Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and social predictions Climate Change Scenarios (Volume 3 of 4)

Report No: 07/2009

J.M. King, et al.

December 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

ENVIRONMENTAL FLOW ASSESSMENT SERIES

DOCUMENT DETAILS

PROJECT	Environment protection and sustainable management of the Okavango River Basin: Preliminary Environmental Flows Assessment
TITLE:	Scenario Report: Ecological and social predictions - Climate Change Scenarios
VOLUME:	Volume 3 of 4
DATE:	December 2009
LEAD AUTHORS:	J.M. King, C. A. Brown.
REPORT NO.:	07/2009 (Volume 3 of 4)
PROJECT NO:	UNTS/RAF/010/GEF
FORMAT:	MSWord and PDF.
CONTRIBUTING AUTHORS:	A.R. Joubert, J. Barnes, H. Beuster, P. Wolski.

THE TEAM

Project Managers
Chaminda Rajapakse
Nkobi Moleele
Geofrey Khwarae

Angola
Manual Quintino (Team Leader and OBSC member)
Carlos Andrade
Helder André de Andrade e Sousa
Amândio Gomes
Filomena Livramento
Paulo Emilio Mendes
Gabriel Luis Miguel
Miguel Morais
Mario João Pereira
Rute Saraiva
Carmen Santos

Namibia
Shirley Bethune (Team Leader)
Colin Christian
Barbara Curtis
Celeste Espach
Aune-Lea Hatutale
Mathews Katjimune assisted by Penehafo Shidute
Andre Mostert
Shishani Nakanwe
Cynthia Ortmann
Mark Paxton
Kevin Roberts
Ben van de Waal
Dorothy Wamunyima assisted by Ndinomwaameni Nashipili

Botswana
Casper Bonyongo (Team Leader)
Pete Hancock
Lapologang Magole
Wellington Masamba
Hilary Masundire
Dominic Mazvimavi
Joseph Mbaiwa
Gagoitseope Mmopelwa
Belda Mosepele
Keta Mosepele
Piotr Wolski

EFA Process Management
Jackie King
Cate Brown
Hans Beuster
Jon Barnes
Alison Joubert
Mark Rountree

Okavango Basin Steering Committee
Tracy Molefi-Mbui
Laura Namene

List of reports in report series

Report 01/2009:	Project Initiation Report
Report 02/2009:	Process Report
Report 03/2009:	Guidelines for data collection, analysis and scenario creation
Report 04/2009:	Delineation Report
Report 05/2009:	Hydrology Report: Data and models
Report 06/2009:	Scenario Report: Hydrology (2 volumes)
Report 07/2009:	Scenario Report: Ecological and social predictions (4 volumes)
Report 08/2009:	Final Report

Other deliverables:
DSS Software
Process Management Team PowerPoint Presentations

Citation

This document should be cited as:

King, J.M. and Brown, C.A. 2009. Scenario Report (ecological and social–climate change) Volume 3 of 4. Report 07-2009 EPSMO/BIOKAVANGO Okavango Basin Environmental Flows Assessment Project, OKACOM, Maun, Botswana. 114 pp.

Acknowledgements

Many thanks for logistical support to:

- Corinne Spadaro of FAO)
- Ros Townsend, Karl Reinecke and Rembu Magoba of Southern Waters

Executive Summary

The Okavango River Basin Commission, OKACOM, initiated a project titled the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO). This was approved by the United Nations Development Program (UNDP), to be executed by the United Nations Food and Agriculture Organization (FAO). The standard UNDP process is a Transboundary Diagnostic Analysis followed by a Strategic Action Programme of joint management to address threats to the basin's linked land and water systems. Because of the pristine nature of the Okavango River, this approach was modified to include an Environmental Flow Assessment (EFA). To complete the EFA, EPSMO collaborated with the BIOKAVANGO Project at the Harry Oppenheimer Okavango Research Centre of the University of Botswana, in 2008 to conduct a basin-wide EFA for the Okavango River system.

This is report number 7 (volume 3) in the report series for the EFA. It summarises the predicted biophysical and socioeconomic impacts linked to climate change, with the details of the DSS outputs provided in volume 4 of this report.

The Low and Medium water-use scenarios were re-assessed under two different climate-change conditions: the wettest and the driest. In the previous assessments (see Volume 1), the low scenario presented few risks for the basin but there was some risk that the medium scenario would result in severe degradation at some points in the basin. Importantly, the impacts associated with both the low and medium scenarios were predominately in-country. With climate change added as an overlay, there are two possible future paths:

- The drier climate change predictions, which would reduce the localized impacts and would increase the impacts in the lower catchment, i.e., the Delta and Boteti.
- The wetter climate change predictions, which would ameliorate the flow-related impacts of development throughout the Delta.

Table of Contents

List of Figures

All photographs that are not acknowledged in the text are by J.M. King and C.A. Brown.
Photographs on the front cover are by The Team.

List of Tables

Acronyms and abbreviations

DRIFT	Downstream Response to Imposed Flow Transformations
DSS	Decision Support System
EFA	Environmental Flow Assessment
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
Ha	hectare
HOORC	Harry Oppenheimer Okavango Research Centre
IFA	Integrated Flow Assessment
IUA	Integrated Units of Analysis
MAR	Mean Annual Runoff
Mcm	Millions of cubic metres
OBSC	Okavango Basic Steering Committee
OKACOM	Okavango River Basin Water Commission
PD	Present day
SADC	Southern African Development Community
SAP	Strategic Action Programme
TDA	Transboundary Diagnostic Analysis

1. INTRODUCTION

1.1. Project background

The origin of the project is described in Report 01/2009: Project Initiation Report. Essentially, an OKACOM initiative titled the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) project was approved by the United Nations Development Program (UNDP), to be executed by the United Nations Food and Agriculture Organization (FAO). In 2008 it collaborated with the Biokavango Project at the Harry Oppenheimer Okavango Research Centre (HOORC) of the University of Botswana, to conduct a basin-wide Environmental Flows Assessment (EFA) for the Okavango River system. This would be a major part of a standard UNDP process: a Transboundary Diagnostic Analysis (TDA) followed by a Strategic Action Programme (SAP) of joint management to address threats to the basin's linked land and water systems. In the case of the Okavango Basin, the standard approach, designed for rehabilitating degraded rivers, would be modified because of the near-pristine nature of the river ecosystem.

The EFA began with a Planning Meeting in July 2008 and was finalised in June 2009. A climate change assessment was added in October 2009. All of the EF assessments used mainly existing knowledge and understanding of the river ecosystem and its users. It was generally acknowledged that this was a first, low-confidence, trial run of an EFA for this system, which should be followed by a more comprehensive and long-term exercise where important missing data and knowledge could be addressed to provide higher-confidence predictions.

1.2. Objectives of the EF assessment

There were two main objectives.

- Complete a basin-wide EFA of the Okavango River system as a major part of the wider Technical Diagnostic Analysis. This would be done through several subsidiary objectives:
    - Collate all existing hydrological data on the river system and set up a basin hydrological model that could simulate flows under various possible future development scenarios
    - Reach agreement with the three riparian governments on the scenarios to be explored
    - Bring together specialists in a range of relevant disciplines from across the basin to share knowledge and data, and reach consensus on the:
        - relationships between flow and a series of biophysical indicators of the river system
        - relationships of the condition of the ecosystem and social indicators
    - Develop a DSS that would capture these relationships and produce predictions of ecological and social change for each scenario that would complement the macroeconomic predictions emanating from a separate exercise
    - Incorporate the EFA findings in the TDA document.
- Promote basin-wide communication and collaboration, and build capacity in collaborative basin-wide Integrated Water Resource Management in all disciplines in all three countries. This was done by appointing a full biophysical and socio-economic team from each of the three countries, with planning, coordination and training done by a Process Management Team.

To this was added a further aim – to assess how climate change might affect the prediction of development-driven change.

1.3. Recap of process and EFA report series

The EFA ran over 12 months, from July 2008 to June 2009. The principal features and their timing were:

- a Planning Meeting (July 2008)
- a Basin Delineation Workshop (September 2008)
- a basin field trip (October 2008)
- a series of hydrological team meetings (September 2008 to May 2009)
- specialist discipline studies and report writing (November 2008 to May 2009)
- development of Decision Support System (DSS) software to capture the specialists' knowledge (November 2008 to May 2009)
- a Knowledge Capture Workshop (April 2009)
- a Scenario Workshop (May 2009)
- a climate change assessment (October 2009).

The full report series produced by the EFA is listed at the beginning of this report, with a summary of the contents of each detailed below. Details aof the climate change assessment are in Report 06 (Volume 2) and Report 07 (Volumes 3 and 4). The summary of the findings on climate change are in the Final Project Report 08.

1.3.1 Report 01/2009: Project Initiation Report

Details the origin of the project, including the July 2008 Planning Meeting and the agreed work plan.

1.3.2 Report 02/2009: Process Report

Describes the technical process followed in the EFA, including the division of the basin into homogeneous units and choosing of representative sites, the data collection and knowledge capture exercises, the hydrological modeling, the choice of indicators with which to describe expected development-driven change, and the nature of the DSS.

1.3.3 Report 03/2009: Guidelines for data collection, analysis and scenario creation

A set of guidelines for basin delineation; site selection, estimating ecological condition of the sites, scenario selection, indicator selection, data collection, Response Curves construction (these describe the flow-ecosystem and ecosystem-social impact relationships), and report writing.

1.3.4 Report 04/2009: Delineation Report

The results of the September 2008 workshop, containing the following: basin location and characteristics; river zonation; delta zonation; socio-economic zonation; Integrated Units of Analysis; and selected study sites/zones. Eight representative sites were chosen along the system: three in Angola, two in Namibia and three in Botswana. Each would be linked to specific socio-economic areas so that the predictions of river change could be interpreted as predictions of social impact.

1.3.5 Report 05/2009: Hydrology Report: Data and models

The initial work of the three-country hydrological team and the international basin hydrologist, including choosing and setting up the hydrological and hydraulic models, field data collection, hydrological and geohydrological data and information, water-resource development information, and data and information sharing arrangements.

1.3.6 Report 06/2009: Scenario Report: Hydrology

Volume 1 of this report details the initial part of the scenario descriptions, including the scenarios chosen, and the hydrological outcomes for all eight sites along the system. Volume 2 provides the same information for the climate change scenarios.

1.3.7 Report 07/2009: Scenario Report: Ecological and social predictions

There are four volumes in this report, each addressing predicted biophysical and socio-economic change emanating from water-resource development of the basin:

- Volume 1: Summary of the predicted impacts of specified low, medium and high levels of development
- Volume 2: Details of the DSS outputs linked to Volume 1
- Volume 3: Summary of the predicted impacts of modelled Wettest and Driest Climate Change conditions on the low and medium scenarios
- Volume 4: Details of the DSS outputs linked to Volume 3.

1.3.8 Report 08/2009: Final Report

Summary report of the project.

1.4. The scenarios

Through a process of government consultation, three scenarios of increasing water-use were chosen for the EFA. The details are provided in Report 06/2009: Scenario Report: Hydrology, and in Chapter 4 of this report.

The impact of Climate Change on two of these scenarios, low and medium water use, was also assessed in a separate exercise. This assessment is the subject of this volume.

1.5. Limitations

The project faced financial, time and knowledge constraints that influenced its outputs. The major of these limitations were as follows:

- A limited budget, which resulted in various important parts of the process having to be excluded, such as training exercises at key points in the process, in-depth review of the specialist reports and production of a glossy information brochure in accessible language for water managers and decision makers.
- Limited warning of the project beginning, which meant that all team members were over-committed throughout the project.
- Limited time to complete the work, which meant that the project ran on available data and general expert knowledge of the system; virtually no new data were collected, even where uncertainty was extremely high.

Despite this, the project stimulated a very strong and constructive team spirit and an inter-basin collaboration that appears set to continue long after it ends.

1.6. Presentation of the results

1.6.1 Rivers and delta

For the low and medium scenarios with two possible levels of climate change, the predicted changes in the river and delta are evaluated in three ways:

1. time-series of abundance, area or concentration of key indicators (see list in Chapter) under the flow regime resulting from the low and medium scenarios each with two levels of climate change (Volume 4);
2. estimated mean percentage changes from present day in the abundance, area or concentration of key indicators (Volume 4);
3. estimated change in discipline-specific integrity, relative to present day and to the low and medium scenarios with no climate change (This report)
4. estimated change in overall ecological integrity, relative to present day and to the low and medium scenarios with no climate change (This report).

1.6.2 Societal wellbeing

The impact on local communities is assessed in terms of changes in wellbeing as a result of the changes in tangible and intangible benefits derived from the use of water and aquatic ecosystem resources. These changes are expressed as:

- Change in household income from agriculture
- Change in household income from natural resources

These values include subsistence and cash income. They are summed to estimate overall change income.

All values are expressed as the aggregate for all households in the affected area. The overall value is expressed as a percentage change in overall household income, taking all other sources of household income into account. Note that the percentage change might not apply to individual households, since this value might be shared by more households under an expanded population.

Intangible impacts are expressed as the percentage change in overall recreational and spiritual wellbeing, taking other intangible sources of wellbeing into account.

1.7. Layout of the report

Chapter 1: Introduction
Chapter 2: Location and description of the EF sites
Chapter 3: A listing and explanation of the indicators
Chapter 4: A description of the chosen scenarios in terms of the location and specifications of each chosen water-resource development; a summary of the changes in the flow regime under each scenario at each site; and introduction of the climate change scenarios
Chapter 5: The predictions of biophysical change per climate change scenario
Chapter 6: The predictions of overall change in ecosystem integrity, per climate change scenario
Chapter 7: The predictions of socio-economic change per climate change scenario
Chapter 8: Conclusions

2. The EF sites/reaches and IUAs

2.1. The location of the ecological sites and links with IUAs

The number, and to some extent the position, of the eight biophysical sites was dictated by financial, time and safety constraints, and they did not represent the entire basin. The locations of the eight sites, chosen in an exercise described in Report 04/2009: Delineation Report, are given in Table 2.1 and Figure 2-1. These sites are described in Volume 1 of this report.

Each biophysical site corresponded to a wider, socio-economic Integrated Unit of Analysis (IUA; Figure 2-1), where it was used to represent the predicted river changes that would affect people. These IUAs are described in Volume 1 of this report.

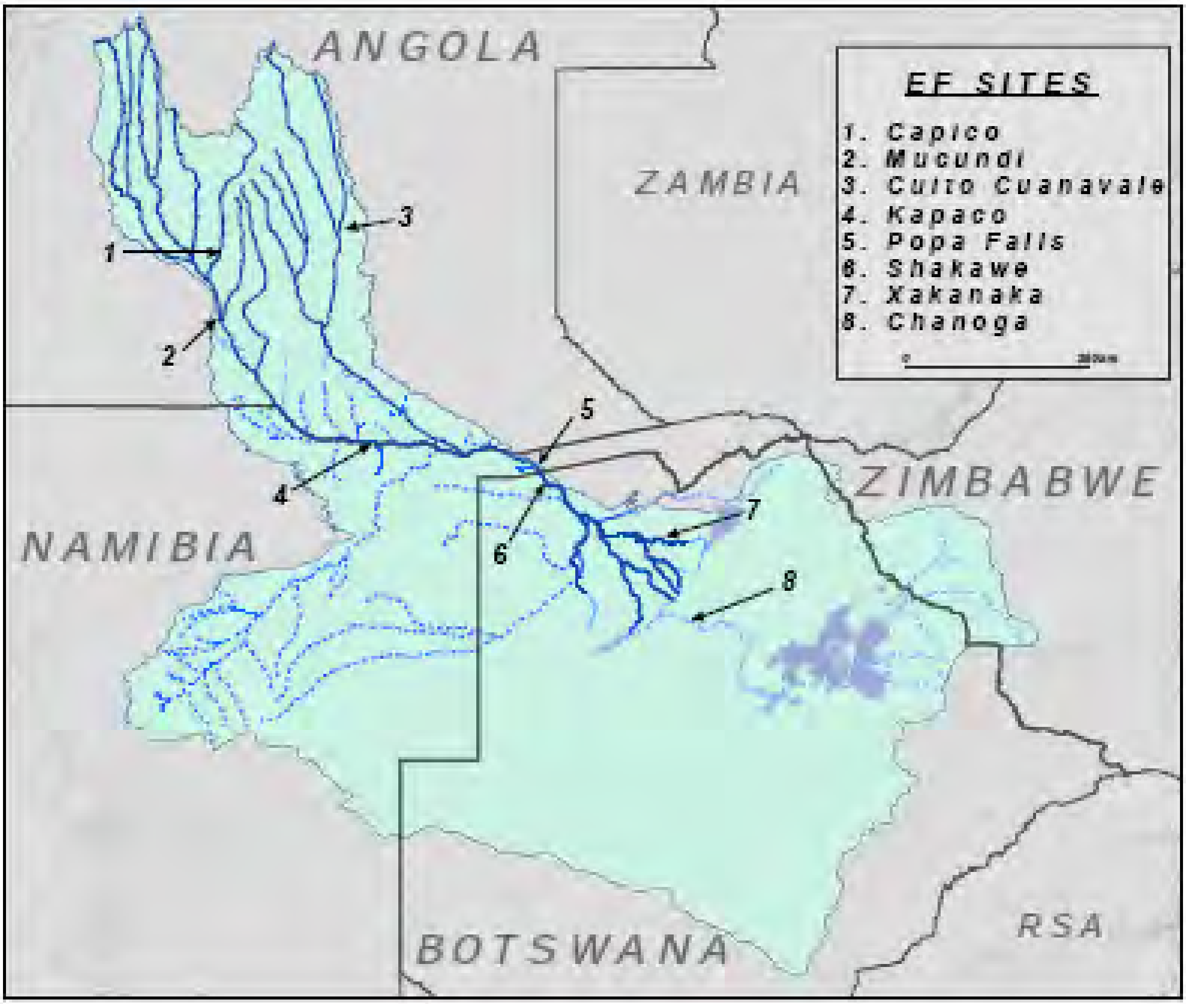
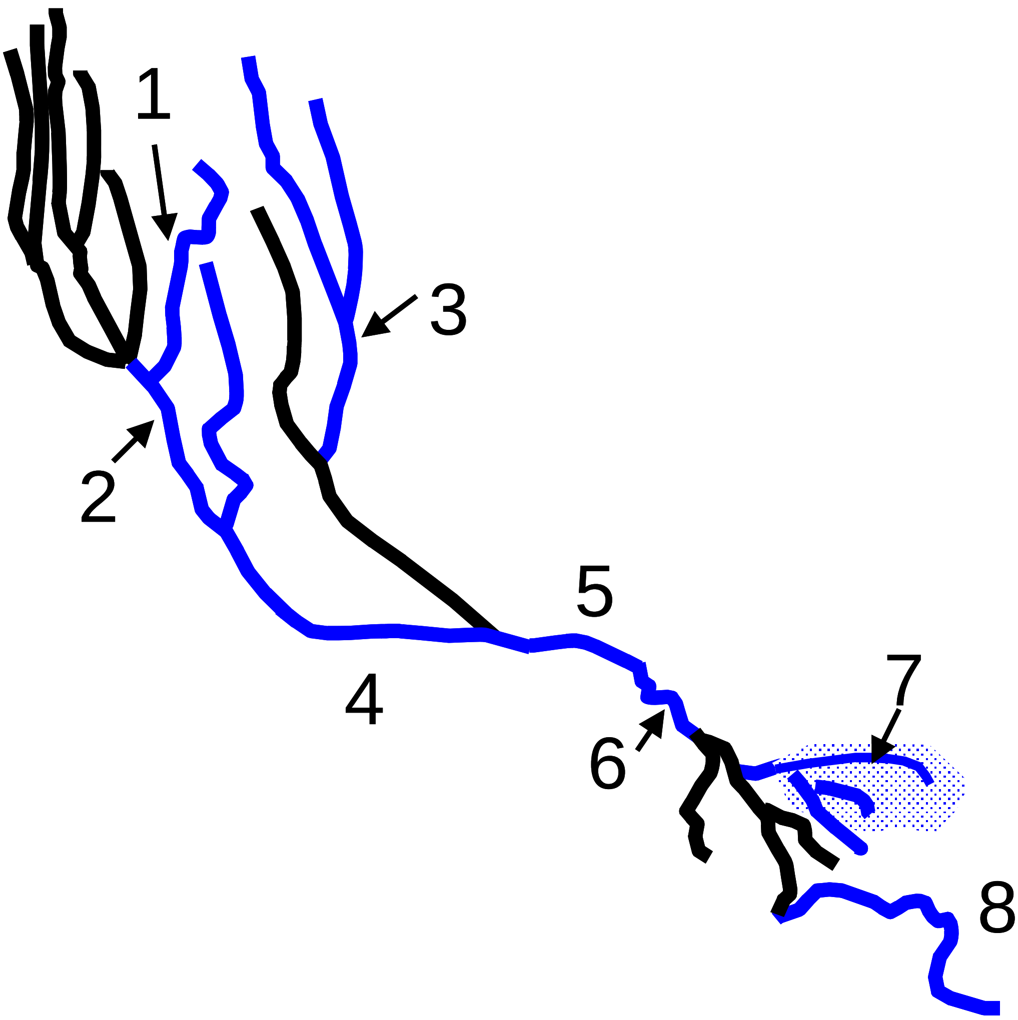


Figure 2-1 Map showing site locations

Table 2.1 The Environmental Flow (EF) sites and their corresponding socio-economic Integrated Unit of Analysis (IUA)

EF Site	EF Site name	Coordinates	Socio-economic IUA
1	Cuebe @ Capico	15˚33'05"S; 17˚34'00"E	3
2	Cubango @ Mucundi	16˚13'05"S; 17˚41'00"E	2
3	Cuito @ Cuito Cuanavale	15˚10'11"S; 19˚10'06"E	6
4	Okavango @ Kapako	17˚49'07"S; 19˚11'44"E	8
5	Okavango @ Popa Falls	18˚07'02"S; 21˚35'03"E	9
6	Okavango @ Panhandle	18˚21'16"S; 21˚50'13"E	10
7	Okavango Delta @ Xaxanaka	19˚11'09"S; 23˚24'48"E	11
8	Boteti River	20˚12'51"S; 24˚07'37"E[1]	12

The location of the study sites resulted in portions of the catchment for which no predictions were possible in this study. These are indicated in Figure 2-2.



[1] Whole river is the site. Bridge crossing provided as reference.

Figure 2-2 **Sketch map of the main channels in the Okavango Basin and the location of the study sites. Channels not represented in the study are shown in black, and those represented are in blue.**

3. Indicators

3.1.1 The nature and purpose of indicators

In this EFA two kinds of indicators are used: biophysical and socioeconomic. They represent attributes of the ecological and social system that are thought to be either directly or indirectly linked to the river and its flow regime. Their predicted changes as flows change provide a composite picture of the ecological and social impacts of the chosen water-resource developments.

3.1.2 Biophysical indicators

Biophysical indicators are attributes of the river ecosystem that can be described in terms of abundance (e.g. number of elephants), area (e.g. area of exposed sand banks), concentration (e.g. nitrates, conductivity) or cover (e.g. vegetation communities).

Those chosen by the biophysical team for use in this project are listed in Table 3.1.

