Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

OKAVANGO RIVER BASIN ENVIRONMENTAL FLOW ASSESSMENT DELINEATION REPORT

Report No: 04/2009

S. Bethune, et al.

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Environmental protection and sustainable management of the Okavango River Basin

EPSMO

ENVIRONMENTAL FLOW ASSESSMENT SERIES

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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)
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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 4 in the report series for the EFA. It outlines the location and main characteristics of the Okavango River Basin, the river and delta zones recognised by hydrologists, geomorphologists, aquatic chemists, biologists, sociologists and resource economists, and how these were harmonised to produce Integrated Units of Analysis (IUAs). The process of selection of IUAs and sites to represent the whole basin during the EFlows work is then described.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
OKACOM	Permanent Okavango River Basin Water Commission
OBSC	Okavango Basin Steering Committee
SADC	Southern African Development Community
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
TDA	Transboundary Diagnostic Assessment
IUA	Integrated Unit of Analysis
ODMP	Okavango Delta Management Plan
WMA	Wildlife Management Area
IUCN	The World Conservation Union

1. INTRODUCTION

1.1. Background

The riparian countries of the Okavango River Basin, Angola, Botswana and Namibia, formed the Permanent Okavango River Basin Water Commission (OKACOM) in 1994. OKACOM was required to develop criteria for conservation, equitable allocation and sustainable utilisation of water within this basin. The environment is now regarded as a legitimate water user and therefore OKACOM needs information on the water needs for maintenance of the river ecosystems when preparing criteria for conservation, equitable allocation and sustainable utilization of water. The Southern African Development Community (SADC), of which the three riparian countries are members, adopted a SADC Water Policy that calls upon member countries to allocate adequate water for maintaining ecosystem integrity. The Revised SADC Protocol on Shared Watercourse Systems requires that member countries should aim to achieve a balance between water development and protection of the environment. Future developments within the Okavango River Basin have the potential to affect the integrity of the river ecosystem as well as human livelihoods and wellbeing that are supported by this river. Therefore, the three riparian countries require information about the links between basin development and river ecosystem health to aid their discussions on acceptable future development pathways.

An Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project is being implemented, with one of the activities being to carry out a transboundary diagnostic assessment (TDA) for the purpose of developing a Strategic Action Programme (SAP). The TDA is an analysis of current and future possible causes of transboundary problems. The Okavango Basic Steering Committee (OBSC) of OKACOM noted during the March 2008 meeting in Windhoek, Namibia, that future transboundary problems within the Okavango River basin are likely to occur due to developments that would modify flow regimes. The OBSC also noted that there was inadequate information about the physico-chemical, ecological and socioeconomic effects of possible future developments. This meeting recommended that an Environmental Flow Assessment (EFA) be carried out to provide information about the effects of possible future developments on the flow regime of the Okavango River and on the related physico-chemical, ecological and socioeconomic attributes of the system.

The Biokavango Project, whose goal is to mainstream biodiversity management into the three main production sectors of water management, tourism and fishery, is being implemented on the Okavango Delta. An EFA will improve an understanding of hydro-ecological relationships in the Delta, which is necessary for biodiversity management. The EPSMO and Biokavango Projects are therefore cooperating in carrying out an EFA for the Okavango River basin.

A planning meeting for the joint project was held in Pretoria, South Africa on 15 and 16 July 2008 (Report 01/2009: Project Initiation Report).

1.2. Okavango River Basin Flow Assessment Objectives and Workplan

1.2.1. Project objectives

The overall goal of the Environmental Flow Assessment was to provide information that would enable decision-makers to select sustainable water-resource development pathways within the Okavango River Basin.

The specific objectives were:

- To ascertain the relationships between river flow regimes and the various ecological processes and ecosystem components along the Okavango River system.

- To ascertain the relationships between the natural flow regime and the natural resources of the Okavango River, and peoples' livelihoods.
- To ascertain the effects of possible future developments on the river's physico-chemical and ecological attributes and on people's related livelihoods.
- To increase understanding of the hydro-ecological relationships within the Okavango Delta in order to enhance biodiversity management by the main production sectors.
- To develop skills for conducting environmental flow assessments in Angola, Botswana, and Namibia.

1.2.2. Work plan

The main tasks to be carried out are presented in Table 1-1. This report covers the first two tasks plus part of the third.

