a sharp decline, with increases occurring mainly in the moderately modified and heavily modified categories. The degree of modification becomes more pronounced along the continuum of longitudinal zones, from mountain streams, through upper and lower foothill streams, to lowland rivers. Lowland main rivers have the steepest increase in heavily modified rivers (over 1000% increase). This is indicative of the cumulative impacts on rivers as they run from source to sea, as well as the fact that lowland rivers with their associated fertile floodplains comprise only 9% of South Africa's rivers (Table 9) and are under extreme utilisation pressure for cultivation and housing.

7.2 Condition account for longitudinal zones, based on the Ecological Condition Index

Trends in the Ecological Condition Index for longitudinal zones are shown in Figure 25 and support the finding that the degree of modification increases sharply along the continuum of longitudinal zones, with mountain streams having the lowest levels of modification and lowland rivers the highest. The rate of decline in the Ecological Condition Index is similar for main rivers and tributaries across all longitudinal zones, although the index for mountain streams is slightly higher when tributaries are included, indicating that tributaries in the mountain stream longitudinal zone are overall in better condition than main rivers in that zone.

Table 18: Ecosystem condition account by longitudinal zone for (a) main rivers and (b) all rivers, using the aggregated ecological condition category, 1999 – 2011

(a)

Kilometres	Degree of modification from natural: Natural	Moderately modified	Heavily modified	Unacceptably modified	No Data	Total
MOUNTAIN STREAM						
Opening stock 1999	**1 141**	**383**	**47**	**22**	**16**	**1 609**
Opening stock as a % total river length	71	24	3	1	1	100
Increase/decreases	-459	175	274	10		
Increases/decreases as % opening stock	-40	46	588	44		
Opening stock 2011	**682**	**558**	**321**	**32**	**16**	**1 609**
Opening stock as a % total river length	42	35	20	2	1	100
UPPER FOOTHILL STREAM						
Opening stock 1999	**15 054**	**5 371**	**621**	**140**	**380**	**21 566**
Opening stock as a % total river length	70	25	3	1	2	100
Increase/decreases	-6 584	2 923	3 249	412		
Increases/decreases as % opening stock	-44	54	523	295		
Opening stock 2011	**8 470**	**8 294**	**3 870**	**551**	**380**	**21 566**
Opening stock as a % total river length	39	38	18	3	2	100
LOWER FOOTHILL STREAM						
Opening stock 1999	**23 683**	**11 820**	**1 714**	**480**	**1 195**	**38 893**
Opening stock as a % total river length	61	30	4	1	3	100
Increase/decreases	-12 755	5 056	6 649	1 050		
Increases/decreases as % opening stock	-54	43	388	218		
Opening stock 2011	**10 929**	**16 876**	**8 364**	**1 530**	**1 195**	**38 893**
Opening stock as a % total river length	28	43	22	4	3	100
LOWLAND RIVER						
Opening stock 1999	**6 663**	**4 741**	**410**	**384**	**2 046**	**14 243**
Opening stock as a % total river length	47	33	3	3	14	100
Increase/decreases	-12 755	5 056	6 649	1 050		
Increases/decreases as % opening stock	-191	107	1 623	273		
Opening stock 2011	**2 359**	**6 054**	**3 405**	**378**	**2 046**	**14 243**

(b)