Table 3.1 Biophysical indicators used in the EPSMO/BIOKAVANGO EF process

Discipline	Sites	Indicators used
Geomorphology	1-6	Extent - exposed Rocky Habitat
		Extent - Coarse Sediments
		Cross Sectional Area of Channel
		Extent of Backwaters
		Extent of Vegetated Islands
		Sand Bars at low flow
		Percentage Clays on Floodplain
		Extent of inundated floodplain
		Inundated Pools and Pans
		Extent of Cut Banks
	7	Carbon sequestration
Water Quality	1-8	pH
		Conductivity
		Temperature
		Turbidity
		Dissolved oxygen
		Total nitrogen
		Total phosphorus
		Chlorophyll a
Vegetation	1-6	Channel macrophytes
		Lower Wet Bank (hippo grass, papyrus)
		Upper Wet Bank 1 (reeds)
		Upper Wet Bank 2 (trees, shrubs)
		River Dry Bank
		Floodplain Dry Bank
		Floodplain residual pools
		Lower floodplain
		Middle floodplain (grasses)
		Upper floodplain (trees,)
	7	Open waters
		Permanent swamps
		Lower floodplain
		Upper floodplain
		Occasionally flooded grassland
		Sporobolus islands
		Riparian woodland, trees
		Savanna and scrub

Discipline	Sites	Indicators used
	8	Open water
		Riparian woodland, trees
Macroinvertebrates	1-8	Channel-submerged vegetation
		Channel-marginal vegetation
		Channel-fine sediments
		Channel-cobbles, boulders
		Channel rapid, fast flowing
		Channel-pools
		Floodplain-marginal vegetation
		Floodplain-pools, backwaters
	Plus for 7	Mopane woodland-pools
Fish	1-8	Fish resident in river
		Migrate floodplain small fish
		Migrate floodplain large fish
		Fish-sandbank dweller
		Fish-rock dweller
		Fish-marginal vegetation
		Fish in backwaters
Wildlife	1-8	Semi Aquatics (hippos, crocodiles)
		Frogs, river snakes
		Lower floodplain grazers
		Middle floodplain grazers
		Outer floodplain grazers
Birds	1-8	Piscivores - open water
		Piscivores - shallow water
		Piscivores and invertebrate feeders
		Specialists - floodplains
		Specialists - water lilies
		Specialists - fruit trees
		Breeders - reedbeds, floodplains
		Breeders - overhanging trees
		Breeders - banks
		Breeders - rocks, sandbars

In the EFA process (Report 02/2009: Process Report), specialists draw Response Curves that describe the relationship between each indicator and each relevant part of the flow regime (Section 4.3).

3.1.3 Social indicators

The economic activities in the basin were identified and described. They were then examined and assessed to select those that might exhibit measurable value change if the river/wetland system would be subjected to flow change. These were then used as the socio-economic indicators in the EFA process. Figure 3-1shows the full list of socio-economic indicators. Most indicators are applicable to all of the eight field study sites and 12 IUAs in the basin. The exceptions apply where, for example, there is no floodplain of significance, and thus no floodplain grazing or floodplain crop production, or where, for example, there are no resident people.

It is important to stress that the indicators selected are limited to values that are expected to change under differing water use scenarios. Some natural resource uses associated with the riverine environment provide livelihood and economic value but are unlikely to change with flow change. An example is use of riparian tree fruits, and another is irrigated commercial agricultural production. Some 2,600 hectares are irrigated in this way in the Namibian basin, contributing significant income and employment for local residents. But irrigated crop production draws water regardless of flow change. New irrigation will also form part of water use development scenarios, itself affecting water flow.

Figure 3-1 List of socio-economic indicators used in the EFA and their links to the broader economy

Possible indicators affecting human wellbeing are those related to health and disease, such as malaria, bilharzia and diarrhoea, were examined. Although their incidence is linked to the aquatic environment these were found to not be affected specifically by flow change. Other possible indicators included natural resource uses such as water lily use (*Nymphaea* sp.) for food, and use of the sedge (*Cyperus papyrus*) for mat making, were rejected as indicators either because they were considered of small import or because in some sites their use was unlikely to be affected by flow changes. Further, not all indicators have been assigned values. Where data are unavailable some relatively minor resources have been treated only in discussion, despite being recognised as possibly responsive to flow change.

The indicators in Figure 3-1 are divided firstly into those affecting both local household income, or livelihoods (indicators 1 to 8) and the broader economy, and secondly those impacting directly on the broader economy or on societal well-being (9.1 to 9.4). The figure shows how these all contribute ultimately to overall social and economic wellbeing.

4. Water-use Scenarios

The hypothetical water use and water-resource developments associated with each of the three scenarios that were originally assessed are provided Table 4.1. Climate change predictions were only applied to two of these: low and medium. The results for the high scenario are presented in Volumes 1 and 2.

The process for scenario selection is described in Report 02/2009: Process Report. Water-use scenarios are not situations that will happen; rather, they are combinations of possible future water-resource developments that can be explored in terms of their implications, as an aid to planning and decision-making.

The outcomes of scenarios depend on what is included as a water-resource development. Changing the location, size or any other aspects of a possible development will change the expected future flow regime and thus the expected ecological and social implications.

Table 4.1 The hypothetical water-resource developments included in each scenario

<table>
<tr><td rowspan="2">Site</td><td rowspan="2">Present</td><td rowspan="2">Low</td><td>Medium</td><td>High</td></tr>
<tr><td>Low schemes plus:</td><td>High schemes plus:</td></tr>
<tr><td rowspan="5">Site 1
Capico</td><td>Menongue: 246 000 people</td><td>Menogue: 257 000 people</td><td>Menogue: 30 000 people</td><td>Menogue: 70 000 people</td></tr>
<tr><td rowspan="4"></td><td colspan="3">Irrigation: Missombo 1000 ha, weir diversion</td></tr>
<tr><td colspan="3">Irrigation: Menongue Agriculture 10 000 ha, pump sump on river bank</td></tr>
<tr><td colspan="3">Irrigation: Ebritex 17 000 ha, pump sump on river bank</td></tr>
<tr><td colspan="3">HEP: Liapeca, run-of-river, low weir, turbines d/s</td></tr>
<tr><td rowspan="8">Site 2
Mucundi</td><td colspan="4">ALL CAPICO DEVELOPMENTS PLUS:</td></tr>
<tr><td rowspan="7"></td><td colspan="3">HEP: Cuvango – Existing / not functioning. Rehabilitation in 2009. 40m high reservoir, 1250 Mm3, Qmax = 3.5 m3/s</td></tr>
<tr><td colspan="3">HEP: Cuchi – (Kaquima (Malobas)). Run-of-river. H = 14m, Qmax = 3 m3/s</td></tr>
<tr><td colspan="3">HEP: Maculungungu (on Cubango u/s Caiundo). Run-of-river. H = 22m, Qmax = 24 m3/s</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td>HEP: Cutato. Run-of-river. H = 30m, Qmax = 6 m3/s</td></tr>
<tr><td>HEP: Rapides do Cuelei. Run-of-river. H = 22m, Qmax = 8 m3/s</td></tr>
<tr><td>Irrigation: Cuchi, 15 000 ha, pump intake</td><td colspan="2">Irrigation: Cuchi, 150 000 ha, pump intake</td></tr>
<tr><td></td><td colspan="2">Irrigation : Cuvango, 10 000 ha, pump sump on river bank</td></tr>
<tr><td rowspan="2">Site 3
Cuito
Cuanavale</td><td>Cuito Cuanavale: 110 435 people</td><td>Cuito Cuanavale: 115 000 people</td><td>Cuito Cuanavale: 128 600 people</td><td>Cuito Cuanavale: 160 000 people</td></tr>
<tr><td></td><td></td><td colspan="2">HEP: Cuito Cuanavale (13 km u/s confluence). Diversion, Run-of-river. H = 7m, Qmax = 90 m3/s</td></tr>
</table>

<table>
<tr><th rowspan="2">Site</th><th rowspan="2">Present</th><th rowspan="2">Low</th><th>Medium</th><th>High</th></tr>
<tr><th>Low schemes plus:</th><th>High schemes plus:</th></tr>
<tr><td rowspan="4">Site 4 Kapako</td><td colspan="4">ALL CAPICO & MUCUNDI DEVELOPMENTS PLUS:</td></tr>
<tr><td>Irrigation: Kahenge 300 ha, pump intake on river bank</td><td>Irrigation: Kahenge 700 ha, pump intake on river bank</td><td colspan="2">Irrigation: Kahenge 900 ha, pump intake on river bank</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="2">Irrigation: Rundu Future 1100 ha, pump intake on river bank</td></tr>
<tr><td></td><td>Irrigation: Cuangar Calais 45 000 ha, pump intake on river bank</td></tr>
<tr><td rowspan="13">Site 5&6 Popa and Panhandle</td><td colspan="4">ALL CAPICO, MUCUNDI, KAPAKO AND CUITO CUANAVALE DEVELOPMENTS PLUS:</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td colspan="2">Irrigation: Longa 10 000 ha, pump intake on river bank</td></tr>
<tr><td rowspan="2"></td><td>Irrigation: Calais Dirico 35 000 ha, pump intake on river bank</td></tr>
<tr><td>Irrigation: Calais Dirico B 60 000 ha, pump intake on river bank</td></tr>
<tr><td colspan="4">Irrigation: Mukwe 560 ha, pump intake on river bank</td></tr>
<tr><td>Irrigation: Rundu-Mashare 521 ha, pump intake on river bank</td><td colspan="3">Irrigation: Rundu-Mashare 551 ha, pump intake on river bank</td></tr>
<tr><td>Irrigation: Ndiyona 870 ha, pump intake on river bank</td><td colspan="3">Irrigation: Ndiyona 1270 ha, pump intake on river bank</td></tr>
<tr><td>Rundu Urban, Tower on right bank, 2.8 Mm3/a</td><td>Rundu Urban, Tower on right bank, 3.0 Mm3/a</td><td>Rundu Urban, Tower on right bank, 3.4 Mm3/a</td><td>Rundu Urban, Tower on right bank, 4.3 Mm3/a</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>Irrigation: Mukwe Future 4000 ha, pump intake on river bank</td><td>Irrigation: Mukwe Future 10 600 ha, pump intake on river bank</td></tr>
<tr><td>Eastern National Carrier (ENC) for water supply from Kavango to Namibia, Tower on right bank, 17 Mm3/a</td><td>Eastern National Carrier (ENC) for water supply from Kavango to Namibia, Tower on right bank, 100 Mm3/a</td></tr>
<tr><td></td><td>HEP: Popa Falls. Run-of-river, Weir at Site 2. H = 7.5 m, Qmax = 280 m3/s, 22.5 Mm3 capacity.</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>HEP: Cuito – M’Pupa. Run-of-river. H = 5m, Qmax = 100 m3/s</td></tr>
<tr><td>HEP: Cuito – Chamavera (d/s M’Pupa). Run-of-river. H = 6m, Qmax = 100 m3/s</td></tr>
</table>

<table>
<tr><td rowspan="2">Site</td><td rowspan="2">Present</td><td rowspan="2">Low</td><td>Medium</td><td>High</td></tr>
<tr><td>Low schemes plus:</td><td>High schemes plus:</td></tr>
<tr><td>Site 7 Xakanaka</td><td colspan="4">ALL CAPICO, MUCUNDI, KAPAKO, CUITO CUANAVALE AND POPA/PANHANDLE DEVELOPMENTS</td></tr>
<tr><td rowspan="2">Site 8 Boteti</td><td colspan="4">ALL CAPICO, MUCUNDI, KAPAKO, CUITO CUANAVALE, POPA/PANHANDLE DEVELOPMENTS, PLUS:</td></tr>
<tr><td></td><td></td><td></td><td>Dam at Samedupi (37 MCM/a)</td></tr>
</table>

Details of the water-resource development included and the modeling thereof for inclusion in the three scenarios are provided in Report 06/2009: Scenario Report: Hydrology.

4.1. Hydrological data generated for the scenarios

The hydrological modelling for the three scenario yielded times series of daily flows for a 43-year hydrological period (1959 - 2001) for the river sites (Sites 1-6) and a 20-year hydrological period (1983 - 2002) for the Delta (Site 7) and Boteti (Site 8). For each scenario, the level of water use outlined in Table 4.1 was imposed on the full hydrological period.

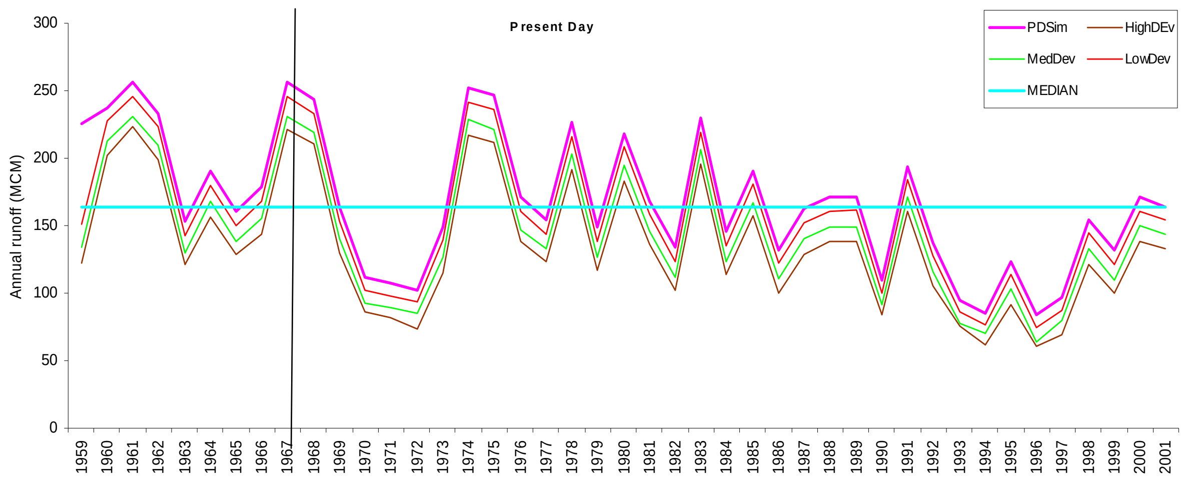


Figure 4-1 Annual runoff data for Site 4: Kapako (1959-2001).

It is important to emphasise that the base hydrological for the period used, 1959-2001, show a declining trend in mean annual runoff (e.g., Figure 4-1). This trend was primarily driven by climatic conditions, as was borne out by a reversal of the trend in 2004-2009. Unfortunately, these more recent data were not available for the modelling exercise. They were, however, made available for certain sites during the Knowledge Capture Workshop. This meant that the biophysical specialists could calibrate their response curves using the more recent data. For the hydrological modelling of the scenarios, however, 'present-day' was represented by a simulated record for 1959-2001.

Thus, for the river sites (Sites 1, 2, 3, 4, 5 and 6), the present-day situation is defined as a 43-year hydrological period (1959 - 2001) with 2008 levels of water use applied throughout.

For the delta (Site 7) and the Boteti River (Site 8), the present-day situation is defined as a 20-year hydrological period (1983 - 2002) with 2008 levels of water use applied throughout.

To facilitate comparison between the scenarios, each scenario comprises the same hydrological period as the present-day scenario, with its water use levels applied throughout. For instance, the medium scenario at Site 4: Kapako comprises the 1959-2003 period and assumes that all of the upstream developments envisaged in the medium scenario would be in place for the entire time.

4.2. Incorporation of climate change predictions into the low and medium scenarios

Three estimates of the likely effects of climate change on flow in the Okavango River system were done. These all predicted increased rainfall and evaporation in the upper basin. These two processes all but cancel each other out in the upper catchment, resulting in a slight nett increase in river flows under both the driest and wettest climate change predictions. In the Delta, however, where the situation is dominated by evaporation, for the driest climate change predictions, the increased evaporation is not completely offset by increased rainfall or inflows. Thus, the net result is that the Delta is drier than present day. Under the wettest climate change predictions, the increased evaporation is offset by increased rainfall and flows, and the resultant condition is wetter than present day. Similarly in Boteti, the driest climate change scenario is slightly drier than present day, and the wettest climate change scenario is slightly wetter than present day.

Higher evaporation rates may also mean that the (largely beneficial) effects of climate change on the floodplains in the middle reaches, Sites 4 and 5, have been overestimated.

The lowest estimate (i.e., the driest predicted future) and the highest estimate (i.e., the wettest predicted future) were subsequently used to assess the possible impacts of climate change on outcomes predicted for the water use scenarios, which initially has not considered climate change. The following assessments were done:

- Low scenario – no climate change (L No CC)
- Low scenario – driest climate change (LCCD)
- Low scenario – wettest climate change (LCCW)
- Medium scenarios – no climate change (M No CC)
- Medium scenario – driest climate change (MCCD)
- Medium scenario – wettest climate change (MCCW).

4.3. The ecologically-relevant summary statistics for the river sites under climate change (Sites 1-6)

The time series of daily flows were analysed using set of hydrological rules to generate the following ecologically-relevant summary statistics for each year of record:

1. Dry season onset in weeks
2. Dry season minimum 5-day discharge in m^3s^{-1}
3. Dry season duration in days
4. Flood season onset in weeks
5. Flood type (0-6)
6. Flood season duration in days.

Details on the division of the flow regime and the generation of ecologically-relevant summary statistics are provided in Report 03/2009: Guidelines for data collection, analysis and scenario creation and Report 06/2009:Scenario Report: Hydrology.

The annual statistics are stored in the DSS. The median values for present day and for the low and medium scenarios with two levels of climate change at each site, with comments where relevant, are provided in Table 4.2 to Table 4.6. The statistics for flood season peak

5-day magnitude and flood season volume are presented separately in Table 4.2 to Table 4.6. These were later combined to provide Flood Type (0-6).

Table 4.2 Median values for the ecologically-relevant summary statistics for the low and medium scenarios with two levels of climate change for Site 1: Capico. PD = simulated present day flow regime.

Flow category	PD	Low			Medium			Comment
		No CC	CCD	CCW	No CC	CCD	CCW	
MAR (McM)	22	14	14	14	14	14	14	No change.
Dry season onset	Aug	May	June	June	May	June	June	Onset slightly later.
Dry season duration (days)	86	212	200	200	212	200	200	Duration not ameliorated by CC.
Dry season minimum flow (m^3s^{-1})	12	0.4	0.4	0.4	0.3	0.4	0.4	No change.
Flood season onset	Dec	Jan	Jan	Jan	Jan	Jan	Jan	No change.
Flood season peak (m^3s^{-1})	38	35	38	38	35	38	38	Offsets development impacts.
Flood season volume (Mcm)	456	231	242	242	231	242	242	Slight offset.
Flood season duration (days)	197	97	103	103	97	103	103	Slight offset of impacts.

Table 4.3 Median values for the ecologically-relevant summary statistics for the low and medium scenarios with two levels of climate change for Site 2: Mucundi. PD = simulated present day flow regime.

Flow category	PD	Low			Medium			Comment
		No CC	CCD	CCW	No CC	CCD	CCW	
MAR (McM)	166	155	166	204	140	152	188	CCW wetter than PD under low and medium scenario. CCD is drier than PD under medium scenario
Dry season onset	July	July	July	July	July	July	July	No change.
Dry season duration (days)	86	124	113	95	143	136	113	Duration slightly ameliorated by CC.
Dry season minimum flow (m^3s^{-1})	32	16	22	28	12	16	22	CC mitigates low flows.
Flood season onset	Jan	Jan	Jan	Dec	Jan	Jan	Dec	Flood season slightly earlier under CCW.
Flood season peak (m^3s^{-1})	429	430	446	562	429	449	563	Flood peak and volume higher that PD under CCW.
Flood season volume (Mcm)	3713	3558	3817	5123	3178	3466	4355	
Flood season duration (days)	148	135	143	183	123	128	150	CCW offsets impacts. Medium scenario impacts not offset under CCD.

Table 4.4 Median values for the ecologically-relevant summary statistics for the low and medium scenarios with two levels of climate change for Site 3: Cuito Cuanavale. PD = simulated present day flow regime.

Flow category	PD	Low			Medium			Comment
		No CC	CCD	CCW	No CC	CCD	CCW	
MAR (McM)	119	119	130	147	119	130	147	CCD and CCW wetter than PD.
Dry season onset	July	July	July	July	July	July	July	No change.
Dry season duration (days)	182	182	121	48	182	121	48	CCW considerable shorter dry season
Dry season minimum flow (m^3s^{-1})	80	80	93	94	80	93	94	CCD and CCW wetter than PD.
Flood season onset	Jan	Jan	Dec	Nov	Jan	Dec	Nov	Onset slightly later under CC.
Flood season peak (m^3s^{-1})	163	163	173	195	163	173	195	CCD and CCW considerably wetter than PD.
Flood season volume (Mcm)	1968	1968	2617	3436	1968	2617	3436	
Flood season duration (days)	162	162	205	263	162	205	263	

Table 4.5 Median values for the ecologically-relevant summary statistics for the low and medium scenarios with two levels of climate change for Site 4: Kapako. PD = simulated present day flow regime.

Flow category	PD	Low			Medium			Comment
		No CC	CCD	CCW	No CC	CCD	CCW	
MAR (McM)	164	152	167	204	140	154	190	CCW wetter than PD under low and medium scenario. CCD is drier than PD under medium scenario
Dry season onset	July	July	July	July	July	July	July	No change.
Dry season duration (days)	135	150	138	109	168	158	132	CC offsets water use impacts.
Dry season minimum flow (m^3s^{-1})	35	20	31	40	15	23	30	CC offsets development impacts.
Flood season onset	Jan	Jan	Jan	Jan	Jan	Jan	Jan	No change.
Flood season peak (m^3s^{-1})	452	446	400	497	453	394	483	CCD offsets water use impacts. CCW peak and volumes scenarios considerably higher than PD.
Flood season volume (Mcm)	3694	3535	3885	5188	3209	3523	4711	
Flood season duration (days)	154	147	154	186	130	144	167	CC offsets water use impacts.

Table 4.6 **Median values for the ecologically-relevant summary statistics for the low and medium scenarios with two levels of climate change for Site 5: Popa Falls and Site 6: Panhandle. PD = simulated present day flow regime.**

Flow category	**PD**	**Low**			**Medium**			**Comment**
		No CC	CCD	CCW	No CC	CCD	CCW	
MAR (McM)	270	261	287	341	245	270	324	CCW wetter than PD under low and medium scenario. CCD is drier than PD under medium scenario.
Dry season onset	Aug	July	Aug	Aug	July	July	Aug	CC offsets water use impacts.
Dry season duration (days)	115	130	110	71	145	133	92	CC offsets water use impacts.
Dry season minimum flow (m^3s^{-1})	114	101	113	125	93	107	122	CC offsets water use impacts.
Flood season onset	Jan	Jan	Jan	Dec	Jan	Jan	Jan	No change.
Flood season peak (m^3s^{-1})	620	618	528	649	611	519	635	CC offsets water use impacts.
Flood season volume (Mcm)	5269	4980	5587	7882	4450	5038	7236	CCD offsets water use impacts. CCW peak and volumes scenarios considerably higher than PD.
Flood season duration (days)	150	143	158	190	129	141	178	

4.4. Summary statistics for Site 7: Xaxanaka

Hydrological data per se are not particularly useful in the analysis of the Okavango Delta, as areas of inundation vary year on year with climate. Thus, while the overall proportion of inundated area may be similar in years with similar flow characteristics, the location of the inundated areas varies over time. For his reason, a semi-conceptual hydraulic model (Wolski *et al*. 2006), which was calibrated using observed data for the period of 1968-2002, was used to generate inundation patterns over the south-western portion of the Okavango delta, as represented by Site 7: Xaxanaka. The output of the model is a series of vegetation types/habitat based on duration and frequency of inundation (Table 4.7).

Table 4.7 **Vegetation types used in the model**

Abbreviation	Description
CH-ps	Channels in permanent swamp
L-ps	Lagoons in permanent swamp
BS-ps	Backswamp in permanent swamp
SP-sf	Seasonal pools in seasonally flooded zone
Sed-sf	Seasonal sedgeland in seasonally flooded zone
Gr-sf	Seasonal grassland in seasonally flooded zone
S-sf	Savanna- dried floodplain in seasonally flooded areas

Mean percentage over for these vegetation types for simulated present-day inflows between 1983-2002 is shown in Table 4.8.

Table 4.8 Mean percentage of cover for vegetation types in the area of the Delta represented by Site 7, for simulated present-day conditions, and for the present day, and for the low and medium scenarios with two levels of climate change.

Inflows		CH-ps	L-ps	BS-ps	SP-sf	Sed-sf	Gr-sf	S-sf
		Mean percentage cover						
Present-day		0.49	0.98	47.58	0.89	27.27	16.32	6.47
Low	No CC	0.46	0.92	44.62	0.94	27.84	18.08	7.13
	CCD	0.21	0.41	20.02	1.18	34.44	23.60	20.13
	CCW	0.49	0.99	47.95	0.94	29.74	16.12	3.77
Medium	No CC	0.43	0.87	41.67	0.98	26.28	21.51	8.29
	CCD	0.11	0.22	10.64	1.29	31.50	31.70	24.55
	CCW	0.44	0.88	42.51	1.03	29.71	20.80	4.64

Details of the model used are provided in Report 05/2009: Hydrology Report: Data and models.

4.5. Summary statistics for Site 8: Boteti

The percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the present-day, low, low with two levels of climate change, medium and medium with two levels of climate change scenarios is provided in Figure 4-2, Figure 4-3, Figure 4-4, Figure 4-5, Figure 4-6, Figure 4-7 and Figure 4-8, respectively.