Table 1-1 Activities and tasks for the Okavango Basin Flow Assessment

Task	Explanatory Notes
Basin delineation	Delineation of the basin into homogenous zones with regards to (a) hydrology and groundwater, (b) geomorphology, (c) water quality, (d) biology, and (e) socio-economy
Site selection	Harmonization of homogeneous river zones and social areas to create Integrated Units of Analysis. Initial identification of sites, with final selection in the field.
Scenario identification	Identification of country issues. Preliminary discussions on selection of four basin-wide water-use scenarios, including the Present Day situation.
Hydrological data collation and synthesis	Inventory of modelling work already done. Selection of hydrological models. Data collection and description of catchment hydrology. Setting up of hydrological models. Simulation of hydrological responses to different scenarios.
Identification of flow-related ecological and social indicators	Identification of indicators specific to each discipline. Linkage of indicators from different disciplines to provide framework of data flow through the project.
Environmental flow modelling	Creation of response curves that capture flow-indicator relationships. Setting up of the Decision Support System (DSS)
Scenario analysis	Use of the DSS to predict ecological and social impacts of water-use scenarios.

A Gantt chart for the Okavango Basin Flow Assessment is given in Report 01/2009: The Project Initiation Report.

1.2.3. The Delineation Workshop

A Basin Delineation Workshop was held from 22 to 26 September 2008 in Maun, Botswana. The objectives of this workshop were:

- To divide the Okavango River into homogenous zones with regards to hydrology, groundwater, geomorphology, water quality, biology, and socioeconomics.
- To harmonize the different homogenous zones into Integrated Units of Analysis (IUAs).
- To choose eight IUAs to represent the river and its people in the Flow Assessment: three in Angola, two in Namibia, and three in Botswana (Report 01/2009: Project Initiation Report)
- To select a study site within each of the eight IUAs.
- To undertake a preliminary identification of indicators for use by the various disciplines.
- To plan for the field visits to the selected sites.

The list of participants is given as Appendix 1.1, while the agenda for the workshop is provided as Appendix 1.2.

1.2.4. The need for delineation

Before a study begins, its limits need to be defined. Some of these limits will be connected with time and some with finances. At a technical level, any study area of a river system needs to define the geographical area to be addressed. In this project, the study area was delineated as the whole Okavango River Basin.

Within the Okavango River Basin, no study can address every kilometre stretch of the river, or every person living within the area. Thus, it is usual practice to search for representative areas that can together represent the whole study area. These representative areas should be reasonably homogeneous in character, at least in terms of the studies that will be done. Thus, a delineation exercise of a river would search for stretches of river that differ from each other but are internally similar, whilst a social delineation might search for areas that differ in livelihoods, wealth and the way the river is used.

Once these homogeneous areas have been identified, one or more representative sites can be chosen in each. These will become the focus of data-collection activities, and the results from each will be extrapolated over the respective area.

In this study, time and financial limitations dictated a maximum of eight sites, i.e., representative sites in eight of the homogenous zones. These were allocated as follows:

- Angola: three sites.
- Namibia: two sites.
- Botswana: three sites.

1.2.5. Approach taken to delineation

At the workshop, an overview of the Environmental Flow Concept, and the linkages between a TDA and an EFA within the Okavango Basin, were given (Appendix 1.2). An introduction to basin delineation as part of an EFA was presented. Participants were then divided into groups according to their disciplines: hydrology, groundwater, geomorphology, aquatic chemistry, ecology, and socio-economy. Each group was requested to use information they had brought to divide the basin into homogenous zones.

Participants considered all the zones identified by the different disciplines, and then combined them for the purpose of selecting study sites.

2. BASIN LOCATION AND CHARACTERISTICS

2.1. Definition of the Okavango River Basin

The Okavango River Basin consists of the areas drained by the Cubango, Cutato, Cuchi, Cuelei, Cuebe, and Cuito Rivers in Angola, the Okavango River in Namibia and Botswana, and the Okavango Delta. This basin topographically includes the area that was drained by the now fossil Omatako River in Namibia. Outflows from the Okavango Delta are drained through the Boteti River which eventually joins the Makgadikgadi Pans. The Nata River, which drains the western part of Zimbabwe, joins the Makgadikgadi Pans. On the basis of topography, the Okavango River basin thus includes the Makgadikgadi Pans and Nata River basin (Figure 2-1; Figure 2-2). This study is however focusing on the parts of the basin situated in Angola, Namibia and Botswana, including the delta and the Boteti River. The Makgadikgadi Pans and Nata River are not included.