Kilometres	Degree of modification from natural: Natural	Moderately modified	Heavily modified	Unacceptably modified	No Data	Total
MOUNTAIN STREAM						
Opening stock 1999	**4 366**	**659**	**174**	**34**	**1 520**	**6 754**
Opening stock as a % total river length	65	10	3	1	23	100
Increase/decreases	-1 589	978	571	41		
Increases/decreases as % opening stock	-36	148	328	118		
Opening stock 2011	**2 777**	**1 637**	**745**	**75**	**1 520**	**6 754**
Opening stock as a % total river length	41	24	11	1	23	100
UPPER FOOTHILL STREAM						
Opening stock 1999	**42 616**	**9 200**	**1 844**	**300**	**20 198**	**74 158**
Opening stock as a % total river length	57	12	2		27	100
Increase/decreases	-18 130	11 212	5 980	938		
Increases/decreases as % opening stock	-43	122	324	313		
Opening stock 2011	**24 485**	**20 412**	**7 824**	**1 238**	**20 198**	**74 158**
Opening stock as a % total river length	33	28	11	2	27	100
LOWER FOOTHILL STREAM						
Opening stock 1999	**32 926**	**15 132**	**2 420**	**632**	**15 335**	**66 445**
Opening stock as a % total river length	50	23	4	1	23	100
Increase/decreases	-17 006	7 213	8 380	1 413		
Increases/decreases as % opening stock	-52	48	346	224		
Opening stock 2011	**15 920**	**22 345**	**10 800**	**2 045**	**15 335**	**66 445**
Opening stock as a % total river length	24	34	16	3	23	100
LOWLAND RIVER						
Opening stock 1999	**6 927**	**4 793**	**437**	**388**	**2 706**	**15 251**
Opening stock as a % total river length	45	31	3	3	18	100
Increase/decreases	-4 437	1 404	3 003	30		
Increases/decreases as % opening stock	-64	29	687	8		
Opening stock 2011	**2 491**	**6 197**	**3 440**	**418**	**2 706**	**15 251**

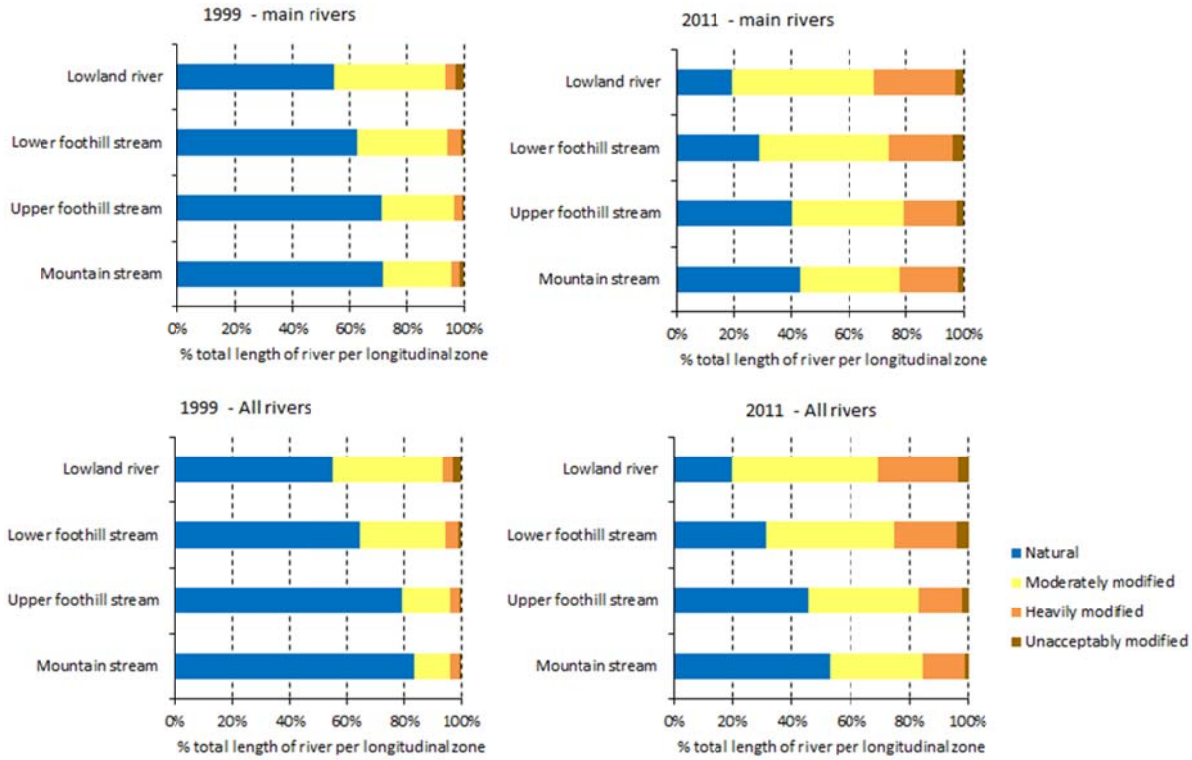

Figure 24: Percentage of river length in each aggregated ecological condition category per longitudinal zone