Details of the model used to provide these data are provided in Report 05/2009: Hydrology Report: Data and models - Volume 1 and Volume 2.

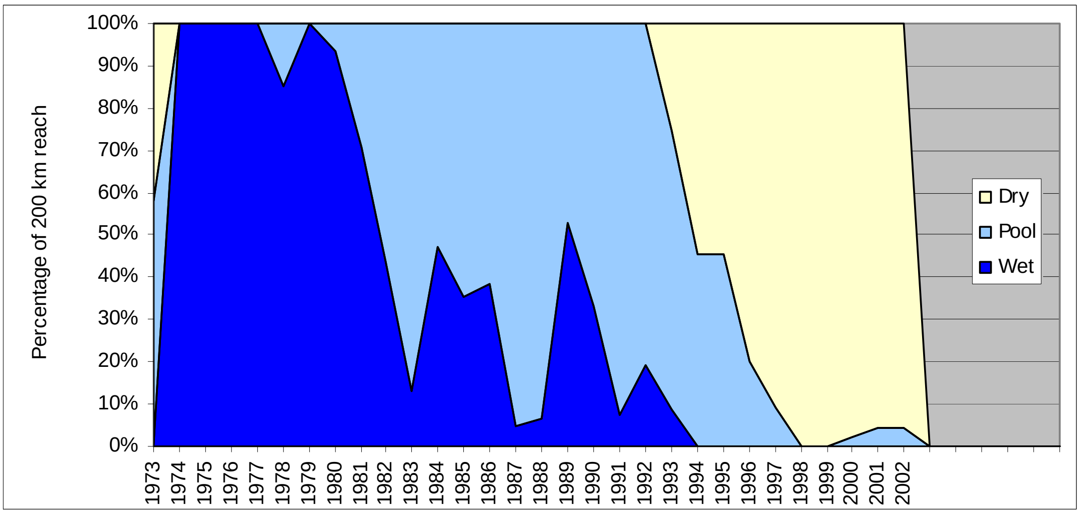


Figure 4-2 Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the present-day simulated conditions given climatic conditions that prevailed from 1973-2002.

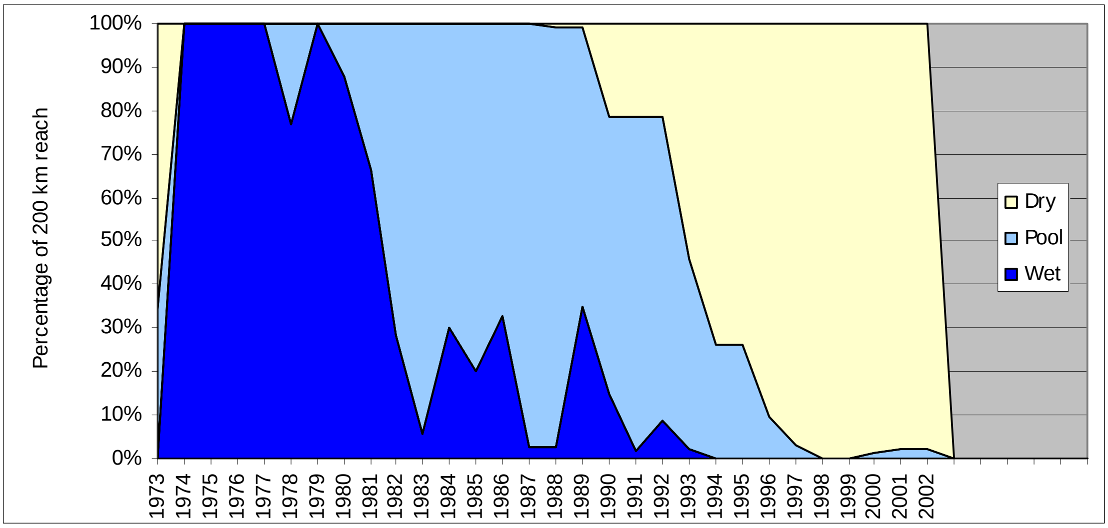


Figure 4-3 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the low scenario given climatic conditions that prevailed from 1973-2002.**

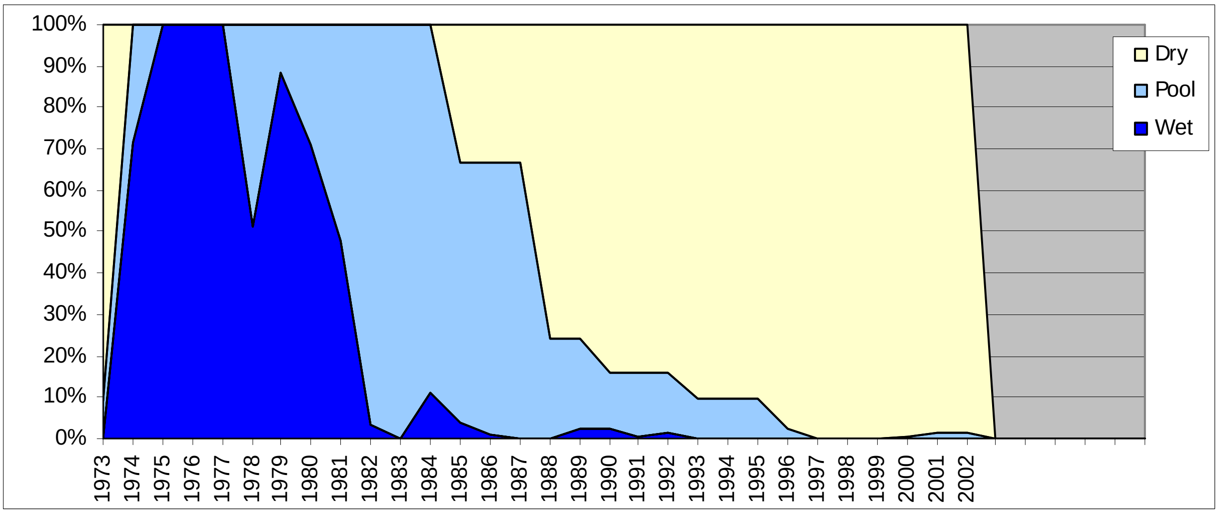


Figure 4-4 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the low scenario with the driest Climatic Change (CCD) imposed on 1973-2002.**

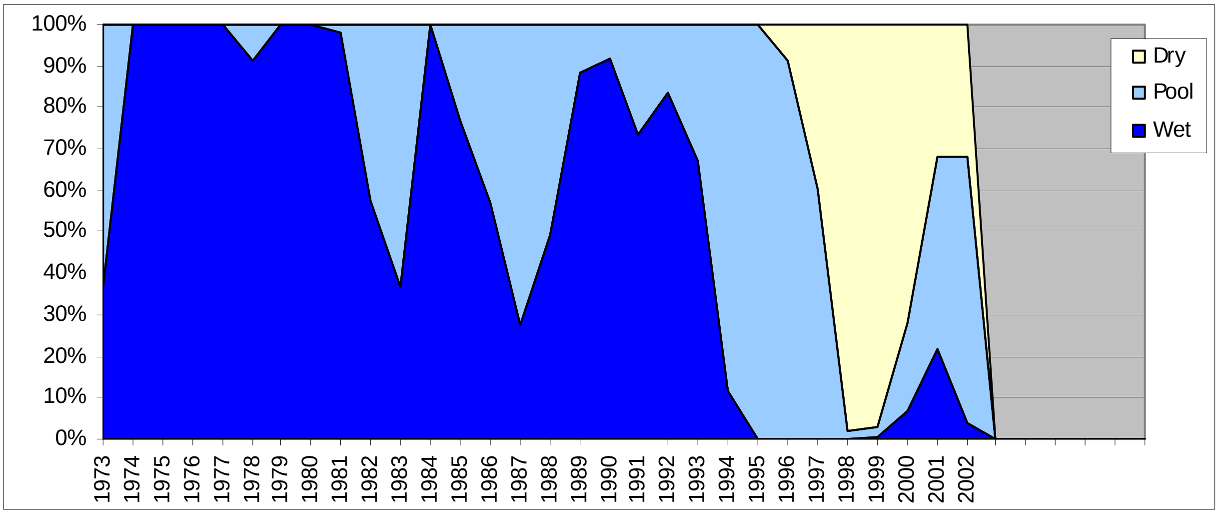


Figure 4-5 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the low scenario with the wettest Climatic Change (CCW) imposed on 1973-2002.**

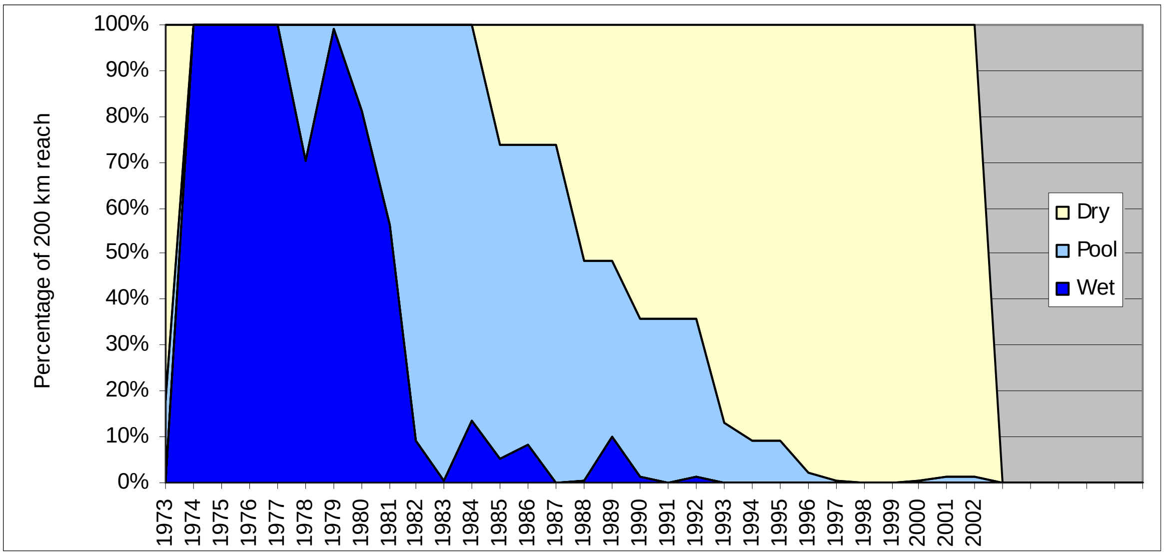


Figure 4-6 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the medium scenario given climatic conditions that prevailed from 1973-2002.**

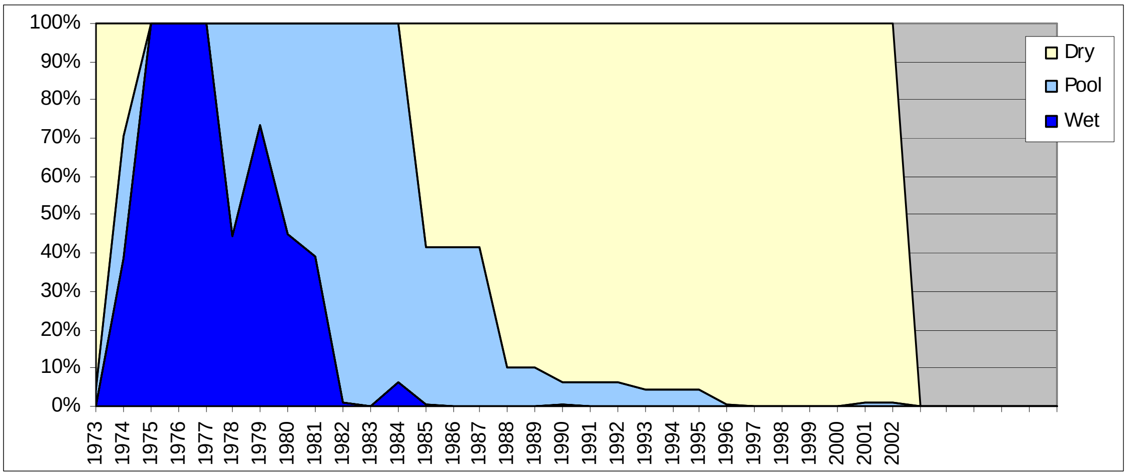


Figure 4-7 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the medium scenario with the driest Climatic Change (CCD) imposed on 1973-2002.**

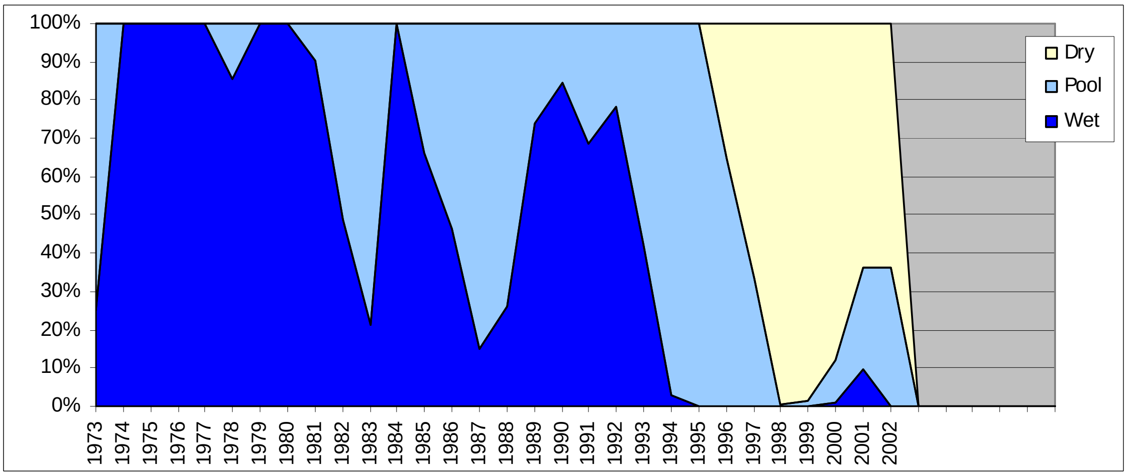


Figure 4-8 **Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the medium scenario with the wettest Climatic Change (CCW) imposed on 1973-2002.**

4.6. Process follow after the generation of ecological summary data

Once the summary ecological data are generated they are entered into the DSS. In the DSS, the response curves are used to predict the biophysical and social outcomes for the flow regime of interest. The DSS is described in more detail in Report 02/2009: Process Report.

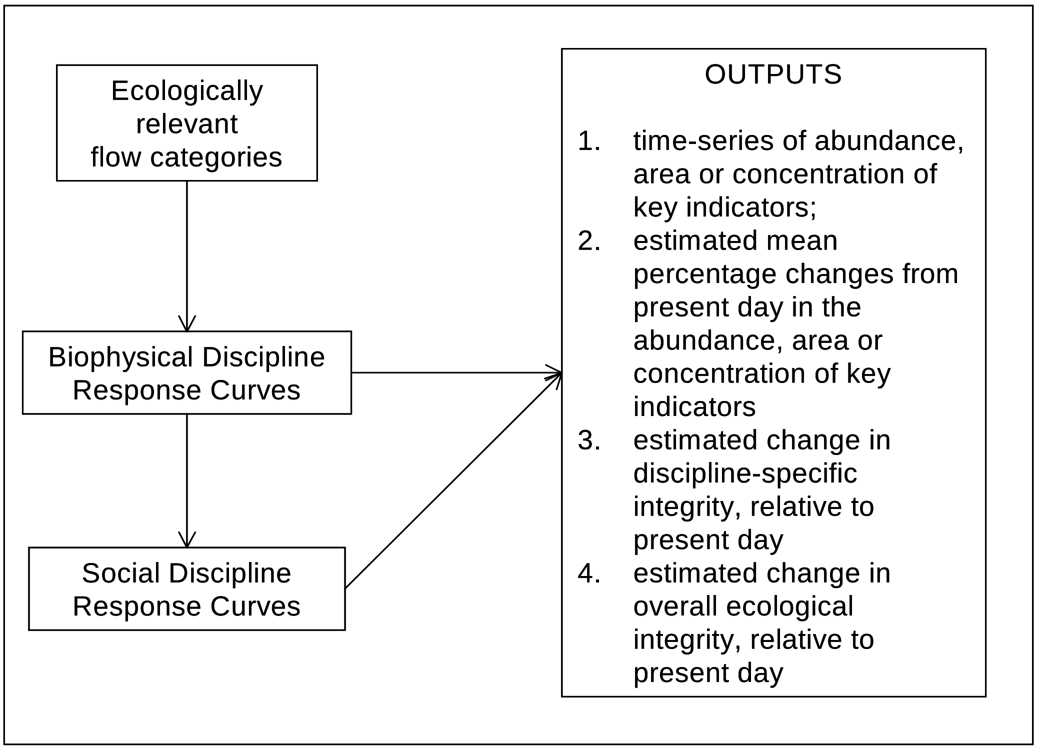


Figure 4-9 Summary of process within the DSS

5. Biophysical results: Disciplines

Note:

1. The results presented here are unique to the configuration of development options, and their operating rules, included in the water-use scenarios. Different configurations, and/or different operating rules would yield different outcomes for the biophysical environment.
2. The results presented here exclude consideration of:impacts of developments other than flow, e.g., changes in sediment supply; landuse changes.
3. The only water use included in the scenarios for the Cuito River upstream of Site 3: Cuito River at Cuito Cuanavale was a run-of-river hydropower plants that had no effect on the flows at Site 3. Thus, none of the scenarios affected Site 3.
4. The locations of the sites prohibit the prediction of likely impacts of any of the scenarios on the lower Cuito River.
5. Climate change impacts are assessed primarily in relation to the low and medium scenarios, but reference is also made to present day situations, as the predicted wetter conditions may change the river from the present.
6. Occasionally the range of summary flow statistics for CC was outside the range used for the Response Curves. Where this occurred, the nearest value was used. Extension of the Response Curves could be done, but was not possible in the CC extension of this project. Using nearest values may have muted some predicted responses.

5.1. Introduction

The Chapter summarises the results for each of the biophysical indicators in terms of overall changes in their area, concentration or abundance relative to the simulated present day situation.

Additional details on the biophysical results for each scenario presented here are provided in Report 07/2009: Scenario Report: Ecological and social predictions (VOLUME4).

5.2. Geomorphology

5.2.1 Indicator 1: Extent - exposed rocky habitat

Summary of characteristics

This indicator considers the extent of exposed rocky habitat at a site during the low flow season. It does not consider the other potential impacts, such as of sediment deposition covering bedrock exposures, only the exposed bedrock above the water surface. Exposed rocky areas provide valuable habitat for birds and wildlife. There is a direct relationship between flow level and rocks exposed above water level. As water level rises, less rocky area is exposed.

This indicator is used for Sites 1, 2 and 5.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	>PD	NSC	NSC	>PD	NSC	>PD+>MS
2	>PD	>PD+<LS	>PD+<LS	>PD	>PD+<MS	>PD+<MS
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	NSC	NSC	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a

5.2.2 Indicator 2: Extent – coarse sediments

Not used in final analysis.

5.2.3 Indicator 3: Cross sectional area of channel

Summary of characteristics

The cross sectional area of the channel responds mainly to flood conditions. Floods larger than the historical maximum should rapidly enlarge the cross sectional area, and a reduction of floods should result in a narrowing of the flood channel (and a reduction in channel cross-sectional area). However, the channel also responds to low flow conditions or extended low flow conditions, which enables vegetation to encroach into the channel, trapping sediment, ultimately reducing the channel cross section. This process is much slower than channel enlargement, and intervening floods will offset this to a certain extent.

This indicator is used for Sites 1, 2, 3, 4, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	PD	NSC	>PD+>LS	<PD	NSC	>PD+>MS
3	PD	NSC	NSC	PD	NSC	NSC
4	<PD	>PD+>LS	>PD+>LS	<PD	NSC	>PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	<PD	NSC	NSC	<PD	NSC	NSC

5.2.4 Indicator 4: Extent: backwaters

Summary of characteristics

Backwater provide valuable habitat for plants, fish, birds and wildlife. Filling or emptying of backwaters is directly related to the water level in the river. Backwaters gradually fill with sediment and therefore may be shallower than the main channel - in that case they may empty before the river dries up. The backwaters tend to be steep sided, so the surface area changes little as water depth changes.

This indicator is used for Sites 1, 3 and 4.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	NSC	<PD+<LS	PD	NSC	<PD+<LS
4	<PD	<PD+>LS	PD+>LS	<PD	<PD+>MS	<PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a

5.2.5 Indicator 5: Extent: vegetated islands

Summary of characteristics

Vegetated islands in the Mukwe-Andara-Popa Falls section of the Okavango River (and upstream) are normally comprised of sand on bedrock. Grass, reeds, bush and trees stabilise the sand by reducing wash away during above-average high flows and also promoting deposition of more sand during overtopping of the island.

Reduced flows have little impact on vegetated islands as long as the plants there still get enough water to survive and regenerate. Excessively high floods, however, are likely to cause erosion of the margins of islands. In many cases this erosion is limited to the margins because of the bedrock base to the island.

This indicator is used for Site 5.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	NSC	NSC	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a

5.2.6 Indicator 6: Sandbars at lowflow

Summary of characteristics

Extensive exposed sand bars exist mainly below Popa Falls. Upriver, although much of the river bed is sand, the sand bars are mostly submerged just below the surface during the low flow season.

If only the effect of water flow on sandbanks is considered, then lower flow will expose a greater extent of sandbanks. However, the real issue the fact that dams and weirs trap sediment. Downstream of a weir or dam the river is deprived of sediment, so it erodes its bed, banks and floodplains until it is once again carrying its maximum load. Thus, for some distance downstream of a weir or dam the sandbanks will be removed. This is important at Sites 2 and 5 were dams/weirs form part of the high scenario, but is not included in the results for this indicator as sediment trapping by dams was not included in the DSS. If there were, the impacts would likely be considerably higher than predicted here.

This indicator is used for Site 5.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	>PD+>LS	>PD+>LS	PD	NSC	>PD+>MS
6	n/a	n/a	n/a	n/a	n/a	n/a

5.2.7 Indicator 7: Percentage clays and silts on floodplain

Summary of characteristics

This refers to the silts and clays in the top 300 mm of the floodplain surface sediments. Floodplains are made predominantly of fine sand, but there is a small amount of silt and clay-sized particles, which is also deposited by the river. The silt and clay is significant for agriculture because it helps to retain moisture and nutrients. Silt and clay tend to get lost due to downward mixing by soil organisms, trampling by livestock, and removal by wind, and are replenished by flooding. Both loss and replenishment occur over fairly long time scales, c. 20 years or so, although sudden depositions do occur under large floods.

This indicator is used for Sites 3 and 4.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	NSC	NSC	PD	NSC	NSC
4	<PD	PD+<LS	PD+<LS	PD	NSC	NSC
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a

5.2.8 Indicator 8: Extent: inundated floodplain

Summary of characteristics

This indicator considers the extent of inundation of the floodplains at Sites 3, 4 and 6. Inundation of the floodplain is strongly linked to the peak and duration of the flood season flows, i.e., their volume (Figure 5-1). Reduced volume of flow in the flood season will result in less over-bank flooding. This results in smaller areas of the floodplain being inundated.

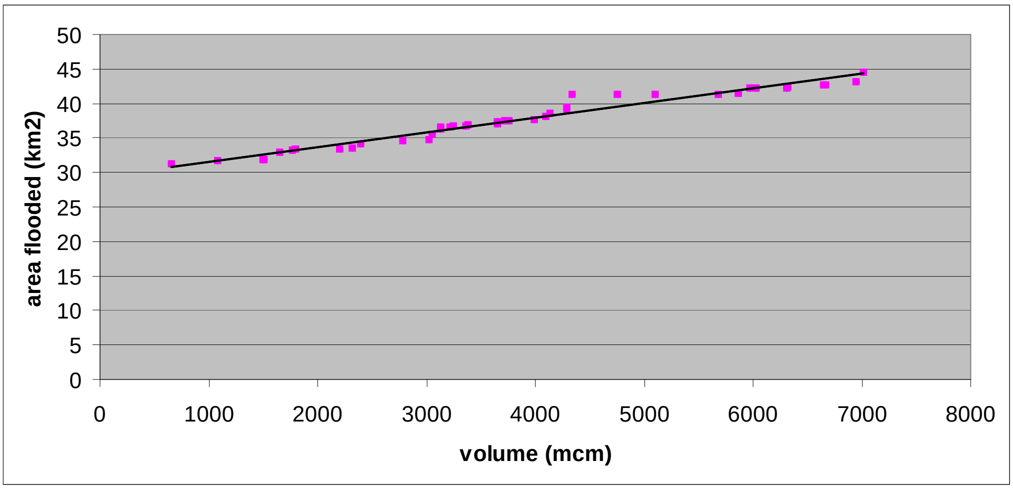


Figure 5-1 Relationship between flood season volume and area of floodplain inundated for Site 4: Kapako.