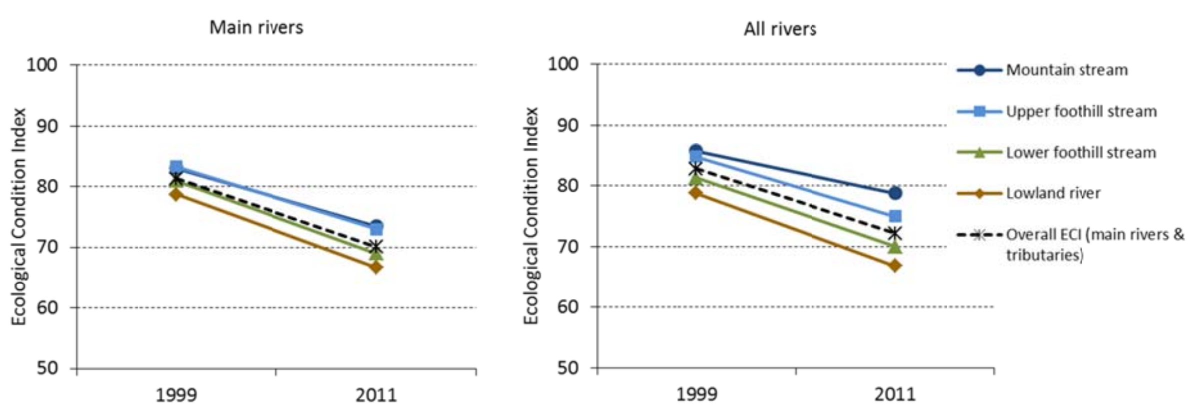

Figure 25: Change in the Ecological Condition Index per longitudinal zone for main rivers and all rivers

8. Ecosystem condition account for rivers by ecoregion

An ecosystem condition account using the aggregated ecological condition category could be developed for each of the 31 river ecoregions, in the same way as we did for the Limpopo Water Management Area (Table 17) and for longitudinal zones (Table 18). We have not done this for this discussion document because of the large number of river ecoregions, but the data that would be used to develop the condition account for main rivers in each ecoregion are shown in Table 19. The Ecological Condition Index for 1999 and 2011 for each ecoregion is also shown in Table 19. The red text in the table indicates river ecoregions with the largest changes.

In absolute terms (length in km), the Highveld, Nama Karoo, Bushveld Basin and Western Bankenveld ecoregions stand out as river ecoregions that experienced extreme increases in the degree of modification between 1999 and 2011 – the extent of river length in the natural category decreased substantially (by over 1 500 km) in these ecoregions, while the extent of river length in the heavily and critically modified categories increased (Table 19). All of these ecoregions except the Nama Karoo are in mining centres (i.e. parts of the country where mining plays a large role in the economy).

In proportional terms, the Bushveld Basin, Nama Karoo and Western Bankenveld showed similar trends, with increases of between 1 124 and 3 929% in the proportion of river length in the heavily and critically modified categories (Table 19). The Highveld ecoregion, which had a high absolute increase, also had a sharp increase in the proportion of river length in the heavily and critically modified categories (384%). The Southern Coastal Belt had a very high increase in the proportion of river length in the critically modified category (3 472%), but the absolute increase was relatively small (208 km). Table 19 shows that nine ecoregions had a decrease of more than 80% in river length in natural condition between 1999 and 2011 – the Bushveld Basin and Western Bankenveld are included in this list. Biodiversity in ecoregions such as these that have lost a high proportion of rivers in a natural ecological condition will be severely jeopardised, and these ecoregions are likely to contain many critically endangered river ecosystem types. This is corroborated by the National Biodiversity Assessment 2011 (Driver et al. 2012).

The Ecological Condition Index of three ecoregions – the South Western Coastal Belt, Natal Coastal Plain and Southern Coastal Belt – fell to 50 or lower in 2011 (Table 19). The first two of these ecoregions (South Western Coastal Belt and Natal Coastal Plain) are subject to intense urbanisation pressures around the Cape Town and eThekwini (Durban) metropolitan centres. The remaining one (Southern Coastal Belt) is in a known biodiversity hotspot (the Agulhas Plain), where the main pressures on rivers are from cultivation (dryland and irrigated) and invasive alien plants. Ecoregions with the biggest changes in Ecological Condition Index included the Natal Coastal Plain (41% change), Southern Coastal Belt (32%), Northern Plateau (30%), Western Bankenveld (23%), Bushveld Basin (22%) and South Western Coastal Belt (21%).