This indicator is used for Sites 3, 4 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	NSC	NSC	PD	NSC	NSC
4	PD	NSC	NSC	PD	NSC	NSC
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	NSC	PD	NSC	NSC

5.2.9 Indicator 9: Extent: pools and pans

Summary of characteristics

This indicator considers the extent of perennial pools and pans on the floodplains at Sites 3, 4 and 6. These are partly dependent on refilling from overbank flooding and rain, but are sustained through the lowflow season by the high water table on the floodplains. As the river level drops, so the water table in the floodplain will also drop. If the bed of a pool no longer intersects the water table, the pool will dry out, although seepage from the non-saturated zone may also contribute to pool water.

This indicator is used for Sites 3, 4 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>LS	>PD+>LS
4	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	<PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	NSC	PD	NSC	NSC

5.2.10 Indicator 9: Extent: cut banks

Summary of characteristics

Cut banks are a natural phenomenon in the Okavango, particularly in the middle reaches through Namibia. Higher flow velocities during flooding erode banks, building meanders and creating cutoffs. This process is enhanced if water levels drop rapidly, as hydrostatic pressure of water in the sandy bank material tends to result in bank collapse. A decline in bank cutting will result in a gradual stabilization of the channel and a loss of habitat.

This indicator is used for Sites1, 3, 4 and 6.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	PD	NSC	NSC	PD	NSC	NSC
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>LS	>PD+>LS
4	<PD	>PD+>LS	>PD+>>LS	PD	NSC	>PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	NSC	PD	NSC	NSC

5.2.11 Indicator 10: Carbon storage

Summary of characteristics

Wetlands affect the levels of atmospheric carbon in two ways: First, many wetlands, particularly boreal and tropical peatlands, are carbon reservoirs. Carbon is contained in the standing crops of trees and other vegetation and in litter, peats, organic soils and sediments that have been built up, in some instances, over thousands of years. These carbon reservoirs may supply large amounts of carbon to the atmosphere if water levels are lowered or land management practices result in oxidation of soils. Second, many wetlands also continue to sequester carbon from the atmosphere through photosynthesis by wetland plants; many also act as sediment traps for carbon-rich sediments from watershed sources. However, wetlands also simultaneously release carbon as carbon dioxide, dissolved carbon, and methane. The net carbon sequestering versus carbon release roles of wetlands are complex and change over time although net, gradual sequestration occurs over time for peatland wetlands such as the Okavango Swamp[2].

This indicator considers the net peat/carbon storage in the swamps.

This indicator is used for Site 7.

[2] www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/1999.08

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
8	PD	NSC	<PD+<LS	PD	NSC	<PD+<MS

5.2.12 Summary of geomorphological response to scenarios

Increasing off-stream water use in the Okavanago catchment is likely to result in a trend towards stabilisation and narrowing of the main channels, possibly accompanied by a deepening of the channel and a terrestrialisation of the vast floodplains. In the upper catchment, some of these flow-related impacts are mitigated by the climate change predictions. In the lower catchment, however, this is less so.

However, exclusion of consideration of changes in sediment supply liked with water-resources developments and/or landuse changes means that the predictions for the geomorphology are incomplete, and quite possibly the changes are seriously underestimated.

5.3. Water Quality

5.3.1 Indicator 1: pH

Summary of characteristics

Values are those for the main channel. Generally, pH increases with decreasing flow.

This indicator is used for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>PD	NSC	NSC	>PD	NSC	NSC
2	PD	NSC	NSC	>PD	NSC	NSC
3	PD	NSC	NSC	PD	NSC	NSC
4	>PD	NSC	PD+<LS	>PD	NSC	NSC
5	PD	NSC	NSC	PD	NSC	PD+<MS
6	PD	NSC	NSC	PD	NSC	NSC
7	PD	>PD+>LS	NSC	PD	>PD+>MS	NSC
8	PD	>PD+>LS	NSC	>PD	>PD+>MS	NSC

5.3.2 Indicator 2: Conductivity

Summary of characteristics

Values are those for the main channel. Generally, conductivity increases with decreasing flow.

This indicator is used for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>>PD	NSC	NSC	>>PD	NSC	NSC
2	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	>PD	PD+<LS	<PD+<LS	>PD	>PD+<MS	PD+<MS
5	PD	NSC	>PD+>LS	>PD	PD+<MS	PD+<MS
6	>PD	NSC	PD+<LS	>PD	>PD+<MS	PD+<MS
7	PD	>PD+>LS	>PD+>LS	>PD	>PD+>MS	>PD+>MS
8	>PD	>PD+>LS	<PD+<LS	>PD	>PD+>MS	<PD+<MS

5.3.3 Indicator 3: Temperature

Summary of characteristics

Diel temperature ranges are addressed. These are expected to increase with development that reduces river flow.

This indicator is used for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>PD	NSC	NSC	>PD	NSC	NSC
2	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	>PD+<MS
3	PD	NSC	>PD+>LS	PD	NSC	>PD+>MS
4	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
5	PD	NSC	NSC	>PD	>PD+<MS	PD+<MS
6	PD	>PD+>LS	>PD+>LS	>PD	>PD+<MS	>PD+<MS
7	PD	>PD+>LS	>PD+>LS	>PD	>>PD+>>MS	>PD+>MS
8	>PD	>PD+>LS	<PD+<LS	>PD	>>PD+>>MS	<PD+<MS

5.3.4 Indicator 4: Turbidity

Summary of characteristics

Turbidity decreases with decreasing flow at Sites 1 and 2. Values increase with high flows in the flood season, as sediments are lifted into suspension.

This indicator is used for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	<PD	<PD+>LS	PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	<PD+<LS	<PD+<LS	PD	<PD+<MS	<PD+<MS
4	PD	NSC	NSC	PD	<PD+<MS	<PD+<MS
5	<PD	PD+>LS	>PD+>LS	<PD	PD+>MS	PD+>MS
6	PD	NSC	>PD+>LS	<PD	PD+>MS	>PD+>MS
7	PD	NSC	NSC	>PD	>PD+>MS	NSC
8	<PD	<PD+<LS	>PD+>LS	<PD	<PD+<MS	>PD+>MS

5.3.5 Indicator 5: Dissolved oxygen

Summary of characteristics

Decrease in flow results in an increase in Dissolved Oxygen at sites 1 - 6. At sites 7 and 8 the concentrations decrease with a decrease in flow.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different. <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>PD	NSC	NSC	>PD	NSC	NSC
2	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	>PD+<MS
3	PD	<PD+<LS	<PD+<LS	PD	<PD+<MS	<PD+<MS
4	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
5	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	<PD+<MS
6	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	<PD+<MS
7	PD	<PD+<LS	PD	<PD	<PD+<MS	NSC
8	<PD	<PD+<LS	>PD+>LS	<PD	<PD+<MS	>PD+>MS

5.3.6 Indicators 6, 7 and 8: Total nitrogen, total phosphorus and chlorophyll a

Summary of characteristics

Concentrations increase with decreasing flow at all the sites, but the relationship is slightly weaker for phosphorus.

This indicator is used for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>PD	NSC	NSC	>PD	NSC	NSC
2	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	>PD+<MS
3	PD	<PD+<LS	PD+<LS	PD	<PD+<MS	PD+<MS
4	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
5	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	<PD+<MS
6	>PD	>PD+<LS	>PD+>LS	>PD	>PD+<MS	PD+<MS
7	>PD	>>PD+>>LS	>PD+>LS	>PD	>>PD+>>MS	>PD+>MS
8	>PD	>PD+>LS	<PD+<LS	>PD	>PD+>MS	<PD+<MS

5.3.7 Summary of water-quality responses to scenarios

The water quality of the Okavango system is good, and values of all indicators are predicted to remain mostly within the natural variability through the low and medium scenarios. The situation remains similar in the upper catchment under climate change, where water quality is expected to be fairly natural. However, in the lower catchment, the driest climate change predictions are expected to result in poor water quality in the Delta and Boteti.

As previously noted (Volume 1), not all chemical variables are addressed in this exercise, and that for those included only the direct changes as a result of flow changes are described. Water-use developments, as represented by the scenarios, will likely cause additional water-quality changes, brought about by increased effluents from urban areas, agricultural return flows carrying pesticides and fertilisers, and changed DO and temperature levels caused by storage dams.

5.4. Vegetation

5.4.1 Indicator 1: Channel macrophytes (submerged)

Representative species: *Potamogeton* spp. (pondweed), *Vallisneria aethiopica* (no common name) and *Lagarosiphon ilicifolius* (oxygen weed).

Summary of characteristics

These are species that grow along the edges of main channel or in side channels. All or part of vegetation is permanently submerged, and the plants are either rooted or floating. They need permanent, flowing, clear water. Their cover increases or decreases depending on water volume in lowflow season and could decline to zero if the channel dries out. Sudden or very large floods could also reduce cover. Poor water quality or low light penetration will also negatively affected them.

These plants are used as indicators for Sites 1, 2, 3, 4, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	PD	NSC	NSC
2	PD	NSC	NSC	<PD	<PD+>MS	<PD+>MS
3	PD	NSC	>PD+>LS	PD	NSC	NSC
4	PD	NSC	NSC	<PD	<PD+>MS	<PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	<PD+<LS	PD	NSC	NSC

5.4.2 Indicator 2: Lower wet bank

Representative species: *Vossia cuspidata*, *Cyperus papyrus.*

Summary of characteristics

These are species that grow along the permanently wet inner margin in main channel. They are either floating plants with stems forming dense mat, with leaves and flowers above water or rooted in the sand/peat. They prefer flowing water to standing water.

Vossia cuspidata is a robust, perennial grass with spongy, floating, creeping stems, associated with deep, permanent water. It is rooted in the channel bed, but the extremely long, floating stems can trail out into the current. *Cyperus papyrus* is a large, perennial sedge with stout creeping stems and erect stems in permanent swamps and on the margins of large rivers.

Papyrus and hippo grass respond slightly differently to flow but as a general rule they do not occur at the same site (or at least they dominate at different sites). Hippo grass will survive as long at there is water to cover its roots, and its leaves will float higher or lower as water level rises or falls. It can tolerate more desiccation than can papyrus.

These plants are used as indicators for Sites 4, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	PD	NSC	NSC	PD	NSC	NSC
5	PD	NSC	NSC	<PD	<PD+>MS	PD+>MS
6	PD	=PD+>LS	=PD+>LS	<PD	PD+>MS	PD+>MS

5.4.3 Indicator 3: Upper wetbank 1 (reeds)

Representative species: *Phragmites australis.*

Summary of characteristics

Phragmites grows on the outer edges of the main channel. It is typically emergent vegetation with its roots wet, but can withstand being out of water provided the soils are water logged. It reproduces vegetatively by means of stolons (underground horizontal stems) and rapidly colonises new areas, extending into areas that are further away from water and often becoming the dominant plants. It does not need flowing water but it does best where there is at least some soil moisture. With a lowering of the volume and duration of flooding it is likely to expand into areas occupied by the indicators on either side of it.

These plants are used as indicators for Sites 1, 2, 3, 4, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different.

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	PD	NSC	NSC	PD	NSC	NSC
3	PD	NSC	NSC	PD	NSC	NSC
4	PD	NSC	NSC	PD	NSC	NSC
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC

5.4.4 Indicator 4: Upper wetbank 2 (trees/shrubs)

Representative species: *Searsia (Rhus) quartiniana, Ziziphus mucronata.*

Summary of characteristics

Searsia (Rhus) quartiniana is a dense shrub or tree with a wide range of ecological tolerances within the context of perennial rivers. It is found along the banks and floodplains of perennial rivers, on islands in permanent swamps, as well as occasionally in ephemeral watercourses. *Ziziphus mucronata* is found in a variety of different habitats; very often close to water, but can also be found far from water.

These plants are used as indicators for Sites 1, 2, 4 and 5.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different.

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
3	n/a	n/a	n/a	n/a	n/a	n/a
4	<PD	PD+>LS	PD+>LS	<PD	<PD+>MS	PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a

5.4.5 Indicator 5: River dry bank

Representative species: *Combretum imberbe*, *Acacia tortilis*, *Albizia versicolor*, *Ficus sycomorus*, *Garcinia livingstonei* and *Diospyros mespiliformis*[3].

Summary of characteristics

This group of species comprises large trees and dense shrubs that grow on the outer margins of river banks. They are important for stabilising the river bank, and filter runoff from the adjacent catchment. They grow near water but generally not in the water, although some can withstand short periods of inundation. These trees and shrubs get their water via groundwater seepage from the river.

These plants are used as indicators for Sites 1, 2, 3, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	PD	NSC	NSC	PD	NSC	NSC
3	PD	NSC	NSC	PD	NSC	NSC
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC

5.4.6 Indicator 6: Floodplain dry bank

Representative species: *Combretum imberbe*, *Acacia tortilis*, *Albizia versicolor*, *Ficus sycomorus*, *Garcinia livingstonei* and *Diospyros mespiliformis.*

Summary of characteristics

This group comprises the same species are Indicator 5: River dry bank. The difference between them lies in the fact that this groups grows on the outer margin of the floodplain, which means that they are more dependent on periodic inundation of the floodplain than are their riverbank counterparts.

These plants are used as indicators for Site 6.

[3] Different species occur at different sites.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	NSC	NSC	NSC	NSC

5.4.7 Indicator 7: River floodplain residual pools

Representative species: *Nymphaea nouchali* var. *caerulea*

Summary of characteristics

The plants of this community are all dependent on standing or slow-flowing, permanent water, which is linked to and recharged by the main river. This is a seasonal effect as rain will fill the pools during the rainy season and flood-waters will fill them during the flood season.

These plants are used as indicators for Sites 3, 4 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>>PD+>>LS	<PD	<PD+>MS	>>PD+>>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	NSC	PD	NSC	NSC

5.4.8 Indicator 8: River lower floodplain

Representative species: *Miscanthus junceus, Persicaria* spp., *Ludwigia* spp.

Summary of characteristics

These plants are found in the deeper depressions on the floodplains, which receive water from the river at high flow and presumably retain water for long periods, based on the water-loving species that are found in them. The group comprises a mixture of species that prefer permanent water or grow on dry land but close to water (*Persicaria, Ludwigia*). They are all tolerant of total inundation for long periods and desiccation for varying periods. Their leaves float on the surface of the water, while the flowers are held above the water.

Miscanthus junceus (swamp savanna grass/pampas grass) is an important floodplain thatching grass in Namibia (Barnes, in litt. 2009).

These plants are used as indicators for Sites 3, 4 and 6.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	>PD	<PD+>LS	<PD+>LS	<PD	<PD+>MS	PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	>PD+>LS	PD	NSC	NSC

5.4.9 Indicator 9: River middle floodplain

Representative species: *Setaria*, *Panicum*, *Vetiveria nigritana*[4], thatching grasses.

Summary of characteristics

Plants in this group are able to grow in areas away from water, but thrive in seasonally wet areas. They are found predominately on the middle floodplain, on either clay or sand. There tend to be large areas dominated by thatching and grazing grasses. An increase in the length of inundation may be detrimental, but they would probably survive longer dry periods.

These plants are used as indicators for Sites 3, 4 and 6.

[4] Angolan sites and the Panhandle.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	NSC	<PD+<LS	PD	PD+<MS	<<PD+<<MS
4	>PD	PD+<LS	<PD+<<LS	>PD	NSC	PD+<MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	<PD+<LS	PD	NSC	<PD+<MS

5.4.10 Indicator 10: River upper floodplain (islands)

Representative species: *Searsia* (Rhus) with *Acacia hebeclada*, *Acacia sieberiana*, *Diospyros lycioides*, grasses.

Summary of characteristics

These are the highest points on the floodplain itself and are seldom inundated. Long inundation is detrimental to these plants. They are, however, dependent on some inundation to recharge ground water, and for nutrients. The plant community is comprised of grasses, shrubs, a few trees, and is equivalent to the wildlife discipline's secondary floodplain.

These plants are used as indicators for Sites 2 and 4.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	PD	NSC	NSC	PD	NSC	NSC
3	n/a	n/a	n/a	n/a	n/a	n/a
4	PD	NSC	NSC	PD	NSC	NSC
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a

5.4.11 Delta (Site 7) Indicators

The indicators used for Site 7: Okavango Delta at Xaxanaka are:

1. Open water
2. Permanent swamps
3. Lower floodplain
4. Upper floodplain
5. Occasionally-flooded grassland
6. *Sporobolus* islands (These are small islands that form on termitaria in the seasonal grasslands).
7. Riparian woodland, trees
8. Savanna, scrub.

These represent a gradient of wetness from open water through to savanna. Under natural conditions proportion of these vegetation types fluctuates with climatic variation. Essentially, under wet conditions there will be a predominance of open water, permanent swamp and lower floodplains. If conditions dry out, the relative extent of upper floodplain and occasionally-flooded grasses will increase. If conditions were to dry out further, there would be a gradual terrestrialisation of the delta and large portions thereof would revert to savanna, with small *Sporobolus* islands on termitaria. If, however, conditions in the delta get wetter then the open water, permanent swamp and floodplain vegetation would increase.

Impact of the Low and Medium Scenarios under Climate Change

The relative proportions of the vegetation indicators in the study area under present day, and the low and medium scenarios with two levels of climate change are shown in Figure 5-2 to Figure 5-8, respectively.

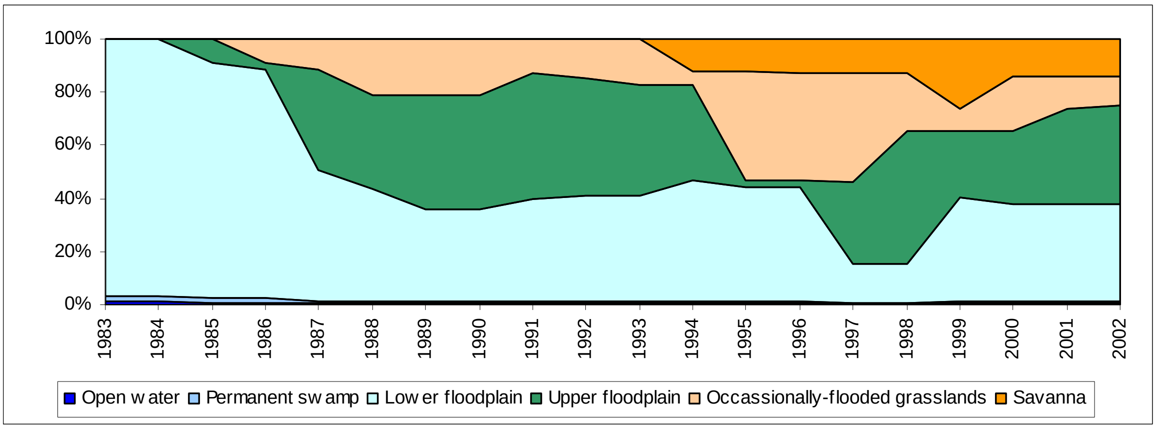


Figure 5-2 Proportions of the vegetation indicators in the study area over a 20-year period under present-day conditions.

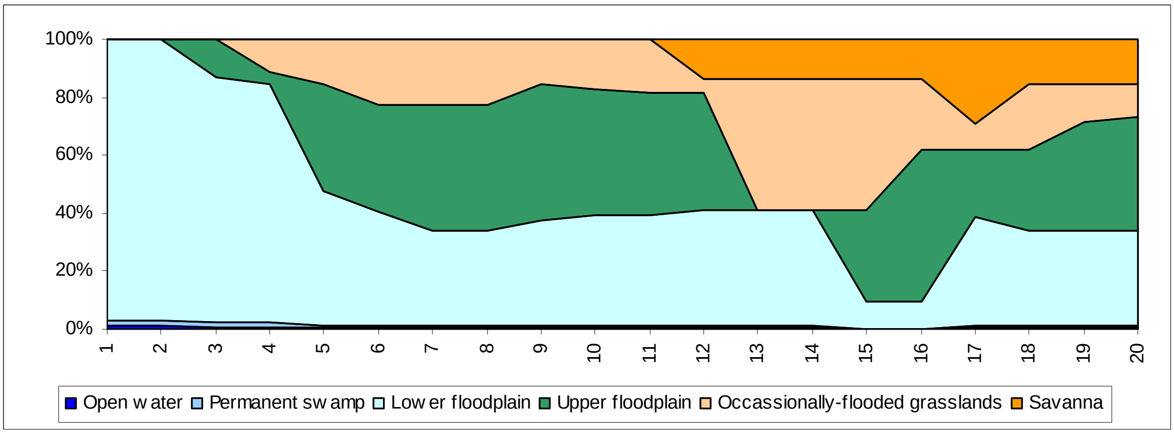


Figure 5-3 **Proportions of the vegetation indicators in the study area over a 20-year period under the low scenario.**

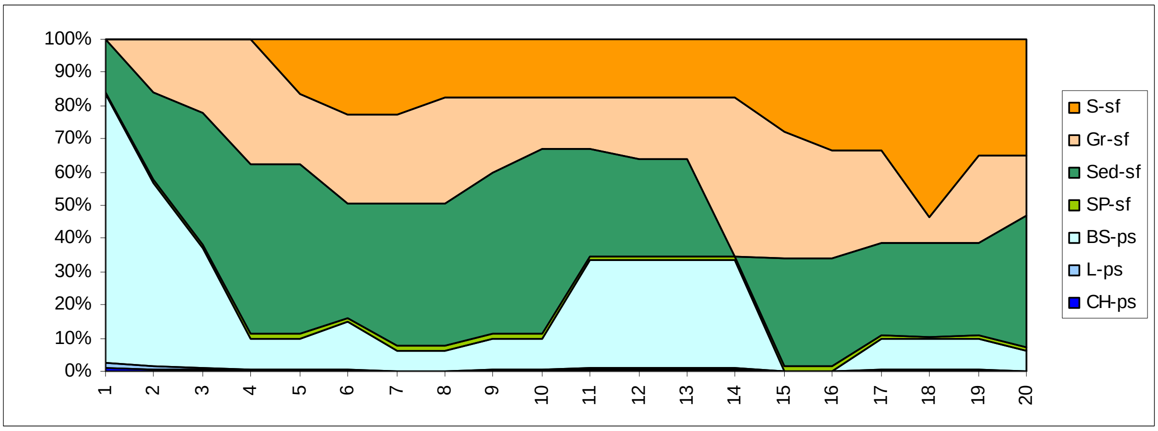


Figure 5-4 **Proportions of the vegetation indicators in the study area over a 20-year period under the low scenario with the driest estimate of climate change.**

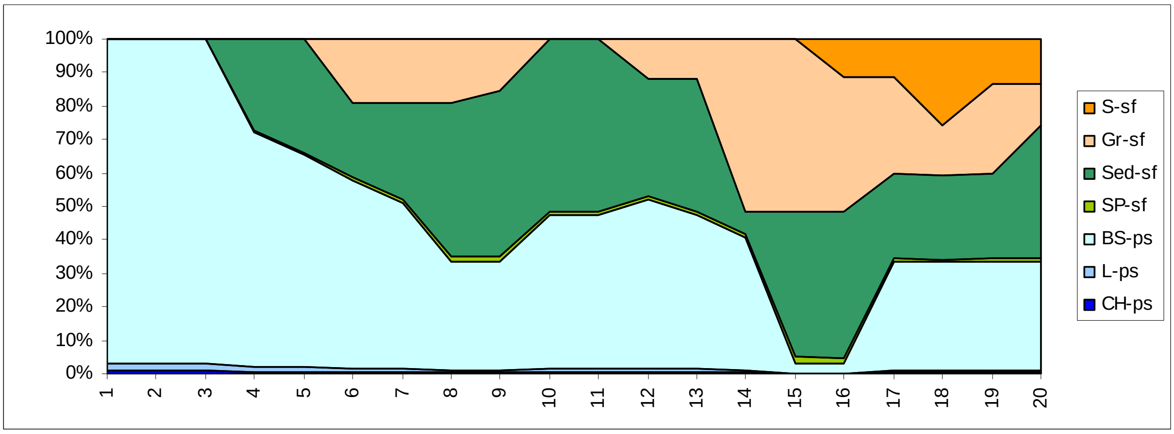


Figure 5-5 **Proportions of the vegetation indicators in the study area over a 20-year period under the low scenario with the wettest estimate of climate change.**