Table 19: Extent of main river in each aggregated ecological condition category (1999 and 2011), per ecoregion, showing changes in absolute and percentage terms

			1999 (km)				2011 (km)				Change between 1999 and 2011 (km)				Change between 1999 and 2011 (as % opening stock)				Ecological Condition Index		
Code	Ecoregion	Total river length (km)	Natural	Moderately modified	Heavily modified	Unacceptably modified	Natural	Moderately modified	Heavily modified	Unacceptbly modified	Natural	Moderately modified	Heavily modified	Unacceptably modified	Natural	Moderately modified	Heavily modified	Unacceptbly modified	ECI 1999	ECI 2011	Change in ECI
1	Limpopo Plain	2 156	1 507	649			188	1 285	683		-1 318	635	683		-87	98	--	--	84	65	-19
2	Soutpansberg	516	375	142			32	334	150		-342	192	150		-91	136	--	--	85	65	-19
3	Lowveld	4 958	3 211	1 655	92		1 702	2 033	983	240	-1 508	378	891	240	-47	23	965	--	83	70	-12
4	North Eastern Highlands	1 242	708	519		15	178	655	371	38	-530	136	371	23	-75	26	--	161	81	65	-15
5	Northern Plateau	366	283	83				103	263		-283	20	263		-100	24	--	--	85	56	-30
6	Waterberg	395	271	81	43		127	194	69	4	-143	113	26	4	-53	139	60	--	82	72	-9
7	Western Bankenveld	1 145	768	349	29		128	519	353	146	-640	170	324	146	-83	49	1 124	--	83	60	-23
8	Bushveld Basin	2 051	1 073	925	24	28	165	724	974	188	-908	-201	950	160	-85	-22	3 929	571	80	58	-22
9	Eastern Bankenveld	1 602	916	686			354	780	442	26	-562	95	442	26	-61	14	--	--	81	68	-13
10	Northern Escarpmt Mountains	993	766	227			149	641	204		-617	414	204	0	-81	182	--	--	85	69	-17
11	Highveld	9 939	4 353	4 857	452	277	1 502	5 653	2 184	600	-2 851	796	1 732	322	-65	16	384	116	76	66	-11
12	Lebombo Uplands	132	98	21	14		98		24	11		-21	10	11		-100	72	--	83	77	-6
13	Natal Coastal Plain	336	336				6	147	68	114	-330	147	68	114	-98	--	--	--	90	49	-41
14	North Eastern Uplands	3 767	3 488	279			1 463	1 947	319	39	-2 025	1 668	319	39	-58	597	--	--	89	76	-13
15	Eastern Escarpment Mountains	3 470	1 877	1 371	157	64	1 694	1 462	297	17	-184	91	140	-48	-10	7	89	-74	79	78	-1
16	South Eastern Uplands	6 051	4 410	1 531	110		2 415	2 806	744	86	-1 995	1 275	634	86	-45	83	578	--	84	75	-9
17	Eastern Coastal Belt	2 055	1 689	367			1 196	545	245	69	-493	178	245	69	-29	49	--	--	86	78	-9
18	Drought Corridor	4 952	1 954	1 950	1 048		992	2 633	1 196	131	-962	683	148	131	-49	35	14	--	74	68	-6
19	Southern Folded Mountains	3 534	1 932	1 376	149	77	1 020	1 264	1 045	205	-912	-112	896	128	-47	-8	600	166	79	67	-12
20	South Eastern Coastal Belt	1 585	775	596	80	134	494	509	553	28	-281	-87	474	-106	-36	-15	593	-79	75	68	-6
21	Great Karoo	4 053	3 271	611	82	88	2 701	1 104	248	1	-571	492	166	-88	-17	81	203	-99	85	82	-3
22	Southern Coastal Belt	1 053	698	297	52	6	46	247	547	214	-652	-51	495	208	-93	-17	958	3 472	82	50	-32
23	Western Folded Mountains	1 452	774	529	50	99	559	314	551	27	-215	-214	501	-71	-28	-41	992	-73	77	69	-7
24	South Western Coastal Belt	847	144	561	90	52		69	641	136	-144	-491	551	84	-100	-88	613	161	68	47	-21
25	Western Coastal Belt	1 096	938	158			629	156	311		-309	-2	311		-33	-1	--	--	87	76	-11
26	Nama Karoo	6 517	4 900	1 416	71	130	1 654	3 188	1 635	41	-3 246	1 771	1 564	-89	-66	125	2 216	-69	84	70	-14
27	Namaqua Highlands	992	992				786	182	24		-206	182	24		-21	--	--	--	90	85	-5
28	Orange River Gorge	611	611				322	289			-289	289			-47	--	--	--	90	81	-9
29	Southern Kalahari	2 376	1 568	752		56	592	1 073	596	116	-976	320	596	60	-62	43	--	106	82	68	-14
30	Ghaap Plateau	58	58				15	30	13		-43	30	13		-74	--	--	--	90	71	-19
31	Eastern Coastal Belt	2 372	1 797	326	249		1 232	895	228	17	-565	569	-22	17	-31	174	-9	--	83	78	-5