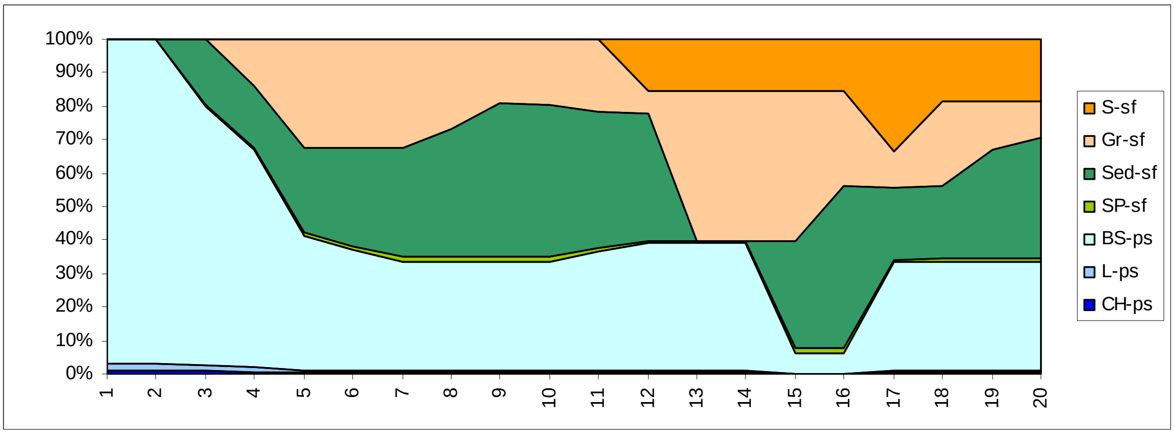


Figure 5-6 **Proportions of the vegetation indicators in the study area over a 20-year period under the medium scenario.**

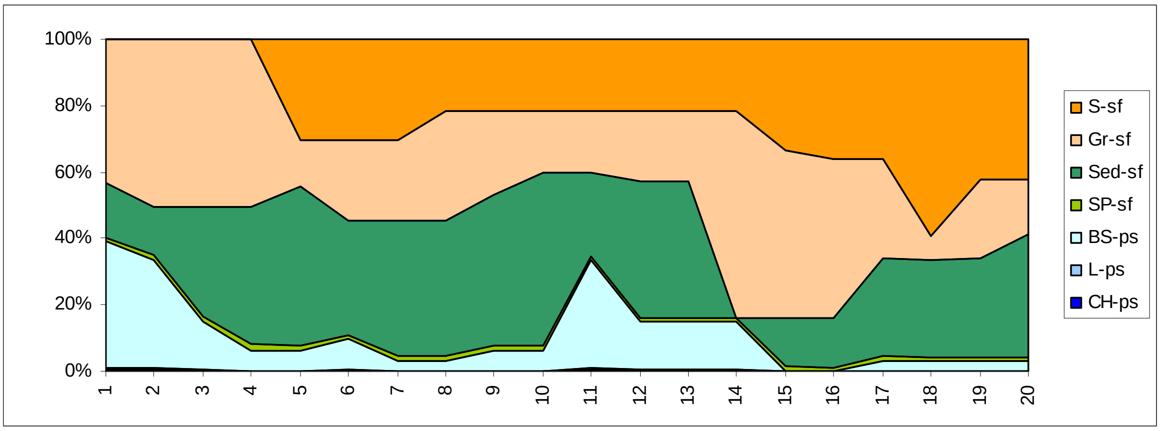


Figure 5-7 **Proportions of the vegetation indicators in the study area over a 20-year period under the medium scenario with the driest estimate of climate change.**

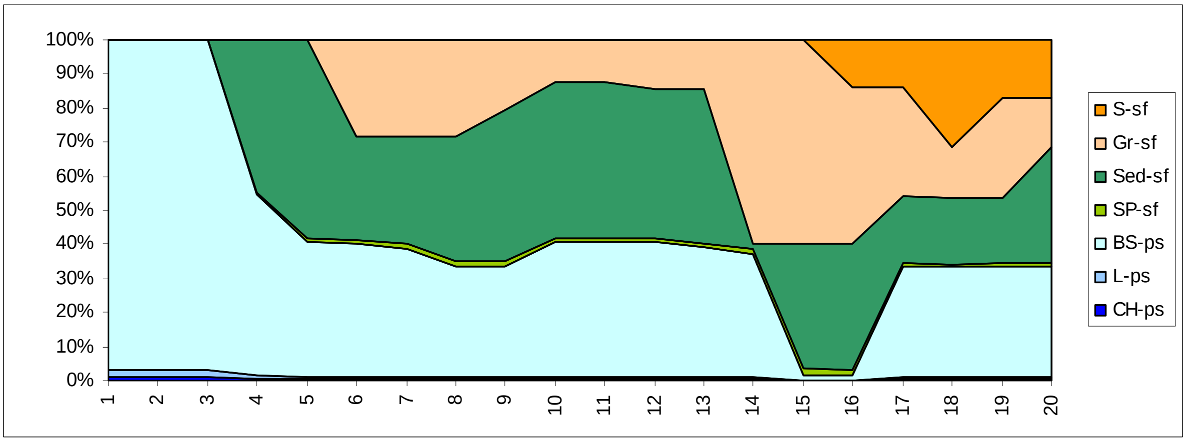


Figure 5-8 **Proportions of the vegetation indicators in the study area over a 20-year period under the medium scenario with the wettest estimate of climate change.**

There were some slight effects evident in the delta under the low and medium scenarios, but these were predicted to be negligible. However, under the driest climate change, these effects would be more marked, and there will be a significant increase in savanna habitats, and gradual terrestrialisation of the Delta. This would of course be exacerbated by water-resource developments in the upper catchment. The wettest predicted climate change, even with low and medium development, will result in a wetter delta than present day, and the proportions of swamp plants are predicted to increase as a consequence.

5.4.12 Boteti (Site 8) Indicators

The indicators used for Site 8: Boteti River are:

1. Open water
2. Riparian woodland, trees.

Open water species occur in the Boteti River when the river course is inundated, when there are isolated pools. The riparian woodland species on the other hand tend to persist for some time (possibly as long as 50 years) even when the river is dry, as they are able to access groundwater. Prolonged periods of no flow would, however, result in a gradual decline in these species.

The relative extent of inundation, isolated pools and dry river bed in the Boteti River varies with climatic variations. Under present day conditions, in wet periods as much as 100% of the channel can become inundated and remain that way for several years. In dry periods however, surface water in the Boteti River can dry up for extended periods, although people are still able to access water by sinking wells into the river bed.

Impact of the Low and Medium Scenarios under Climate Change

Under the low and medium scenarios without climate change and with the wettest climate change scenarios there was little change expected the riparian vegetation of the Boteti. Under the driest climate change however, there will be a significant decline in the cover of woodlands species as a result of extended periods on no-flow.

5.4.13 Summary of vegetation responses to scenarios

The riparian vegetation can loosely be divided into in-channel vegetation, floodplain-pool vegetation, marginal vegetation, floodplain grasses and riparian trees and shrubs. In general, the in-channel vegetation, floodplain-pool vegetation and marginal vegetation are more dependent on lowflows and the floodplain grasses, and riparian trees and shrubs on flood flows. The climate change predictions for the upper catchment slightly reduce the expected impact of the low and medium developments at Sites 1, 2 and 4, but this is mainly in the floodplains in response to expected increases in flood peak and duration. In the delta and at Boteti, the drier climate change predictions will exacerbate the impacts of the low and medium scenarios.

5.5. Aquatic macroinvertebrates

5.5.1 Indicator 1: Invertebrates in channel submerged vegetation

Representative species: Crustacea (Freshwater shrimps).

Summary of characteristics

Water must always be present. At minimum flow habitat will be greatly reduced leading to population decline as predation increases.

These invertebrates are used as indicators for Site 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
6	PD	NSC	<PD+<LS	PD	NSC	NSC

5.5.2 Indicator 2: Invertebrates in channel marginal vegetation

Representative species: Crustacea (Freshwater shrimps).

Summary of characteristics

Water must always be present. High, long-duration flooding may lead to destruction of habitat and reduction in abundance. Long duration of minimum flows restricted to the river bed may also lead to loss of habitat.

These invertebrates are used as indicators for Sites 1, 2, 3, 4, 5, 6 and 8.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	NSC
2	<PD	PD+>LS	PD+>LS	<PD	<PD+>MS	PD+>MS
3	PD	NSC	<PD+<LS	PD	NSC	<PD+<MS
4	PD	NSC	NSC	PD	NSC	NSC
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC
7	n/a	n/a	n/a	n/a	n/a	n/a
8	<PD	<<PD+<<LS	>>PD+>>LS	<PD	<<PD+<<MS	>>PD+>>MS

5.5.3 Indicator 3: Invertebrates in channel fine sediments

Representative species: Unionidae, Sphaeridae.

Summary of characteristics

This group of invertebrates lives under the sediments of the river bed. They will normally survive as long as there is some water covering the sediment. Long dry spells will reduce abundance or even eliminate these indicators.

These invertebrates are used as indicators for Sites 1, 4, 5 and 6.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	PD	NSC	NSC	PD	NSC	NSC
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC
7	n/a	n/a	n/a	n/a	n/a	n/a
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.4 Indicator 4: Invertebrates of channel cobbles and boulders

Representative species: Hydropsychidae, Ecnomidae.

Summary of characteristics

This group of indicators lives among the cobbles and boulders of rocky river beds. They will decline in abundance and may disappear if exposed to long duration of low flows that expose the rocks.

These invertebrates are used as indicators for Sites 2, 5 and 8.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	PD	NSC	NSC	PD	NSC	NSC
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	NSC	NSC	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a
7	n/a	n/a	n/a	n/a	n/a	n/a
8	<PD	<<PD+<<LS	>PD+>LS	<PD	<<PD+<<MS	>PD+>MS

5.5.5 Indicator 5: Invertebrates of fast-flowing channels

Representative species: Simuliidae, Hydropsychidae.

Summary of characteristics

These species inhabit fast-flowing sections of channels, where they depend on the flow of water to provide food in suspension, which they collect from the current. They must live in water throughout their lives. They will reduce in abundance and may disappear if flow slows and water levels drop to expose the river bed.

These invertebrates are used as indicators for Sites 2,5 and 7

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	PD	NSC	NSC	PD	NSC	NSC
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	PD	NSC	NSC	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a
7	<PD	<PD+<LS	PD+>LS	<PD	<<PD+<<MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.6 Indicator 6: Invertebrates in channel bedrock pools

Representative species: Dytiscidae.

Summary of characteristics

The representative species is dytiscid diving beetles that inhabit pools in bedrock. High, long-duration flooding will destroy this habitat through constant scouring flows while long durations of low flows may result in the pools drying out and all habitat being lost.

These invertebrates are used as indicators for Site 2.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	PD+>LS	PD+>LS	<PD	NSC	NSC
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a
7	n/a	n/a	n/a	n/a	n/a	n/a
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.7 Indicator 7: Invertebrates of floodplain marginal vegetation

Representative species: Coenagrionidae, Physidae, Planorbidae.

Summary of characteristics

The species inhabit vegetation growing at the sides of wet channels. They need water at all times. Drying out of floodplains consequent to prolonged low flows will reduce or eradicate their habitat and their abundances will decline accordingly.

These invertebrates are used as indicators for Sites 3 and 4.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	>>PD+>>LS	>>PD+>>LS	PD	>>PD+>>MS	>>PD+>>MS
4	<PD	PD+>LS	>PD+>LS	PD	NSC	>PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a
7	n/a	n/a	n/a	n/a	n/a	n/a
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.8 Indicator 8: Invertebrates of seasonal floodplain pools and backwaters

Representative species: Dytiscidae

Summary of characteristics

These species inhabit backwaters and temporary pools in seasonal floodplains. Drying out of these areas will eradicate their habitat.

These invertebrates are used as indicators for Sites 4, 6 and 7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	<PD	NSC	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	PD	NSC	>PD+>LS	<PD	<PD+>MS	PD+>MS
7	<PD	<PD+<LS	PD+>LS	<PD	<<PD+<<LS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.9 Indicator 9: Invertebrates of mopane woodland pools

Representative species: Lyncedae, Daphnidae, *Gammarus* sp.

Summary of characteristics

Pools in mopane woodlands are rain-fed and so not dependent on flow regimes. Areas of mopane woodland will expand where seasonal floodplains receive less flooding.

These invertebrates are used as indicators for Site 7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	n/a	n/a	n/a	n/a	n/a	n/a
6	n/a	n/a	n/a	n/a	n/a	n/a
7	>PD	>>PD+>>LS	<PD+<LS	>PD	>>PD+>>MS	<PD+<MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.5.10 Summary of aquatic invertebrate responses to scenarios

With the exception of Site 1, the Low and Medium Scenarios are expected to have a low to negligible impact on all indicators. In the upper catchment, Sites 1 and 2, the climate change predictions result in little or no change from the original low and medium scenarios. In the middle and lower catchment, Sites 4, 5, 7, and 8, the wettest scenario will result in an increase in floodplain invertebrates. In the lower catchment, however, the direst climate change predictions will exacerbate the flow related impacts of development.

5.6. Fish

5.6.1 Indicator 1: Fish resident in river

Representative species: Tigerfish [*Hydrocynus vittatus*]

Summary of characteristics

This fish guild spends most of its time in the main channel, undertaking longitudinal migrations along the river system. They require deep, clear, running water and pools throughout the year. They respond readily to seasonal and annual flow variability, increasing in abundance up to double their median numbers in wet years/cycles and decreasing in abundance to possibly half their median numbers in dry years/cycles. Natural variability in abundance is greater in the upper basin and less from Site 5 (Popa) downstream probably due to a less flashy hydrograph. Numbers can decline to zero in the Site 8 (Boteti) as this ephemeral river periodically dries out. Changes in the natural flow pattern, increased turbidity and deteriorating water quality will affect this guild of fish negatively.

These fish are used as indicators for Sites 1, 2, 3, 4, 5, 6, 7 and 8.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	<<PD	NSC	NSC	<<PD	NSC	<PD+>MS
2	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	PD+>MS	>PD+>MS
5	PD	NSC	NSC	<PD	PD+>MS	>PD+>MS
6	<PD	<PD+<LS	<PD+<LS	<PD	PD+>MS	>PD+>MS
7	<PD	<<PD+<<LS	PD+>LS	<PD		
8	<PD	<<PD+<<LS	>PD+>LS	<PD		

5.6.2 Indicator 2: Migratory floodplain dependent fish: small species

Representative species: Bulldog [*Marcusenius macrolepidotus*]

Summary of characteristics

These are small-bodied fish species that are dependent on lateral migration to floodplains for breeding and feeding. They are resident in the river through the lowflow season and migrate into floodplains during the flood season for feeding, breeding and protection against predation. As a result they depend on regular flooding of shallow vegetated floodplains in the flood season. They are also reliant on deeper [>50 cm] refuges during low flow conditions. Major disruptions of the flooding patterns or sedimentation regimes will have a detrimental effect on this species. However, minor changes that fall within the natural variability will not have a major effect on these species.

These small, relatively short-lived fish can respond quickly, and increase to large numbers, under good flooding conditions. As such their numbers are highly variable even under present day (350-50%, and possibly even higher) as they track climatic variations in the system.

These fish are used as indicators for Sites 1, 2, 3, 4, 5, 6 and 7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	<PD+>MS
2	<PD	<PD+>LS	>PD+>LS	<<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
5	<PD	NSC	PD+>LS	<PD	<PD+>MS	>PD+>MS
6	<PD	NSC	PD+>LS	<PD	<PD+>MS	PD+>MS
7	<PD	<<PD+<<LS	PD+>LS	<PD	<<PD+<<MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.6.3 Indicator 3: Migratory floodplain dependent fish: large species

Representative species: Redbreast tilapia [*Tilapia rendalli*]

Summary of characteristics

These are large-bodied fish species that are dependent on lateral migration to floodplains for breeding and feeding. They are resident in the river through the lowflow season and migrate into floodplains during the flood season for feeding, breeding and protection against predation. As a result they depend on regular flooding of shallow vegetated floodplains in the flood season. They are also reliant on deeper [>200 cm] refuges during low flow conditions. Major disruptions of the flooding patterns or sedimentation regimes will have a detrimental effect on this species. However, minor changes that fall within the natural variability will not have any major effect on these species.

These large, relatively long-lived fish can respond quickly, and increase numbers, under good flooding conditions, but their numbers tend to be less variable year-on-year than those of the small-bodies counterparts (Indicator 2).

These fish are used as indicators for Sites 1, 2, 3, 4, 5, 6 and 7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	<<PD+>MS
2	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	PD	NSC	>PD+>LS	<PD	PD+>MS	>PD+>MS
6	>PD	NSC	>PD+>LS	<PD	<PD+>MS	PD+>MS
7	PD	<<PD+<<LS	NSC	<PD	<<PD+<<MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.6.4 Indicator 4: Sandbank dwelling fish

Representative species: Sand catlet [*Leptoglanis cf dorae*]

Summary of characteristics

This group of species lives on actively moving sandbanks and habitats with sandy bottoms. As such they are dependent on flows that maintain sandbanks. However, the real issue here is not water but the fact that dams and weirs trap sediment. Downstream of a weir or dam the river is deprived of sediment, so it erodes its bed, banks and floodplains until it is once again carrying its maximum load. Thus, for some distance downstream of a weir or dam the sandbanks will be removed.

These fish are used as indicators for Sites 1, 2, 3, 4, 6 and 7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	<<PD	NSC	NSC	<<PD	NSC	<<PD+>MS
2	<PD	<PD+>LS	<PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	PD	NSC	NSC	PD	NSC	NSC
5	n/a	n/a	n/a	n/a	n/a	n/a
6	<PD	NSC	NSC	<PD	<PD+>MS	PD+>MS
7	<PD	<<PD+<<LS	PD+>LS	<PD	<<PD+<<MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.6.5 Indicator 5: Rock dwelling fish

Representative species: Sand catlet [*Leptoglanis cf dorae*]

Summary of characteristics

These are rheophillic (flow-loving) species of riffles and rapids, which are usually found living amongst the rocks and in crevices in strongly flowing water. Unlike some of the other groups these fish tend to be resident in a particular part of the river and their numbers show much less marked fluctuations under present day.

These fish are used as indicators for Sites 2, 4 and 5.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	>PD+>LS	PD>+>LS	<PD	<PD>MS	<PD>MS
3	n/a	n/a	n/a	n/a	n/a	n/a
4	<PD	PD+>LS	<PD+LS	<PD	NSC	NSC
5	PD	NSC	<PD+<LS	PD	NSC	NSC
6	n/a	n/a	n/a	n/a	n/a	n/a
7	n/a	n/a	n/a	n/a	n/a	n/a
8	n/a	n/a	n/a	n/a	n/a	n/a

5.6.6 Indicator 6: Marginal vegetation fish

Representative species: Banded tilapia [*Tilapia sparrmanii*].

Summary of characteristics

This group of species lives mainly amongst vegetation on margins of river and may move into floodplains during flood conditions. As such they are depend on the presence of marginal vegetation, stable soils and naturally varying water levels for establishment of emergent and submerged vegetation.

These fish are used as indicators for Sites 1, 2, 3, 4, 5, 6, 7 and 8.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	<<PD+>MS	<<PD+>MS	<<PD	<<PD+>MS	<<PD+>MS
2	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	PD	NSC	>PD+>LS	PD	NSC	NSC
5	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
6	PD	NSC	>PD+>LS	<PD	PD+>MS	PD+>MS
7	<PD	<<PD+<<LS	PD+>LS	<PD	<<PD+<<MS	NSC
8	<PD	<PD+<LS	>PD+>LS	<PD	<PD+<MS	>PD+>MS

5.6.7 Indicator 7: Backwater dwelling fish

Representative species: Okavango tilapia [*Tilapia ruweti*]

Summary of characteristics

This group of species shares a similar habitat with the marginal vegetation group but tends to be more restricted to vegetated backwater areas and pools. They may also move into floodplains during flood conditions. Their continued presence is dependent on the maintenance of oxbows and pools on the margin of the floodplain of the river by the hydrological regime, including standing-water conditions during low flow.

These fish are used as indicators for Sites 4, 6 and 7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	n/a	n/a	n/a	n/a	n/a	n/a
6	<PD	NSC	>PD+>LS	<PD	<PD+>MS	PD+>MS
7	<PD	<<PD+<LS	PD+>LS	<PD	<<PD+<MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.6.8 Summary of fish responses to scenarios

With the exception of Site 1, where fish losses are expected to be high for both scenarios, mainly as a result of run-of-river abstraction during the lowflow season, the fish assemblages are expected to cope fairly well with the low scenario, and slightly less well with the medium scenario.

Under the climate change predictions, in the upper catchment (again with the exception of Site 1), the flow impacts of water resource developments under the low and medium scenario are significantly offset for both the driest and the wettest predictions. In the lower catchment, however, the impacts of the low and medium scenario are significantly greater under the drier climate change predictions, as this results in a general drying out of the lower part of the catchment as a result of higher evaporation. Under the wetter climate change predictions, the expected impacts in the lower catchment under the low and the medium scenario are reduced.

5.7. Wildlife

5.7.1 Indicator 1: Semi aquatic animals

Representative species: Hippopotamus, crocodile, otters, monitors and terrapins.

Summary of characteristics

These animals dwell in the main channel, and also range over banks, floodplains and islands. They are particularly sensitive to dry-season water depths, as they need sufficient water to maintain their aquatic habitat but not too much so that islands are present. The DSS predicts that they will increase in abundances in wet cycles and decrease during dry cycles.

These animals are used as indicators for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	NSC
2	<PD	<PD+>LS	PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	<PD+>LS	PD+>LS	<PD	<PD+>MS	PD+>MS
5	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
6	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
7	<PD	<PD+<LS	PD+>LS	<PD	<PD+<MS	NSC
8	<PD	<PD+<LS	>PD+>LS	<PD	<PD+<MS	>PD+>MS

5.7.2 Indicator 2: Frogs, snakes and small mammals

Representative species: snakes, ridged frogs, musk shrews.

Summary of characteristics

These animals inhabit pools, permanent swamps and the lowest floodplain areas. They are particularly sensitive to dry-season water levels and duration, and reduced floods, as they depend on backwaters and marginal vegetation.

These animals are used as indicators for Sites 2-7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	<PD+>LS	PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>>PD+>>LS	>>PD+>>LS	PD	>>PD+>>MS	>>PD+>>MS
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
6	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
7	<PD	<PD+<LS	PD+>LS	<PD	<PD+<MS	PD+>MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.7.3 Indicator 3: Lower floodplain grazers

Representative species: Lechwe, sitatunga, reedbuck, waterbuck.

Summary of characteristics

The species in this indicator rely on grazing in areas of permanent swamp, and primary and secondary floodplain. These areas need floods for 4-6 months per year.

The animals are used as indicators for Sites 1-3 and 5-8.They would also have occurred at Site 4: Kapako, but this is no longer the case and cattle have no replaced them.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	<PD+>LS	<PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
6	<PD	NSC	PD+>LS	<PD	<PD+>MS	PD+>MS
7	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	>PD+>LS	<PD	<<PD+<<LS	>PD+>LS

5.7.4 Indicator 4: Middle floodplain grazers

Representative species: elephant, buffalo, tsesebe, warthog.

Summary of characteristics

This guild of animals depends for grazing on primary and secondary floodplains, which flood for 2-6 months per year.

These animals are used as indicators for Sites 2, 3, 5, 7 and 8.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	PD+>LS	>PD+>LS	<PD	NSC	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	n/a	n/a	n/a	n/a	n/a	n/a
5	<PD	>PD+>LS	>>PD+>>LS	<PD	<PD+>MS	>PD+>MS
6	n/a	n/a	n/a	n/a	n/a	n/a
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.7.5 Indicator 5: Outer floodplain grazers

Representative species: Wildebeest, zebra, impala, duiker, aarvark, mice.

Summary of characteristics

This group of animals relies for grazing on secondary and tertiary floodplains that must flood periodically.

They are used as indicators for Sites 1-3 and 5-7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	NSC
2	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	n/a	n/a	n/a	n/a	n/a	n/a
5	<PD	PD+>LS	>>PD+>>LS	<PD	<PD+>MS	>PD+>MS
6	n/a	n/a	n/a	n/a	n/a	n/a
7	>PD	>PD+>LS	<PD+<LS	>PD	>PD+>MS	NSC
8	n/a	n/a	n/a	n/a	n/a	n/a

5.7.6 Summary of wildlife responses to scenarios

Abundances of wildlife are predicted to decline progressively with increasing water-resource development. The notable exception to this is the Delta, where the three indicator groups of grazers would benefit from the scenarios as permanent swamp gave way to seasonal floodplains. Many of the wildlife species no longer occur at the other floodplain sites, but in areas where they do occur, similar patterns would be expected in response to the scenarios.

In the upper catchment, these patterns would be reversed for both sets of predictions (drier and wetter). In the lower catchment, however, specifically in the Delta and Boteti, the trends shown for the low and medium scenarios without climate change, would be exacerbated under the drier climate change predictions, as the increased evaporation that accompanies these predictions would lead to the Delta becoming drier than present. Although grazers would benefit initially as permanent swamp gave way to seasonal floodplains, they may show an eventual decline as wetlands give way to savanna.

Under the wetter climate change predictions, some of the flow reductions as a result of development would be offset by higher flows in the rivers, and thus a higher inflow into the Delta and Boteti.

5.8. Birds

5.8.1 Indicator 1: Piscivores of open water.

Representative species: kingfisher, cormorant, darter, fish eagle.

Summary of characteristics

This group of birds predominantly feeds on fish from the river and adjacent pools. They generally thrive in times of low flow because their fish prey is more concentrated and vulnerable in the main river and/or isolated pools. The DSS indicates that present-day conditions produce more variability in abundances in the higher parts of the basin than in the lower parts, and abundances are generally lower in wet years and higher in drier years. If low flows are prolonged, however, the prey base will be negatively affected if the floodplains where fish breed are not inundated.

These birds are used as indicators for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
3	PD	NSC	>PD+>LS	PD	NSC	>PD+>MS
4	>PD	>PD+<LS	PD+<LS	>PD	>PD+<MS	PD+<MS
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	>PD	PD+<MS	<PD+<MS
7	>PD	>PD+>LS	>PD+>LS	>PD	>PD+>MS	NSC
8	<PD	<PD+<LS	>PD+>LS	<PD	<<PD+<MS	>PD+>MS

5.8.2 Indicator 2: Piscivores of shallow waters

Representative species: larger herons and egrets.

Summary of characteristics

These birds hunt fish from overhanging trees on shallow backwaters using ambush techniques. Under Present Day conditions, the DSS indicates that their numbers tend to be lower in drier years, with good variability from year to year and many years with above median abundances. In the lower part of the basin they are less abundant in the lagoon and savanna parts of the Delta/Boteti and rather favour the seasonally flooded areas. Shallow waters in the main channels and on the floodplains concentrate the prey species into smaller areas and hunting opportunities are thus better than in lagoon areas.

These birds are used as indicators for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	NSC
2	<<PD	<PD+>LS	PD+<LS	<<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>>PD+>>LS	PD	>PD+>MS	>PD+>MS
4	>PD	PD+<LS	PD+<LS	>PD	PD+<MS	PD+<MS
5	PD	NSC	<PD+<LS	PD	NSC	<PD+<MS
6	>PD	PD+<LS	<PD+<LS	>PD	>PD+<MS	PD+<MS
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	PD+>LS	<PD	<<PD+<MS	PD+>MS

5.8.3 Indicator 3: Piscivores and invertebrate feeders

Representative species: Little Egret, Black Heron, Glossy Ibis, Saddle-billed Stork, Lapwings.

Summary of characteristics

This group of birds feeds on fish-fry and invertebrates when water levels are receding after spawning in flood-plains; they also feed on fish trapped in drying pools. They respond to the flooding and draining of floodplains, when feeding conditions are optimal, and tend to be more abundant in wetter years.

These birds are used as indicators for all eight sites.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<<PD	NSC	NSC	<<PD	NSC	NSC
2	<PD	PD+>LS	PD+>LS	<PD	<PD+>MS	<PD+>MS
3	PD	>PD+>LS	>>PD+>>LS	PD	>PD+>MS	>>PD+>>MS
4	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	<PD	NSC	>PD+>LS	<PD	NSC	>PD+>MS
7	PD	>PD+>LS	NSC	PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	PD+>LS	<PD	<PD+<MS	>PD+>MS

5.8.4 Indicator 4: Specialists of floodplains

Representative species: African Openbill, ducks, geese, Wattled Crane.

Summary of characteristics

This group of birds feeds on molluscs, frogs, fish or selective vegetation and organisms occurring in shallow floodplains. They utilise newly-flooded floodplains because food availability is optimal due to new breeding and germination activities. They also take advantage of times when waters are receding from floodplains and food items are confined and concentrated into smaller areas. Thus, times of both new inundation and receding of waters are vitally important to them. Abundances increase in wet years and decrease in dry years.

These birds are used as indicators for Sites 2, and 4-8. They were not used as indicators for Site 3 due to lack of information.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
2	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
3	n/a	n/a	n/a	n/a	n/a	n/a
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	<PD	>PD+>LS	>PD+>LS	<PD	NSC	>PD+>MS
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	>PD+>LS	<PD	<<PD+<MS	>PD+>MS

5.8.5 Indicator 5: Specialists of water-lily habitats

Representative species: African and Lesser Jacanas.

Summary of characteristics

This group frequents floodplain pools, in both rising and receding water levels, and also lily-pad covered inlets, both of which are essential feeding habitats. Whatever the flood regime, pockets of water lilies generally survive, either in backwaters, lagoons or isolated pools, providing suitable habitat for these birds, and so they appear less vulnerable to flow changes than some other indicators.

These birds are used as indicators for Sites 2-7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	PD	NSC	NSC	PD	NSC	NSC
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	PD+>LS	>PD+>LS	<PD	NSC	>PD+>MS
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	<PD	NSC	PD+>MS
7	PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	>PD+>LS	<PD	<<PD+<LS	>PD+>MS

5.8.6 Indicator 6: Specialists inhabitants of riparian fruit trees

Representative species: Turacos, bulbuls.

Summary of characteristics

This group of birds are specialist frugivores in riparian fruit trees; when the trees are in fruit they are an important food source for many bird species. The birds are indirectly influenced by changes in water flows because they depend on the fruit-bearing riparian trees, which in turn respond to changes in water flows. Because most of the trees are long-lived, there will be a time lag of several years after the onset of unfavourable flows before fruit production fails and the trees start dying from lack of water. Abundance of the birds should mirror to some extent that of the trees since if the trees die due to low flows, there will not be a source of food for the birds.

These birds are used as indicators for Sites 2-7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	n/a	n/a	n/a	n/a	n/a	n/a
2	<PD	NSC	PD+>LS	<PD	NSC	<PD+>MS
3	n/a	n/a	n/a	n/a	n/a	n/a
4	<PD	PD+>LS	>PD+>LS	<PD	<PD+>MS	>PD+>MS
5	PD	NSC	>PD+>LS	PD	NSC	>PD+>MS
6	PD	NSC	NSC	PD	NSC	NSC
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	<PD	<PD+<LS	>PD+>LS	<PD	NSC	>PD+>MS

5.8.7 Indicator 7: Breeders in reedbeds and floodplains

Representative species: Fan-tailed widowbird, weavers, bishops, herons and egrets.

Summary of characteristics

This guild of birds relies on reedbeds lining river banks and islands, and other vegetation that stands in water, for nest-building. This is a protective mechanism against predator access to their nests. The birds generally wait for high water levels before constructing nests, so that their nests do not become flooded and so that the water level stays high throughout the breeding cycle. The DSS predicts that they increase in abundance in wet years and decline in dry years.

These birds are used as indicators for Sites 1-7.

Impact of the Low and Medium Scenarios under Climate Change

‘No CC’ columns are relative to Present Day. ‘Driest CC’ and ‘Wettest CC’ columns are relative to relevant ‘No CC’ scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	**Low scenario**			**Medium scenario**		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	<PD	NSC	NSC	<PD	NSC	NSC
2	<PD	<PD+>LS	>>PD+>>LS	<PD	<PD+>MS	<PD+>MS
3	PD	NSC	NSC	PD	NSC	NSC
4	PD	NSC	>PD+>LS	<PD	<PD+>MS	PD+>MLS
5	PD	NSC	>PD+>LS	PD	NSC	>PD+>MS
6	PD	<PD+<LS	NSC	PD	<PD+<MS	NSC
7	>PD	>PD+>LS	>PD+>LS	>PD	>PD+>MS	>PD+>MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.8.8 Indicator 8: Breeders in overhanging trees

Representative species: Herons, cormorants, darters.

Summary of characteristics

These species are colonial breeders or solitary nesters in trees hanging over the water. The trees are critical to their breeding success, providing protection against predators, safety for the nest and a refuge for chicks as they begin to vacate the nest. They should not be affected by changing flows in this aspect of their lives as long as the trees are not affected.

These birds are used as indicators for Sites 1-7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	Driest CC	Wettest CC	No CC	Driest CC	Wettest CC
1	<PD	NSC	NSC	<PD	NSC	NSC
2	<PD	<PD+>LS	>PD+>LS	<PD	NSC	<PD+>MS
3	PD	>PD+>LS	>PD+>LS	PD	>PD+>MS	>PD+>MS
4	<PD	<PD+>LS	>PD+>LS	<PD	<PD+>MS	<PD+>MLS
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.8.9 Indicator 9: Breeders in banks

Representative species: Bee-eaters, Collared Pratincoles, lapwings.

Summary of characteristics

This guild of birds requires vertical banks for nest holes or grassy banks for nest sites and fledgling development (note that kingfishers have been excluded). The birds need reliably lowering water levels that expose vertical or grassy banks for breeding. They are not necessarily dependent on flow for their food supply, but will be affected if changing flows influence the moisture level and texture of the bank materials or if unexpected high flows flood their nests. The guild has not been included for Sites 1, 2 and 8.

These birds are used as indicators for Sites 3-7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a
3	PD	NSC	<PD+<LS	PD	NSC	<PD+<MS
4	PD	NSC	NSC	PD	NSC	NSC
5	PD	NSC	NSC	PD	NSC	NSC
6	PD	NSC	NSC	PD	NSC	NSC
7	>PD	>PD+>LS	<PD+<LS	>PD	>PD+>MS	PD+<MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.8.10 Indicator 10: Breeders on rocks and sandbars

Representative species: Rock Pratincole, African Skimmer, sandpipers, thick-knees.

Summary of characteristics

These species are totally dependent for nesting on rocks, sandbars and islands in the main river that emerge above the water. Low flow levels generally benefit them, as this is the time when sandbanks and rocks are exposed for breeding. Very low flows will result in sandbanks becoming accessible to predators, however, and negatively affect the food supply of those that eat floodplain-breeding fish. Unseasonal high flows could swamp nests.

These birds are used as indicators for Sites 1, and 5-7.

Impact of the Low and Medium Scenarios under Climate Change

'No CC' columns are relative to Present Day. 'Driest CC' and 'Wettest CC' columns are relative to relevant 'No CC' scenario. NSC = no significant change. PD = Present Day. LS = low scenario. MS = medium scenario. </> = slightly different; <</>> = significantly different

Site	Low scenario			Medium scenario		
	No CC	**Driest CC**	**Wettest CC**	**No CC**	**Driest CC**	**Wettest CC**
1	>PD	NSC	NSC	>PD	NSC	NSC
2	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a
5	>PD	>PD+<LS	<PD+<LS	>PD	>PD+<MS	<PD+<M
6	>PD	NSC	>PD+>LS	>PD	PD+<MS	PD+>LS
7	>PD	>PD+>LS	NSC	>PD	>PD+>MS	>PD+>MS
8	n/a	n/a	n/a	n/a	n/a	n/a

5.8.11 Summary of bird responses to scenarios

The increased flows in the upper catchment under the climate change have an ameliorating effect on the flow-related impacts of the low and medium scenarios, with the exception of Site 1 (Capico), where the effect is minimal. The same is true for the wettest climate change predictions in the lower parts of the catchment. However, this is probably insufficient to prevent local extinctions at Site 2 (Mucundi). The drier climate change predictions at Site 7 (Delta), conversely, are predicted to have mild to moderate increases in several indicators as open water and permanent swamp give way to seasonal grass and sedge lands.

As previously noted (Volume 1), birds are highly mobile and will soon arrive when conditions become favourable or leave when they are unfavourable provided they have other areas for them to arrive from or depart to.

6. Biophysical results: Integrity

6.1. Integrity ratings and classification of overall impact

The predictions presented in the previous Chapter were generated from the information provided by the biophysical specialists in the form of Response Curves. This is essentially a set of consequences for a particular indicator to changes in a range of flow categories expressed as Severity Ratings of that describe increase/decreases for an indictor on a scale of 0 (no measurable change) to 5 (very large change; see Section 1.3). These rating were then taken further to indicate whether that change would be a shift toward or away from the natural condition. The Severity Ratings hold their original numerical value of between 0 and 5, but are given an additional negative or positive sign, to transform them from *Severity Ratings* (of changes in abundance or extent) to *Integrity Ratings* (of shift to/away from naturalness), where (Brown and Joubert 2003):

- *toward natural* is represented by a positive Integrity Rating; and
- *away from natural* is represented by a negative Integrity Rating.

The Integrity Ratings were then used to place the three flow scenarios within a classification of overall discipline integrity and overall river condition, using the South African ecoclassification categories A to F (Table 6.1; DWAF 1999; Kleynhans 1996; Brown and Joubert 2003). The ecological integrity of a river is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of ecosystems of the region.

Table 6.1. The South African River Categories (DWAF 1999)

CATEGORY	DESCRIPTION
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Modifications have reached a critical level and the lotic 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.

Note : A D-category is widely considered to represent the lower limit of degradation allowable under sustainable development (e.g., Dollar et al. 2006; Dollar *et al*. In press).

In this study, the predictions provided by the specialists for each of the three were summarized in terms of their effects on the integrity of each discipline at each study site and the overall riverine ecosystem represented by each study site. If the present status of a river is say a B-category, a scenario with a negative Integrity Score would represent movement in the direction of a Category C-F river, whilst one with a positive score would indicate movement toward a Category A river.

6.2. Present-day ecological integrity for the study sites

The present day ecological integrity of the aquatic ecosystems at each of the eight study sites was determined using a Habitat Integrity Assessment (Kleynhans 1996). The Habitat Integrity Method uses easily assessed physico-chemical and habitat characteristics as surrogates for physical and biotic condition. The method is based on the qualitative assessment of a number of pre-weighted criteria that indicate the integrity of the instream and riparian habitats available for use by riverine biota (Table 6.2). The criteria used are the basis that anthropogenic modification of their characteristics can generally be regarded as the primary causes of degradation of the integrity of a river.

The assessment of the severity of impact of modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact).

The assessment was done using the professional judgement and experience of the study team, and was conducted on-site at each of the study sites. Assessments were made separately for instream and riparian components, and then combined and expressed as a percentage and subtracted from 100 to produce a score for overall Habitat Integrity.

Table 6.2 Criteria and weights used for the assessment (from Kleynhans 1996).

INSTREAM CRITERIA	WEIGHT	RIPARIAN ZONE CRITERIA	WEIGHT
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	100	TOTAL	100

The results of the assessments are presented in Table 6.3. The total scores for the instream and riparian zone components are then used to place the habitat integrity of both in a specific intermediate habitat integrity category. These categories are also indicated in Table 6.3.

Table 6.3 **Results of the Habitat Integrity (after Kleynhans 1996) assessments done on-site by the biophysical specialists at each of the study sites (October 2008)**

Site No	River	Place	PD Category	Habitat Integrity	Instream	Riparian	Abstraction	Quality	Floods	Lowflows	Bed	Channel	Inundation	Macrophytes	Fish	Waste	Removal	Encroachment	Erosion
1	**Cuebe**	**Capico**	**B**	84.1	91.7	76.48	8	0	0	5	0	5	0	0	0	0	18	0	5
2	**Cubango**	**Mucundi**	**B**	87.3	92.8	81.76	6	0	0	5	0	5	0	0	0	0	16	0	0
3	**Cuito**	**Cuito Cuanavale**	**B**	91.0	93.5	88.52	0	1	0	5	1	5	1	0	0	5	12	0	0
4	**Okavango**	**Kapako**	**B**	86.2	86.6	85.72	5	7	0	0	8	0	0	1	0	9	16	1	0
5	**Okavango**	**Popa Falls**	**B**	91.2	92.6	89.72	2	3	0	0	0	1	0	0	0	17	11	0	2
6	**Okavango**	**Panhandle**	**B**	93.5	96.7	90.28	2	2	0	0	0	2	0	0	0	0	11	0	0
7	**Okavango**	**Xaxanaka**	**B**	98.6	98.3	98.88	2	1	0	0	0	0	0	0	0	0	0	0	0
8	**Boteti**	**Maun**	**B**	88.2	88.5	87.88	6	6	0	4	3	3	0	2	0	0	9	0	0

Where:
A Category = 100
B Category = 80-99
C Category = 60-79
D Category = 40-59
E Category = 20-39
F Category = 0-19.

Additional details for the method used are provided in Report 03/2009: Guidelines for data collection, analysis and scenario creation.

6.3. Interpretation of integrity plots

The integrity plots presented in this Chapter list each of the study sites (1-8) along the x-axis, and the Overall Integrity Rating on the y-axis. Zero on the y-axis equals the present day integrity of the system. Since all of the study sites have a present-day integrity of a B category, zero on the y-axis equals a B-category.

There is a series of lines marked on the integrity plot representing the general position on the graph when the overall integrity ratings would be expected to result in a move from one category to the next.

6.4. Effects on the integrity of each discipline

The present-day (2008) integrity was a B-category for all disciplines.

6.4.1 Geomorphology

The integrity plot for geomorphology for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-1.

The impacts on geomorphological integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico):	Drop of two categories from a B-category to a D-category for both low and medium scenarios. The driest climate change predictions have no appreciable effect on this, but the wetter predictions reduce the drop to one and a half categories, i.e., from a B-Category to C/D-Category.
Site 2 (Mucundi):	For the low scenario, the driest climate change pedictions would improve the overall condition by about half a category, but it would remain in a C-Category. The wettest climate change predictions would offset most of the flow related impacts, and the system would be in a B-category (i.e., present day condition). There is a similar pattern of the medium scenario, although both would still result in a C-category.
Site 3 (Cuito Cuanavale):	No change.
Site 4 (Kapako):	A drop of half a category to a B/C for the low scenario, and a drop of two categories to a C-category for the medium scenario. The driest climate change predictions would reduce this by half a catgeory for both scenarios. The wettest climate change predictions would offset the flow related effects of development at Kapako.

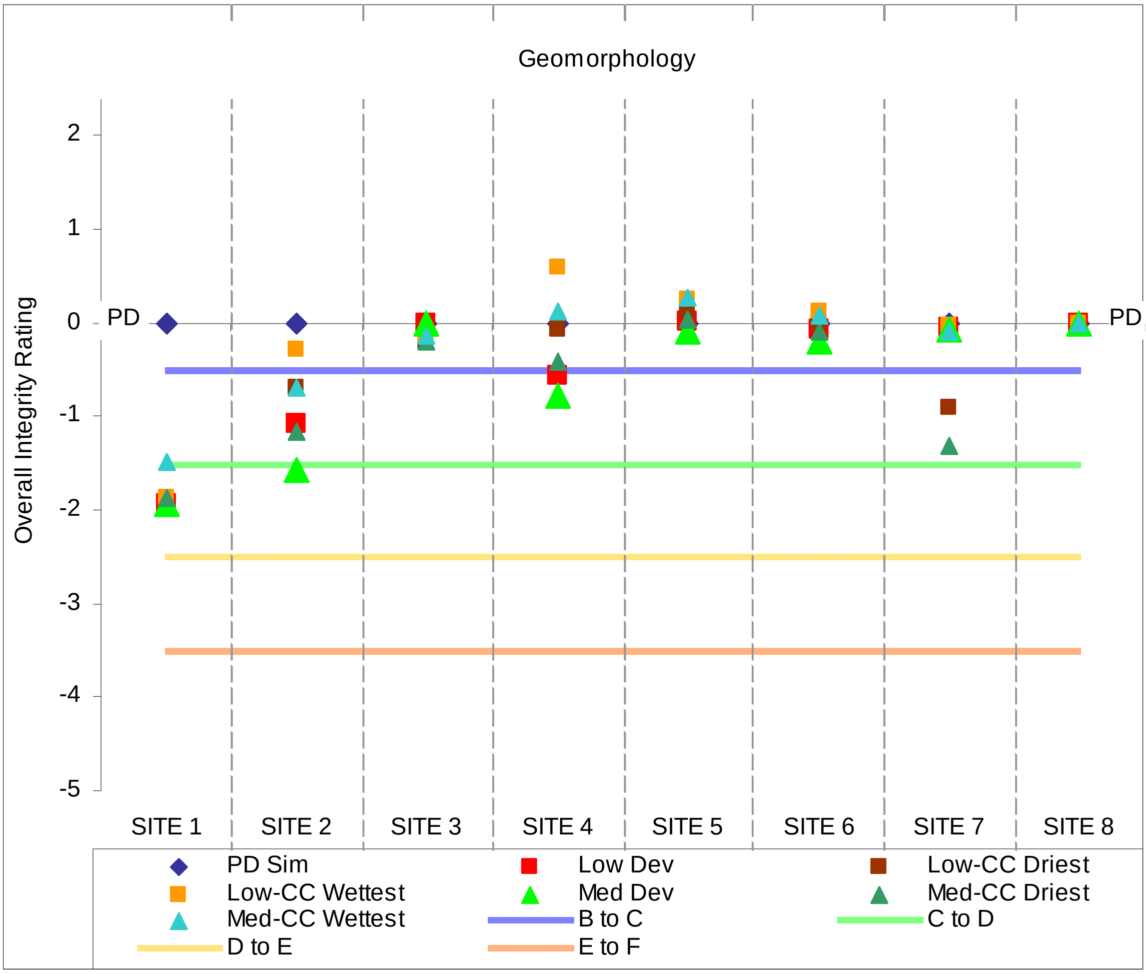


Figure 6-1 **Integrity plot for geomorphology for the low and medium scenarios, with and without climate change, at each of the study sites**

Site 5 (Popa Falls):	No change in category.
Site 6 (Panhandle):	No change in category.
Site 7 (Xaxanaka):	Without climate change there is no change for the low and medium scenarios. Under the driest climate change predictions this would change to a one-category drop from a B-category to a C-category.
Site 8 (Boteti):	Geomorphology not assessed for the Boteti.

6.4.2 Water Quality

The integrity plot for water quality for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-2.