9. Recommendations and priorities for further work

In this section we provide recommendations for enhancing ecosystem condition accounts, drawing on our experience in developing the accounts presented here, with a view to contributing to the global research agenda. We set out priorities for national river ecosystem accounting work in South Africa, and suggest further testing that could be done based directly on these pilot accounts. Lastly we make recommendations for improving the collection and recording of the data on ecological condition of rivers that underpins ecosystem accounting. We hope that this will address some of the key data limitations that we encountered in developing the ecosystem condition accounts presented here, which are likely to be common among many countries.

9.1 Proposed indicators of ecological condition for ecosystem asset classes

As summarised in Section 2.3, SEEA Experimental Ecosystem Accounting and the accompanying draft technical guidelines set out steps for assessing ecosystem condition, including identifying relevant characteristics of ecosystem condition and then identifying indicators associated with those characteristics. Examples of characteristics of ecosystem condition that are often used are vegetation, biodiversity, soil, water and carbon (as reflected in Table 2 which is reproduced from SEEA Experimental Ecosystem Accounting). We discussed in Section 2.3 the fact that these characteristics are unlikely to be suitable for all classes of ecosystem assets, and we have shown in the accounts presented here how a different set of characteristics and indicators is needed for river ecosystem condition accounts, relating to system drivers and habitat attributes in the freshwater realm (see Figure 3). Based on our experience in developing these accounts, we propose an approach to developing indicators of ecological condition that could be applied across the terrestrial, freshwater and marine realms. While the approach is common across realms, the resulting set indicators is likely to be different for each realm, as shown in Table 20(a)-(e).

Key points about the proposed approach include:

- For each broad class of ecosystem assets (e.g. terrestrial, river, wetland, coastal, marine), four to six indicators of ecological condition should be selected, which can be aggregated to give an overall index of ecological condition.
- *Indicators of ecological condition should ideally reflect a combination of:*
    - *System drivers* in the class of ecosystems concerned (such as land cover/land use change in terrestrial systems, hydrological changes in freshwater systems, harvesting pressure in marine systems);
    - *Habitat attributes* (such as degree of fragmentation, instream siltation); and
    - *Biological responses* of the ecosystems and associated species (such as changes in population levels of particular species, loss of species richness).

- Ecologists in the different realms (terrestrial, freshwater, marine) have done substantial thinking on this, and it is important to draw on this existing work in the process of developing the condition accounts for a particular class of assets. It is essential for ecologists to be closely involved in the selection of indicators of ecological condition, and in determining the method used for aggregating them, to ensure that the result is ecologically meaningful and sensible.
- It is not possible to devise a single set of indicators of ecological condition that applies to *all* ecosystem asset classes; however, some indicators are likely to be common across more than one asset class. Some examples are given in Table 20(a)-(e). The set of indicators of ecological condition eventually selected for a particular asset class may depend partly on data availability, but ideally should not be driven by data availability as the starting point.
- All indicators should be assessed/quantified in relation to a reference condition for the ecosystem type concerned (e.g. on a scale of 0 to 100, where 100 represents the reference condition). Where possible, the reference condition should be the natural condition in the absence of significant modification by human activity. If this is not possible, an alternative stable reference condition can be selected (e.g. condition at a particular baseline date).

Table 20 (a) to (e) provides an example of what the ecosystem condition table might look like for different classes of ecosystem assets. These are simply suggestions to illustrate the approach – the indicators suggested here are not intended to be exhaustive or definitive.

Table 20: Examples of possible indicators for assessing ecological condition in terrestrial, river, wetland, coastal and marine realms

(a) Terrestrial ecosystems

	Indicators of ecological condition – *possible examples*				
Ecosystem type	**Habitat modification/intensity of land-use** indicator(s) (e.g. loss of natural vegetation, density of invasive species, quantity of irrigation, quantity of fertilizer, density of livestock)	**Fragmentation**-related indictor(s) (there are many possible ways to measure fragmentation)	**Soil**-related indicator(s) (e.g extent of erosion gullies and rills, sediment loss or accumulation, soil chemistry (pH, salinization), extent of tillage)	**Species-related indicator**(s) (e.g. loss of keystone species, loss of palatable species, reduced populations of harvested species, loss of species richness)	**Overall index of ecological condition**
e.g. Grassland					
Savannah					
Forest					
Desert					
…					

(b) River ecosystems

Ecosystem type	Indicators of ecological condition – *possible examples*					Overall index of ecological condition
	Hydrological modification Indicators (e.g. quantity, timing, velocity of flow)	**Water quality** indicator(s) (e.g. pH, turbidity, electrical conductivity levels of phosphate/nitrogen/oxygen)	**Instream habitat modification** indicator(s) (e.g. sediment overload, channelisa-tion, temperature changes)	**Riparian habitat modification** indicator(s) (e.g. bank stability, loss of natural vegetation in riparian buffer, density invasive alien plants in riparian buffer)	**Species-related** indicator(s) (e.g. loss of sensitive species, loss of species richness, reduced populations of harvested species)	
e.g. Mountain streams						
Foothill streams						
Lowland rivers						
…						

(c) Wetland ecosystems

Ecosystem type	Indicators of ecological condition – *possible examples*					Overall index of ecological condition
	Hydrological modification indicators (quantity, timing velocity)	**Water quality** indicator(s)	**Habitat modification land-use intensity** indicator(s)	**Species-related** indicator(s)	…	
e.g. Lakes						
Seeps						
Floodplain wetlands						
Valley-bottom wetlands						
…						

(d) Coastal ecosystems

Ecosystem type	Indicators of ecological condition – *possible examples*					Overall index of ecological condition
	Habitat modification / land-use intensity indicator(s)	**Harvesting pressure** indicator(s)	**Freshwater inputs**	**Species-related** indicator(s)	…	
e.g. Estuaries and lagoons						
Sandy beaches						
Rocky shores						
Coastal dunes						
…						

(e) Marine ecosystems (may need different indicators for inshore and offshore ecosystems, and for pelagic and benthic ecosystems)

Ecosystem type	Indicators of ecological condition – *possible examples*					Overall index of ecological condition
	Harvesting pressure indicator(s)	**Habitat modification** indicator(s)	**Species-related** indicator(s)	…	…	
e.g. Reefs						
Soft shelf						
Rocky shelf						
Deep-sea sediment						
Sea mounts						
Pelagic ecosystems						
…						

9.2 Priorities for national river ecosystem accounting work

This initial set of accounts for river ecosystems has been undertaken with a view to informing subsequent development of national accounts for other classes of ecosystem assets in South Africa, such as wetlands, marine and coastal ecosystems, and terrestrial ecosystems, as well as developing a full set of physical ecosystem accounts (see Figure 2 in Section 2.1) for rivers. We hope to build on this work with continued partnership between SANBI, Stats SA, DWS and CSIR. Below we suggest some priorities for taking forward the work on national river ecosystem accounts:

- ***Producing a full set of physical ecosystem accounts for rivers***: This would include extent and condition accounts, as well as ecosystem service generation and use accounts (see Figure 2 in Section 2.1).