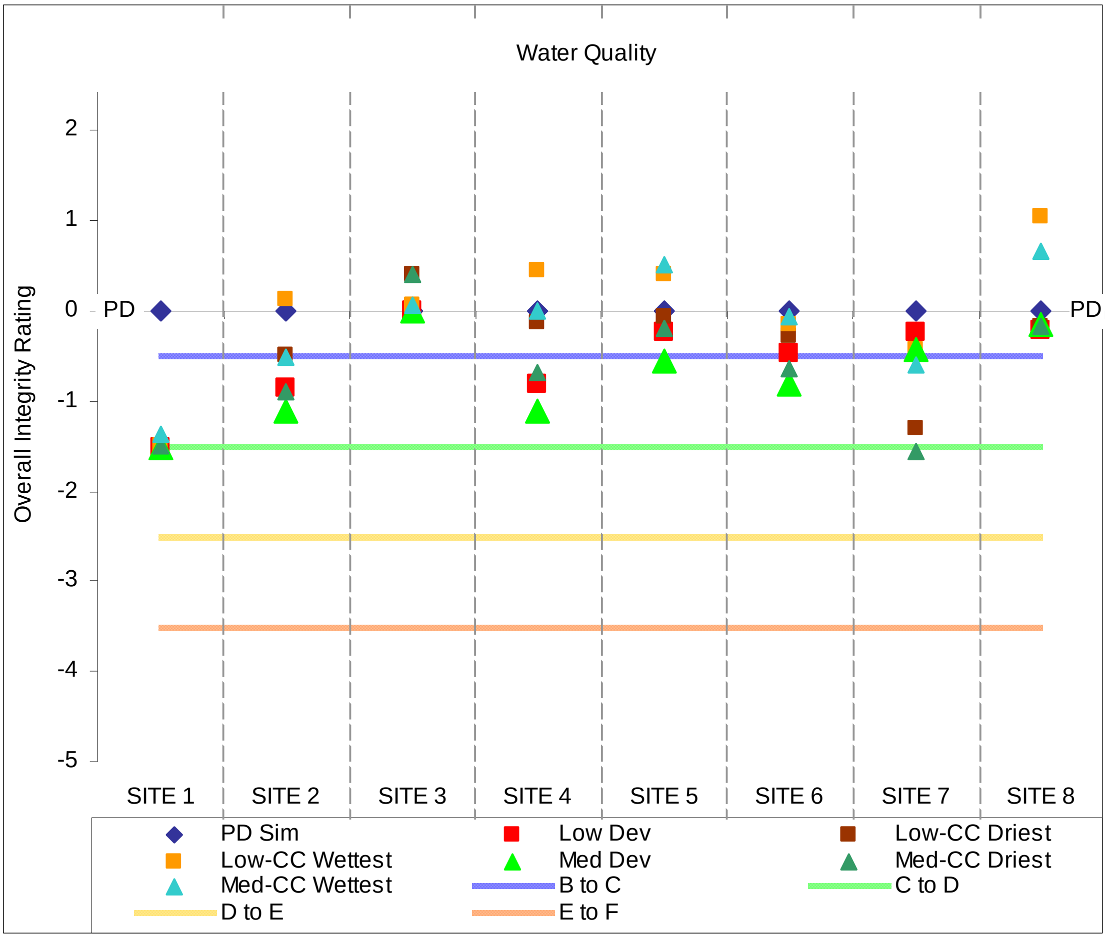


Figure 6-2 Integrity plot for water quality for the low and medium scenarios, with and without climate change, at each of the study sites

The impacts on water quality integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico): Drop of two categories from a B-category to a D-category for low and medium scenarios. The predicted climate change will have no appreciable effect on this.

Site 2 (Mucundi): The drop of half a category from a B-category to a B/C-category for the low and medium scenarios without climate change reduce by a half and a full category under the driest and wettest climate change predictions, respectively.

Site 3 (Cuito Cuanavale): No change.

Site 4 (Kapako): The predicted climate change will offset the flow related impacts of the low scenario. The wettest climate change predictions would also offset the flow related impacts of the medium scenario. However the driest climate change predictions would mean that the river at Kapako dropped to a C-category in the medium scenario.

Site 5 (Popa Falls): The predicted climate change will offset the flow related impacts of the low and medium scenarios.

Site 6 (Panhandle): The predicted climate change would have very slight ameliorating effect on the flow related impacts on the low and medium scenarios. The medium scenario without climate change and the medium scenario with driest climate change, would drop to a C-category.

Site 7 (Xaxanaka): The limited effects of the low and medium scenarios without climate change would increase by a full category drop under the driest climate change predictions. Thus for the low scenario the Delta would be in a C-category and for the medium scenario, it would be in a D-category.

Site 8 (Boteti): No significant change in water quality, mainly because the river is predominately dry under the medium and high scenarios without climate change and under the driest predictions. The river would flow more frequently, and water quality would improve from present, under the wetter climate change predictions.

6.4.3 Vegetation

The integrity plot for vegetation for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-3.

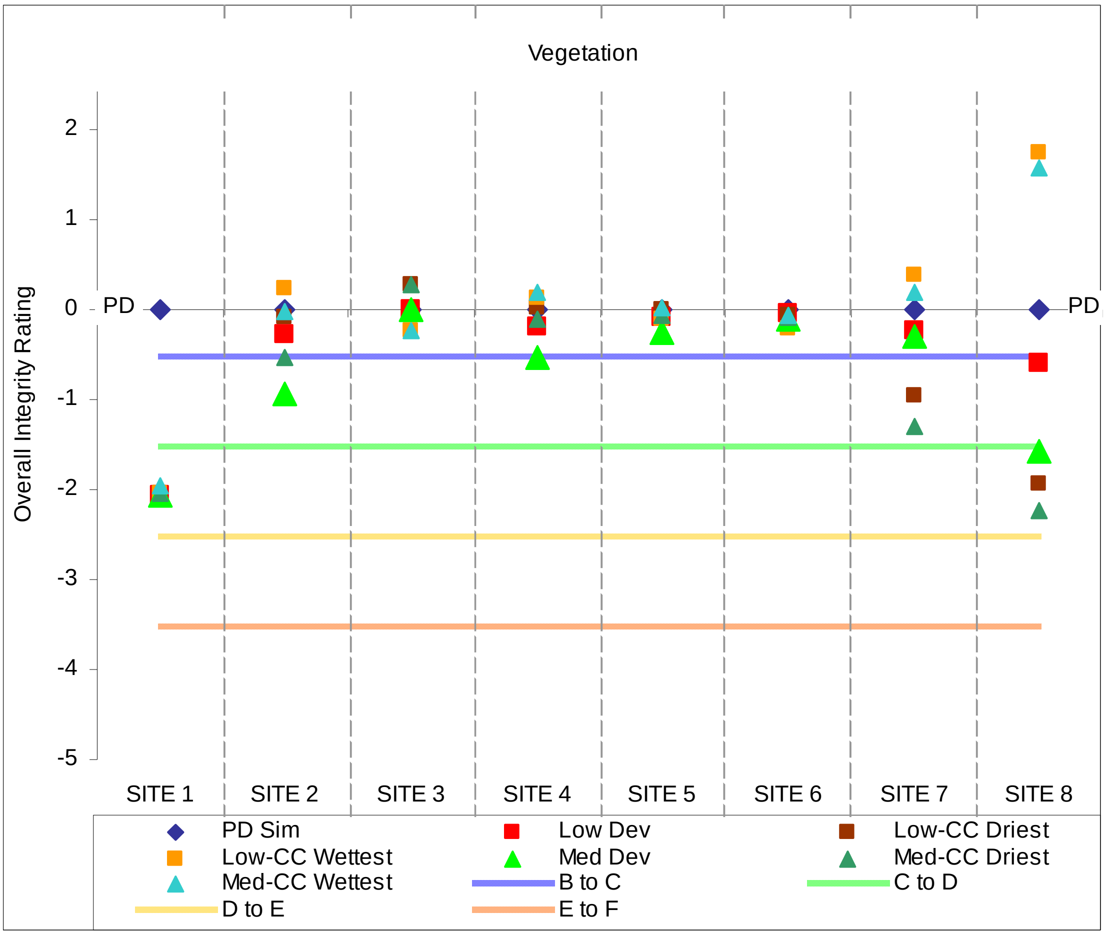


Figure 6-3 **Integrity plot for vegetation for the low and medium scenarios, with and without climate change, at each of the study sites**

The impacts on vegetation integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico): Drop of two categories from a B-category to a D-category for all scenarios. The predicted climate change will have no appreciable effect on this.

Site 2 (Mucundi): The driest and wettest climate change will mean that the flow changes as a result of the low scenario will have little or no

	effect onthe vegetation at Mucundi. For the medium scenario, under the driest climate change predictions the river will be in a B/C-category instread of the D-category under no climate change, and ther wettest climate change will mean that the flow changes as a result of the medium scenario will have little or no overall effect on vegetation.
Site 3 (Cuito Cuanavale):	No change.
Site 4 (Kapako):	The predicted climate change will offset the flow related impacts of the low and medium scenarios.
Site 5 (Popa Falls):	No change.
Site 6 (Panhandle):	No change.
Site 7 (Xaxanaka):	The limited effects of the low and medium scenarios without climate change would increase by a full category drop under the driest climate change predictions. This would mean the Delta would be in a C-category for both the low and medium scenarios.
Site 8 (Boteti):	The drier climate change scenario will exacerbate the impacts of water-resource development on vegetation in the Boteti. The wettest climate change predictions would offset these impacts.

6.4.4 Aquatic macroinvertebrates

The integrity plot for aquatic macroinvertebrates for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-4.

The impacts on aquatic macroinvertebrate integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico):	No change.
Site 2 (Mucundi):	No change.
Site 3 (Cuito Cuanavale):	No change.
Site 4 (Kapako):	No change.
Site 5 (Popa Falls):	No change.
Site 6 (Panhandle):	No change.
Site 7 (Xaxanaka):	The limited effects of the low and medium scenarios without climate change would increase by a full category drop under the driest climate change predictions. This would mean the Delta would be in a C-category for both the low and medium scenarios.

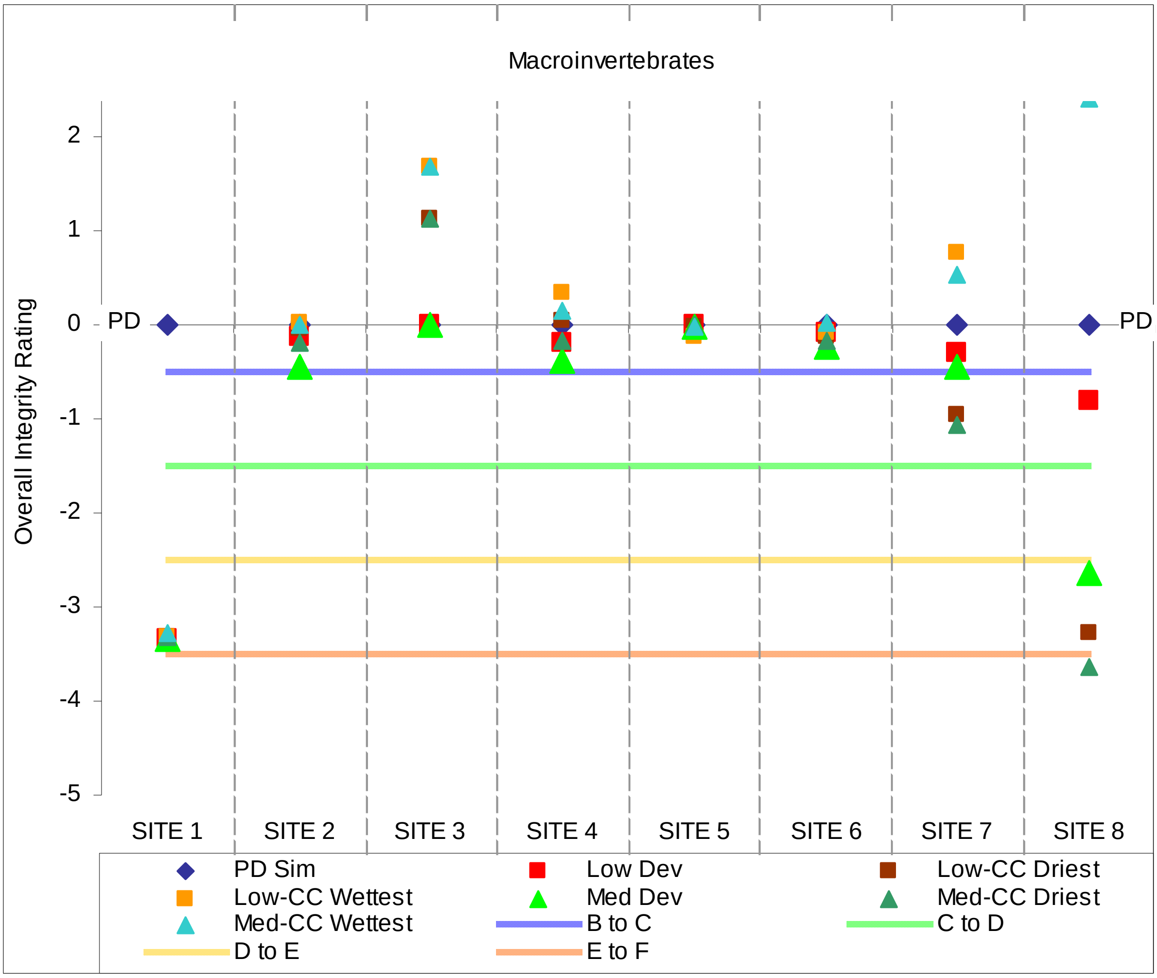


Figure 6-4 **Integrity plot for aquatic macroinvertebrates for the low and medium scenarios, with and without climate change, at each of the study sites**

Site 8 (Boteti): The drier climate change scenario will exacerbate the impacts of water-resource development on macroinvertebrates in the Boteti. The wettest climate change predictions would offset these impacts.

6.4.5 Fish

The integrity plot for fish for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-5.

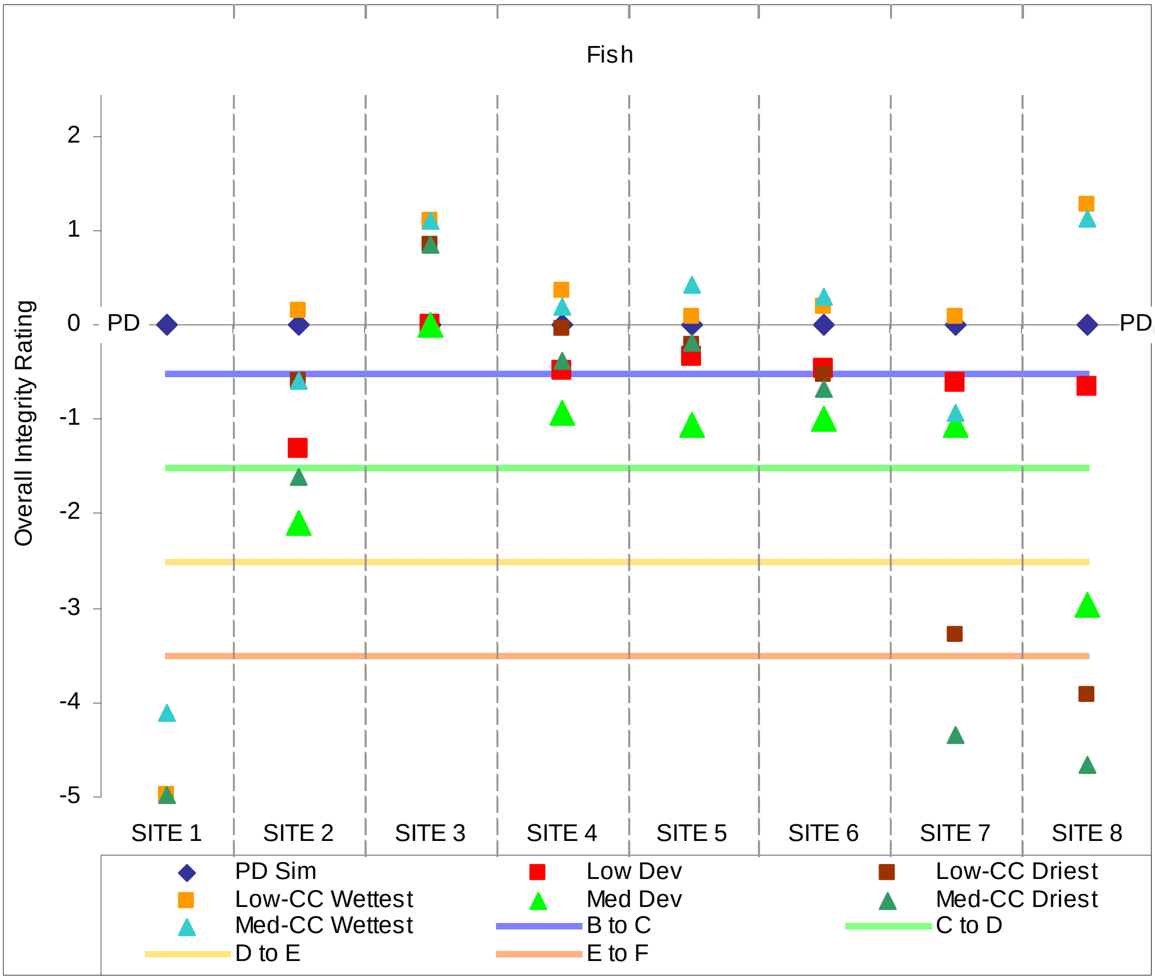


Figure 6-5 **Integrity plot for fish for the low and medium scenarios, with and without climate change, at each of the study sites**

The impacts on fish integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico): The drop of four categories from a B-category to an F-category for the low and medium scenarios is not affected by climate change.

Site 2 (Mucundi): The driest and wettest predicted climate change will offset the flow related impacts of the low scenario. For the medium scenario, the wettest climate change predictions will mean a B/C-category instead of a D-category, and the driest predictions a C-category instead of a D-category.

Site 3 (Cuito Cuanavale): Wetter conditions at Cuito would mean more fish.

Site 4 (Kapako): The driest and wettest predicted climate change will offset the flow related impacts of the low scenario. They wettest will also offset the flow related impacts of the medium scenario. The driest will partly offset the impacts resulting in a C-category instead of a B-category.

Site 5 (Popa Falls): The predicted climate change will offset the flow related impacts of the low and medium scenarios.

Site 6 (Panhandle): The wettest climate change predictions will offset the the flow related impacts of the low and medium scenarios. The driest predicted will have little effect.

Site 7 (Xaxanaka): The limited negative effects of the low and medium scenarios without climate change would increase by a two full categories under the driest climate change predictions. This would mean the Delta would be in an a D- and E-category for the low and medium scenarios, respectively.

Site 8 (Boteti): The wettest climate change predictions would be positive for fish in the Boteti, but the driest predictions mean that even under low scenario the fish community in the Boteti is in an E-category.

6.4.6 Wildlife

The integrity plot for wildlife for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-6.

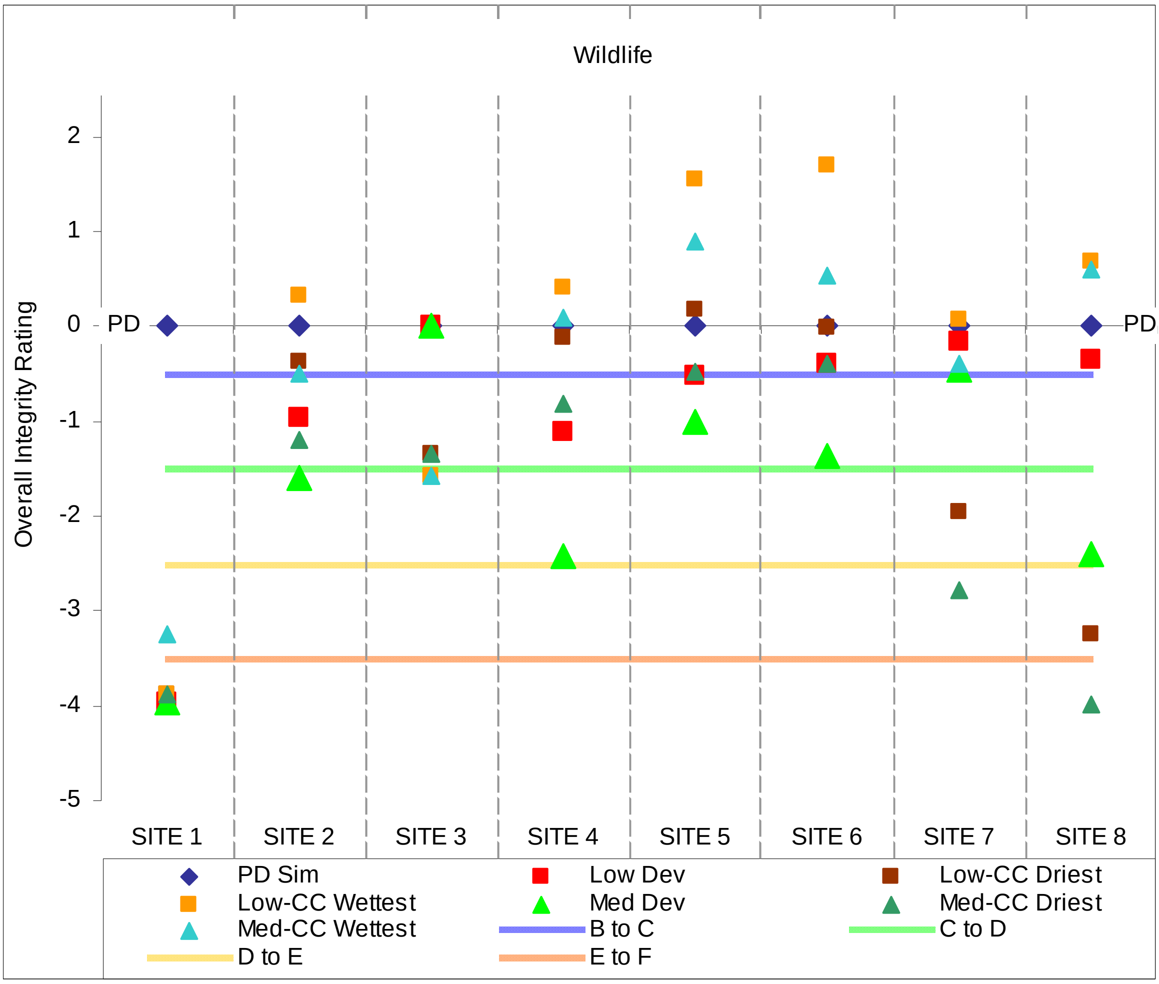


Figure 6-6 Integrity plot for wildlife for the low and medium scenarios, with and without climate change, at each of the study sites

The impacts on wildlife integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico): The drop of four categories from a B-category to an F-category for the low and medium scenarios would be slightly offset by the wettest climate change predictions.

Site 2 (Mucundi):	The driest and wettest predicted climate change will offset the flow related impacts of the low scenario. For the medium scenario, the wettest climate change predictions will mean a B/C-category instead of a D-category, and the driest a C-category instead of a D-category.
Site 3 (Cuito Cuanavale):	The wetter conditions under climate change will means less grazing for wildlife.
Site 4 (Kapako):	The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.
Site 5 (Popa Falls):	The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.
Site 6 (Panhandle):	The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.
Site 7 (Xaxanaka):	No change major change for the low and medium scenarios without climate change or under the wettest climate change, however, the driest climate change will lead to a drop of one category to a C-Category for the medium scenario.
Site 8 (Boteti):	The drier climate change scenario will exacerbate the impacts of water-resource development on macroinvertebrates in the Boteti. The wettest climate change predictions would offset these impacts.

6.4.7 Birds

The integrity plot for birds for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-7.

The impacts on bird integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico):	Drop of three categories from a B-category to an E-category for all scenarios. The predicted climate change will have no appreciable effect on this.
Site 2 (Mucundi):	The driest and wettest predicted climate change will offset the flow related impacts of the low scenario. For the medium scenario, the wettest climate change predictions will mean a B/C-category instead of a D-category, but the driest predictions will not improve on the D-category.
Site 3 (Cuito Cuanavale):	No change.
Site 4 (Kapako):	The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.