- ***Linking the ecosystem accounts for rivers with national water accounts***: Water accounts differ from ecosystem accounts in that they focus on the water resource, while ecosystem accounts focus on the underlying river ecosystems. Initiatives are currently underway in South Africa to further develop the country's national water accounts, which will include physical (volumetric and quality) and monetary accounts for the water resource. The water accounts will present, *inter alia*, water availability and quality for specified reporting units, sectoral and population water use, and monetary value. If the water accounts are at a scale that is sufficiently spatially disaggregated, they may help us understand the drivers of change in river ecosystems and develop ecosystem service accounts linked to river ecosystems (by providing information both about the generation of water as an ecosystem service and the users of the service). Ideally the national river ecosystem accounts and the national water accounts should complement each other.

- ***Developing land accounts for key ecological infrastructure features related to rivers***, such as strategic water source areas, riparian zones, and wetlands.

- ***Developing an integrated national map of ecosystem types across the terrestrial and freshwater realms***: Rivers in South Africa are currently mapped as lines, and these accounts measured their extent in terms of length. In future we would ideally like to map river channels as areas and to embed them in the national vegetation map. If this is achieved, the extent of rivers could be measured in terms of either length or area, or both.

- ***Analysing ecosystem condition trends for rivers in relation to other socio-economic indicators***, which includes exploring:
  - Links to census information especially for poor communities that rely on use of water directly from rivers,
  - Links to GDP and other aspects of the economy, especially if these can be spatially disaggregated,
  - Investigating use of integrated indicators for monitoring the implementation of Sustainable Development Goals in South Africa.

Further priorities for national ecosystem accounting work, including the development of national land and ecosystem accounts, are discussed in the companion discussion document to this one.

9.3 Priorities for further testing based on the extent and condition accounts presented here

Further work and testing could be done based on the data and information already compiled for the accounts, as well as with through the collation of other existing data that is currently scattered across different regions and institutions. This includes:

- ***Reporting on the extent of rivers in terms of volume of water***: In addition to reporting on river extent in terms of length, it is feasible to report on the extent of rivers in terms of naturalised, non-cumulative volume of water (m^3) using currently available data on mean annual runoff in South Africa. This option may hold particular potential for linking more directly to water accounts, as well as for linking to ecosystem service generation and use accounts.

- ***Testing which of the condition accounts, graphics and maps are most useful for communicating trends to different target audiences***: At this developmental stage of river ecosystem accounting, we have deliberately shown many different options for presenting and summarising the ecosystem condition accounts – e.g. showing condition accounts that use the ecological condition indicators and ones that use aggregated ecological condition category, presenting an Ecological Condition Index, and summarising the condition accounts according to three different reporting units (Water Management Areas, longitudinal zones and river ecoregions). We felt that presenting all these alternatives was necessary so that stakeholders could further explore the utility of each option. Further testing is required to understand which of the options are most useful for taking forward, and which may differ depending on the targeted stakeholder group or decision-making process.

- ***Developing a more robust Ecological Condition Index***: The index, as it is presented in this report, serves primarily to demonstrate the usefulness of having a single index. Feedback from the stakeholder workshops – primarily from DWS water resource planners – indicates that it is a useful index that helps communicate the trends in ecological condition of rivers more easily than the trends in the aggregated ecological condition categories. While we acknowledge the limitations of the data we had available for developing the Ecological Condition Index reported here, we feel optimistic about constructing a more statistically robust index in future. This will require improving the underpinning data, primarily by ensuring that the Present Ecological State is expressed as a continuous range from 100 (reference condition) to 0.

- ***Testing how to integrate and display confidence limits and uncertainty***: This applies to the ecological condition indicators and the aggregated ecological condition categories that are provided in the Present Ecological State data, as well as the Ecological Condition Index.

- ***Testing the application of the ecosystem condition account in water resource planning and policy***: A key implementation mechanism for this could be catchment-level water resource planning (known as 'Classification of Water Resources' in terms of the National Water Act), which sets a Management Class for every significant water resource in a catchment (e.g. stretches of river). The Management Class stipulates a desired condition of the resource (based on the aggregated ecological condition categories) and the extent to which it can be utilised. The Class is determined through environmental flow assessment at a basin-wide scale and scenario development (Dollar et al. 2010). Using river condition accounts to compare the actual condition trends over time to the desired condition would be a way of tracking the effectiveness of the Classification process.

- ***Exploring options for using more quantitative, site-based ecological condition data for rivers***: We used the Present Ecological State data as our underpinning data on ecological condition primarily because the data were national in scope, at a relatively fine scale, and collated for two time periods. The use of quantitative, site-based assessment data from other sources should be explored (e.g. historical River Health Programme data and DWS monitoring sites for resource quality objectives and environmental water requirements; see Box 3).

Box 3: South Africa's site-based monitoring of river condition

Prior to the late 1980s, water quality was monitored using only chemical and physical water quality variables. This 'stressor monitoring' (which focuses on the stressors that are likely to cause pollution or ecological change) was complemented with 'response monitoring' (which uses of biological or ecological indicators to characterise the response of the environment to a stressor) by the introduction of the South African Scoring System or SASS in the late 1980s (Chutter 1998; Dickens and Graham 2002). SASS is a bioassessment protocol which uses the identification of families of aquatic invertebrates in the field to assess the condition or health of river systems. Since then, the suite of tools for response monitoring has grown to also include biological indices for fish, and riparian and instream habitats.

Initially, between the late 1990s and mid-2000s, DWS and provincial conservation authorities collected site level data under the coordination of the River Health Programme. This programme evolved into the River Ecostatus Monitoring Programme, which was brought in line with the National Water Act, to meet DWS needs for monitoring Resource Quality Objectives and Environmental Water Requirements. Bringing the monitoring in line with national legislation represents an important opportunity for maintaining ongoing monitoring of river condition across the country. However, to use these data effectively in time series assessment for ecosystem accounting, it will be essential to explore how the data are collected and collated, and at what scale. Although some of the historical river health data have been collated into a single database, much of it is still scattered across the country, and the information in the database is often incomplete or referenced with incorrect geographic coordinates. Furthermore, the sampling sites tend to focus on monitoring of cumulative effects in main rivers – monitoring in the tributaries is heavily under-represented, and an effort should be made to correct this bias.

9.4 Improved systems for collecting and recording time series data on ecological condition of rivers

The ecological condition data that we used to generate the ecosystem condition accounts are traditionally used for water resource planning and decision-making, and not for monitoring trends in river condition. Using them in an accounting context was challenging and highlighted two major data constraints for ecosystem accounts:

- ***The scope of the ecological condition data needs to be national, but the spatial scale should be sufficiently disaggregated*** to help understand the likely drivers of change in order to inform management interventions. Sites for monitoring the ecological condition of rivers tend to be on large, main rivers, and are often intended to monitor the cumulative impacts in very large catchments. Ideally, ecological condition should be provided not just for the main rivers of a country but also for the smaller tributaries. Inclusion of tributaries will not only give a finer-scale understanding of the drivers of change, but also alerts us to trends in the condition of tributaries that may impact negatively on the condition of downstream main rivers. We suggest that ecological condition data should be collected for river reaches in sub-catchments of approximately 150-200 km^2. This recommended spatial scale is derived from freshwater conservation planning experience over the last decade in Australia (Linke et al. 2007) and South

Africa (Nel et al. 2009). Setting up an entirely site-based national monitoring programme at a relatively fine spatial scale may not be possible or sustainable in most countries. A more feasible option is to investigate modern technologies for achieving this, which combine remote sensing with traditional site-based assessment (Janse et al. 2015; Stein et al. 2014). In addition, citizen science is emerging as a major source of new data (Dickinson et al. 2012), and it offers enormous potential for expanding the coverage of ecological condition data for rivers and for validating estimates of condition based on remote sensing products. In South Africa, citizen scientists are already being used to collect river condition data (www.groundtruth.co.za/projects/minisass.html).

- ***Data need to be comparable over time***, which requires agreeing on a defined set of ecological condition indicators and achieving methodological consistency in measuring these indicators and quantifying the confidence of this measurement. This will help to ensure that changes detected over time do not merely reflect data artefacts from different methodologies. Assessment of the degree of modification of each indicator should ideally be based on a quantitative measurement, and not rely solely on expert judgement. We recommend that river extent and condition accounts be produced every five years in South Africa – more often than that is not feasible given resource constraints. A major challenge in this regard is that there is currently no plan for another national assessment of the Present Ecological State of rivers. If this is not done through a national assessment, then we need to ensure that there is regular monitoring in a comprehensive set of sites that can be built up to a national picture, together with further testing of modern technologies for collecting data, as discussed above.

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