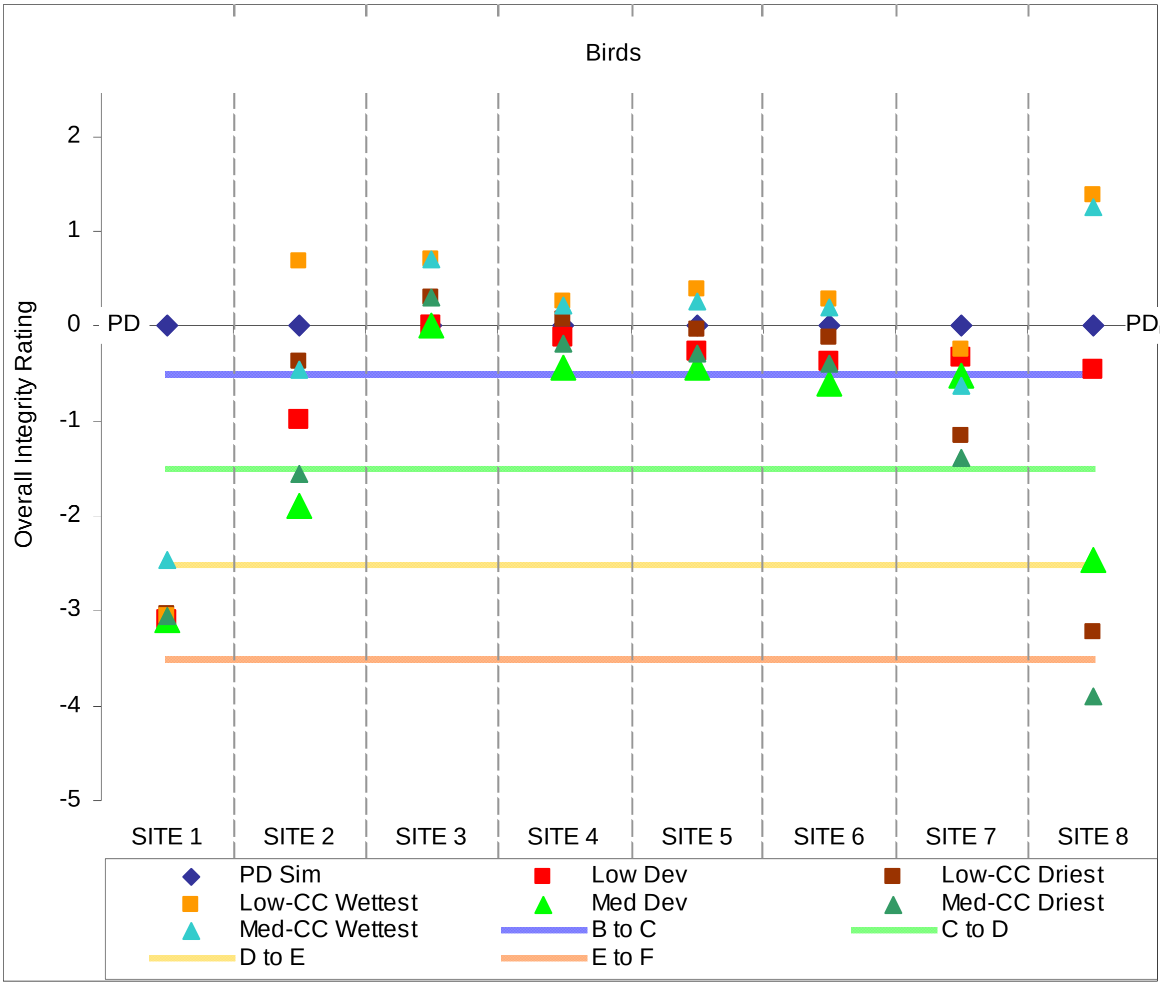


Figure 6-7 Integrity plot for birds for the low and medium scenarios, with and without climate change, at each of the study sites

Site 5 (Popa Falls): The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.

Site 6 (Panhandle): The driest and wettest predicted climate change will offset the flow related impacts of the low and medium scenarios.

Site 7 (Xaxanaka): The relatively minor effect of the low and medium scenario without climate change increase to a one-category drop under the driest climate change predictions. This does not, however, mean that there will be fewer birds, only fewer of the species that are dependent on open water and swamp land.

Site 8 (Boteti): The drier climate change scenario will exacerbate the impacts of water-resource development on macroinvertebrates in the Boteti, such as loss of water-dependent birds. The wettest climate change predictions would offset these impacts.

6.5. Effects on the integrity of the whole ecosystem

The plot for overall ecosystem integrity for the low and medium scenarios, with and without climate change, at each of the study sites is shown in Figure 6-8.

Please note: In Figure 6-8, the integrity scores greater than 0 may denote an improvement back towards natural conditions, but more likely denote a change in the overall ecosystem towards one that is wetter than it has been in the recent past.

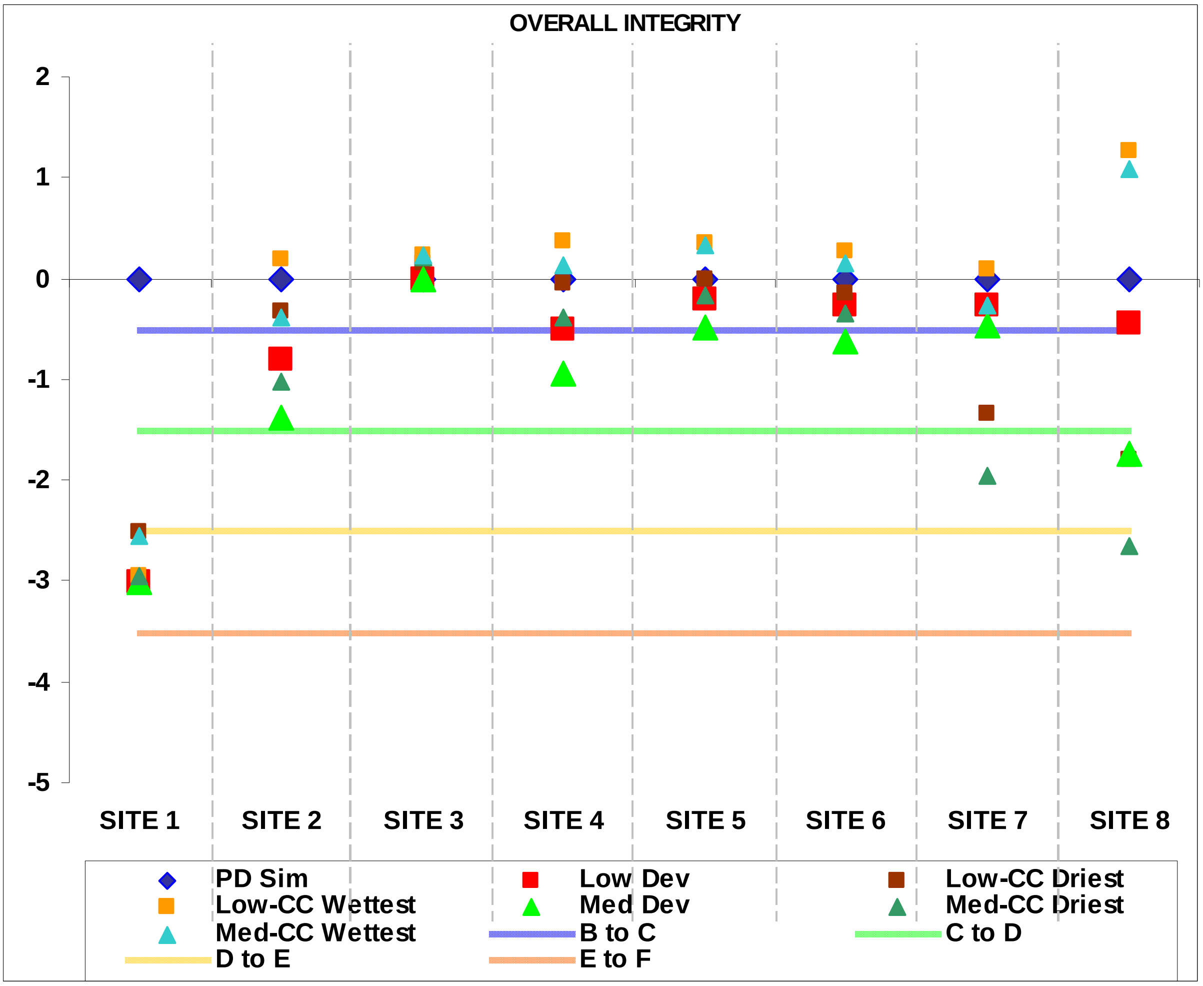


Figure 6-8 Overall ecosystem integrity for the low and medium scenarios, with and without climate change, at each of the study sites

The impacts on overall ecosystem integrity for the low and medium scenarios under the two levels of climate change can be summarised as follows:

Site 1 (Capico):	The drop of three categories to a E-category for the medium and low scenarios, was reduced slightly to a D/E-category under the wettest climate change predictions, but there was no significant difference under the drier climate change predictions.
Site 2 (Mucundi):	Under the low and medium the condition of the system dropped from a B-category to a C-category. For the low scenario both climate change prediction levels result in a return to a B-category. For the medium scenario, there is no significant change in overal condition under the driest predictions, but

	there is an improvement to a B-category under the wettest predictions.
Site 3 (Cuito Cuanavale):	No change.
Site 4 (Kapako):	The driest and wettest climate change will mean that the flow changes as a result of the low scenario will have little or no effect on ecosystem condition. For the medium scenario, under the driest climate change predictions the river will be in a low B-category instread of the C-category under no climate change, and ther wettest climate change will mean that the flow changes as a result of the medium scenario will have little or no effect on ecosystem condition.
Site 5 (Popa Falls):	The climate change prediction would mean that the flow changes as a result of the low and medium scenarios will have little or no effect on ecosystem condition.
Site 6 (Panhandle):	The climate change prediction would mean that the flow changes as a result of the low and medium scenarios will have little or no effect on ecosystem condition.
Site 7 (Xaxanaka):	The wettest climate change prediction would mean that the flow changes as a result of the low and medium scenarios will have little or no effect on ecosystem condition. However, the driest climate change prediction under both the low and medium scenarios would result in significantly greater decline that for the medium scenario without climate change. This is because, in Botswana, the overall effect of the drier climate change prediction is towards a drier ecosystem.
Site 8 (Boteti):	The pattern of the Boteti is similar to that for the Delta, i.e., the drier climate change scenario will exacerbate the impacts of water-resource development on the Boteti. The wettest climate change predictions would offset these impacts.

The most striking aspect of the climate change predictions is the possible exacerbation of flow-related impacts in the Delta and Boteti, if the drier climate change prediction occurs. These are particularly acute for the medium scenario where the condition of the Delta and Boteti will two and three categories lower than at present, respectively. Under the medium scenario, this means that the Boteti will cease to flow in most years in a forty-year sequence, and there will be considerable terrestrialisation of the Delta. This is equivalent to the predicted impacts for high development without climate change (see Volume 1). This be less severe under the low scenario and is not expected to occur if water-resource development stays at present day levels.

In Figure 6-9, those sections of the river in a D-category and in an E-category have been marked with a red flag. This is because the expected decline in their condition is likely to result in difficulties in sustaining the benefits offered by theses ecosystems. This is particularly so given the fact that neither the localised impacts of the water-resource developments themselves (such as sediment changes) nor the longitudinal impacts of a fragmented river system have been considered in these predictions.

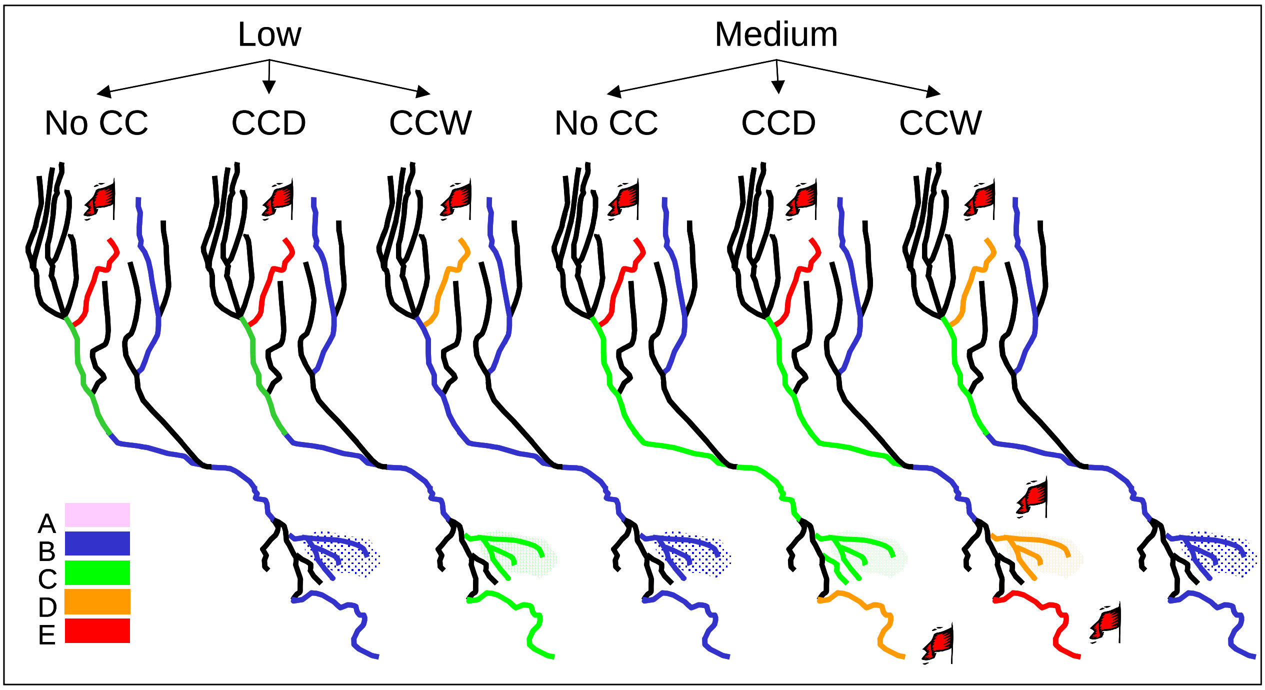


Figure 6-9 **Summary of expected changes in ecosystem integrity for the low and medium scenarios under the two levels of climate change. Present-day conditions are estimated as B-category. No CC = without climate change; CCD = driest climate change predictions; CCW = wettest climate change predictions.**

7. Social results

8. Conclusions

Scenarios describe the impacts of the specific developments that were chosen for consideration, and any other permutation making up a particular level of development (low, medium or high in this case) would not necessarily have the described impacts. A different arrangement of proposed water-resource schemes could produce different impacts. Altering the development placed in the hydrological model upstream of Capico, for instance, so that more water would continue to flow down the river in the dry season, could greatly reduce the predicted impact at that site. This highlights the value of the DSS, which has been set up to be queried, and to provide predictions of the impact of, any permutation of possible developments.

In this project, the EFlow Assessment was preliminary, based on available information, and the predictions are thus of low confidence. It sets the scene for a Phase 2 research-based EFlow Assessment, where major data gaps can be addressed, models improved, more scenarios and sites investigated, and higher-confidence predictions produced. Such a Phase 2 would also incorporate an improved DSS with indicators linked in series to better show the domino effect of changing flows – through hydraulic and water-quality changes, to impacts on the vegetation, then the fauna, then people.

The EF Scenarios focused on changes that were considered likely through potential changes in flow patterns. Impacts of constructing and operating water-resource infrastructure were not addressed, nor were knock-on effects such as increased agricultural return flows potentially laden with pesticide residues and fertilisers. Another aspect not addressed because of the lack of data and models, yet vitally important, is the sediment dynamics of the system and how flow changes and in-channel dams could change the movement of sediments through the system and thus the character of the channels, floodplains and delta.

Social aspects not addressed

In the previous assessments (see Volume 1), the low scenario presented few risks for the basin but there was some risk that the medium scenario would result in severe degradation at some points in the basin. Importantly, the impacts associated with both the low and medium scenarios were predominately in-country. With climate change added as an overlay, there are two possible future paths:

- The drier climate change predictions, which would reduce the localized impacts and would increase the impacts in the lower catchment, i.e., the Delta and Boteti.
- The wetter climate change predictions, which would ameliorate the flow-related impacts of development throughout the Delta.

Impacts on people

9. References

Adamson, P. 2006. Hydrological background and the generation of exploratory flow regimes for the development of the impact analysis tools. Integrated Basin Flow Management. Internal Report of the Mekong River Commission, Laos PDR. 45 pp.

Brown, C.A. and Joubert, A.R. 2003. Using multicriteria analysis to develop environmental flow scenarios for rivers targeted for water-resource development. *Water SA* Vol. 29 (No. 4).

Department of Water Affairs and Forestry. 1999. Resource Directed Measures for the Protection of Water Resources. Version 1.0. Pretoria, South Africa.

Dollar, E.S.J., Brown, C.A., Turpie, J.K., Joubert, A.R., Nicolson, C.R. and Manyaka, S.M. 2006: The development of the Water Resource Classification System (WRCS). Volume 1. Overview and 7-step classification procedure. CSIR Report No., Department of Water Affairs and Forestry, Pretoria, 70pp.

Dollar, E.S.J, Nicolson, C.R., Brown, C.A., Turpie, J.K., Joubert, A.R, Turton, A.R., Grobler, D.F. and Manyaka, S.M. In press. The development of the South African Water Resource Classification System (WRCS): a tool towards the sustainable, equitable and efficient use of water resources in a developing country. *Water Policy*..

King, J.M., Brown, C.A. and Sabet, H. 2003. A scenario-based holistic approach to environmental flow assessments for regulated rivers. *Rivers Research and Application*s 19 (5-6). Pg 619-640.

Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River. Journal of Aquatic Ecosystem Health 5: 41 - 54.

The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

In 1994, the three riparian countries of the Okavango River Basin – Angola, Botswana and Namibia – agreed to plan for collaborative management of the natural resources of the Okavango, forming the Permanent Okavango River Basin Water Commission (OKACOM). In 2003, with funding from the Global Environment Facility, OKACOM launched the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project to coordinate development and to anticipate and address threats to the river and the associated communities and environment. Implemented by the United Nations Development Program and executed by the United Nations Food and Agriculture Organization, the project produced the Transboundary Diagnostic Analysis to establish a base of available scientific evidence to guide future decision making. The study, created from inputs from multi-disciplinary teams in each country, with specialists in hydrology, hydraulics, channel form, water quality, vegetation, aquatic invertebrates, fish, birds, river-dependent terrestrial wildlife, resource economics and socio-cultural issues, was coordinated and managed by a group of specialists from the southern African region in 2008 and 2009.

The following specialist technical reports were produced as part of this process and form substantive background content for the Okavango River Basin Transboundary Diagnostic Analysis.

Final Study Reports	***Reports integrating findings from all country and background reports, and covering the entire basin.***		
		Aylward, B.	*Economic Valuation of Basin Resources: Final Report to EPSMO Project of the UN Food & Agriculture Organization as an Input to the Okavango River Basin Transboundary Diagnostic Analysis*
		Barnes, J. et al.	*Okavango River Basin Transboundary Diagnostic Analysis: Socio-Economic Assessment Final Report*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Project Initiation Report (Report No: 01/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009)*
		Bethune, S. Mazvimavi, D. and Quintino, M.	*Okavango River Basin Environmental Flow Assessment Delineation Report (Report No: 04/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Hydrology Report: Data And Models(Report No: 05/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Scenario Report : Hydrology (Report No: 06/2009)*
		Jones, M.J.	*The Groundwater Hydrology of The Okavango Basin (FAO Internal Report, April 2010)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 1 of 4)(Report No. 07/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 2 of 4: Indicator results) (Report No. 07/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions: Climate Change Scenarios (Volume 3 of 4) (Report No. 07/2009)*
		King, J., Brown, C.A., Joubert, A.R. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Biophysical Predictions (Volume 4 of 4: Climate Change Indicator Results) (Report No: 07/2009)*
		King, J., Brown, C.A. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Project Final Report (Report No: 08/2009)*
		Malzbender, D.	*Environmental Protection And Sustainable Management Of The Okavango River Basin (EPSMO): Governance Review*
		Vanderpost, C. and Dhliwayo, M.	*Database and GIS design for an expanded Okavango Basin Information System (OBIS)*
		Veríssimo, Luis	*GIS Database for the Environment Protection and Sustainable Management of the Okavango River Basin Project*
		Wolski, P.	*Assessment of hydrological effects of climate change in the Okavango Basin*
Country Reports Biophysical Series	***Angola***	*Andrade e Sousa, Helder André de*	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do*

			Especialista: País: Angola: Disciplina: Sedimentologia & Geomorfologia
		Gomes, Amândio	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Vegetação*
		Gomes, Amândio	*Análise Técnica, Biofísica e Socio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final:Vegetação da Parte Angolana da Bacia Hidrográfica Do Rio Cubango*
		Livramento, Filomena	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina:Macroinvertebrados*
		Miguel, Gabriel Luís	*Análise Técnica, Biofísica E Sócio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Subsídio Para o Conhecimento Hidrogeológico Relatório de Hidrogeologia*
		Morais, Miguel	*Análise Diagnóstica Transfronteiriça da Bacia do Análise Rio Cubango (Okavango): Módulo da Avaliação do Caudal Ambiental: Relatório do Especialista País: Angola Disciplina: Ictiofauna*
		Morais, Miguel	*Análise Técnica, Biófisica e Sócio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final: Peixes e Pesca Fluvial da Bacia do Okavango em Angola*
		Pereira, Maria João	*Qualidade da Água, no Lado Angolano da Bacia Hidrográfica do Rio Cubango*
		Santos, Carmen Ivelize Van-Dúnem S. N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório de Especialidade: Angola: Vida Selvagem*
		Santos, Carmen Ivelize Van-Dúnem S.N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango:Módulo Avaliação do Caudal Ambiental: Relatório de Especialidade: Angola: Aves*
	Botswana	*Bonyongo, M.C.*	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Wildlife*
		Hancock, P.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report: Country: Botswana: Discipline: Birds*
		Mosepele, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Fish*
		Mosepele, B. and Dallas, Helen	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Aquatic Macro Invertebrates*
	Namibia	*Collin Christian & Associates CC*	*Okavango River Basin: Transboundary Diagnostic Analysis Project: Environmental Flow Assessment Module: Geomorphology*
		Curtis, B.A.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report Country: Namibia Discipline: Vegetation*
		Bethune, S.	*Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO): Transboundary Diagnostic Analysis: Basin Ecosystems Report*
		Nakanwe, S.N.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Aquatic Macro Invertebrates*
		Paxton, M.	*Okavango River Basin Transboundary Diagnostic Analysis: Environmental Flow Module: Specialist Report:Country:Namibia: Discipline: Birds (Avifauna)*
		Roberts, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Wildlife*
		Waal, B.V.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia:Discipline: Fish Life*
Country Reports Socioeconomic Series	***Angola***	*Gomes, Joaquim Duarte*	*Análise Técnica dos Aspectos Relacionados com o Potencial de Irrigação no Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final*
		Mendelsohn, .J.	*Land use in Kavango: Past, Present and Future*
		Pereira, Maria João	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Qualidade da Água*
		Saraiva, Rute et al.	*Diagnóstico Transfronteiriço Bacia do Okavango: Análise Socioeconómica Angola*
	Botswana	*Chimbari, M. and*	*Okavango River Basin Trans-Boundary Diagnostic Assessment*

		Magole, Lapologang	*(TDA): Botswana Component: Partial Report: Key Public Health Issues in the Okavango Basin, Botswana*
		Magole, Lapologang	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Land Use Planning*
		Magole, Lapologang	*Transboundary Diagnostic Analysis (TDA) of the Botswana p Portion of the Okavango River Basin: Stakeholder Involvement in the ODMP and its Relevance to the TDA Process*
		Masamba, W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Output 4: Water Supply and Sanitation*
		Masamba,W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Irrigation Development*
		Mbaiwa.J.E.	*Transboundary Diagnostic Analysis of the Okavango River Basin: the Status of Tourism Development in the Okavango Delta: Botswana*
		Mbaiwa.J.E. & Mmopelwa, G.	*Assessing the Impact of Climate Change on Tourism Activities and their Economic Benefits in the Okavango Delta*
		Mmopelwa, G.	*Okavango River Basin Trans-boundary Diagnostic Assessment: Botswana Component: Output 5: Socio-Economic Profile*
		Ngwenya, B.N.	*Final Report: A Socio-Economic Profile of River Resources and HIV and AIDS in the Okavango Basin: Botswana*
		Vanderpost, C.	*Assessment of Existing Social Services and Projected Growth in the Context of the Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin*
	Namibia	*Barnes, J and Wamunyima, D*	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Socio-economics*
		Collin Christian & Associates CC	*Technical Report on Hydro-electric Power Development in the Namibian Section of the Okavango River Basin*
		Liebenberg, J.P.	*Technical Report on Irrigation Development in the Namibia Section of the Okavango River Basin*
		Ortmann, Cynthia L.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report Country: Namibia: discipline: Water Quality*
		Nashipili, Ndinomwaameni	*Okavango River Basin Technical Diagnostic Analysis: Specialist Report: Country: Namibia: Discipline: Water Supply and Sanitation*
		Paxton, C.	*Transboundary Diagnostic Analysis: Specialist Report: Discipline: Water Quality Requirements For Human Health in the Okavango River Basin: Country: Namibia*

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

Boteti River shoreline, Botswana

Republic of Botswana

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Sida

OKACOM

Tel +267 680 0023 Fax +267 680 0024 Email okasec@okacom.org www.okacom.org
PO Box 35, Airport Industrial, Maun, Botswana