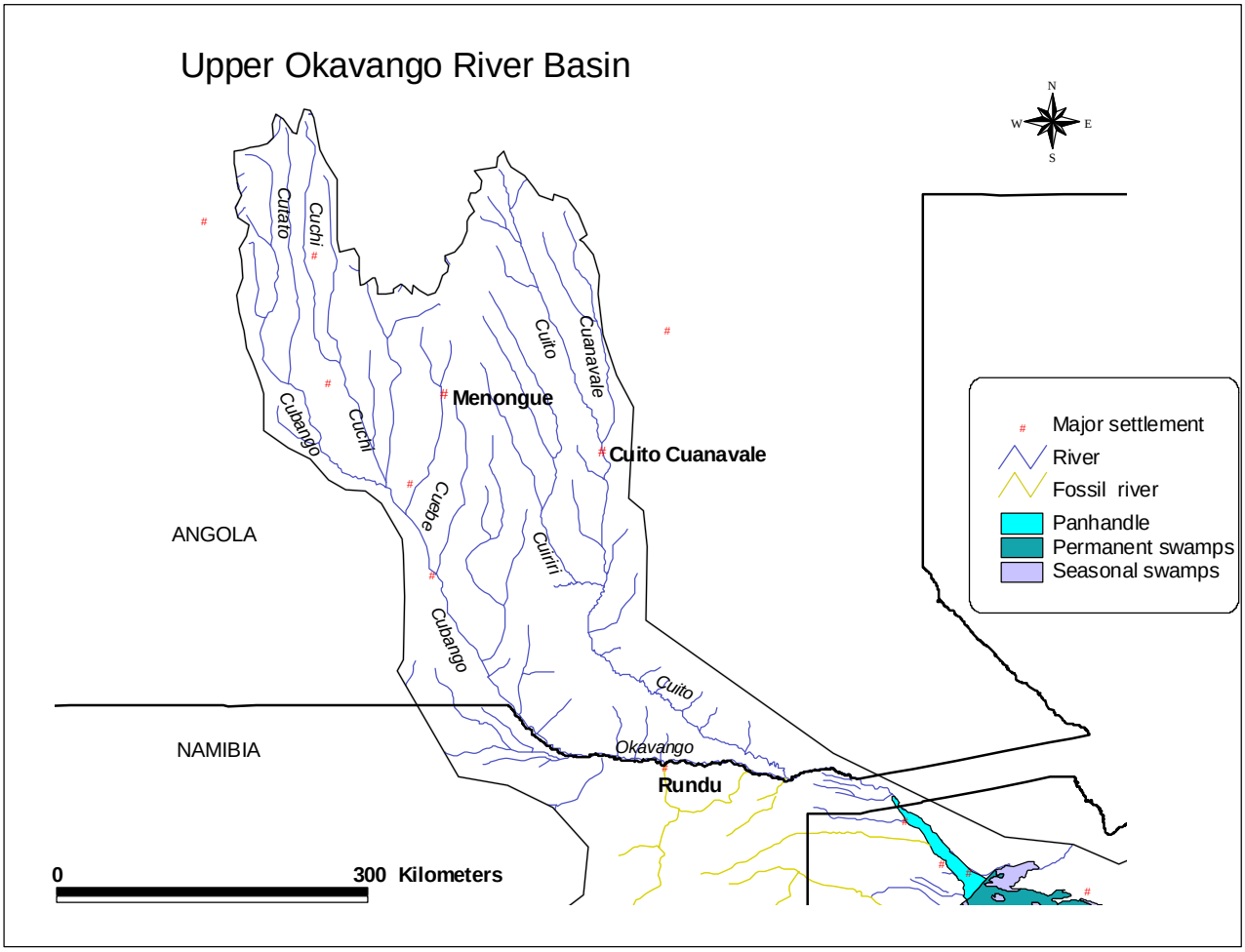

Figure 2-1 Upper Okavango River Basin

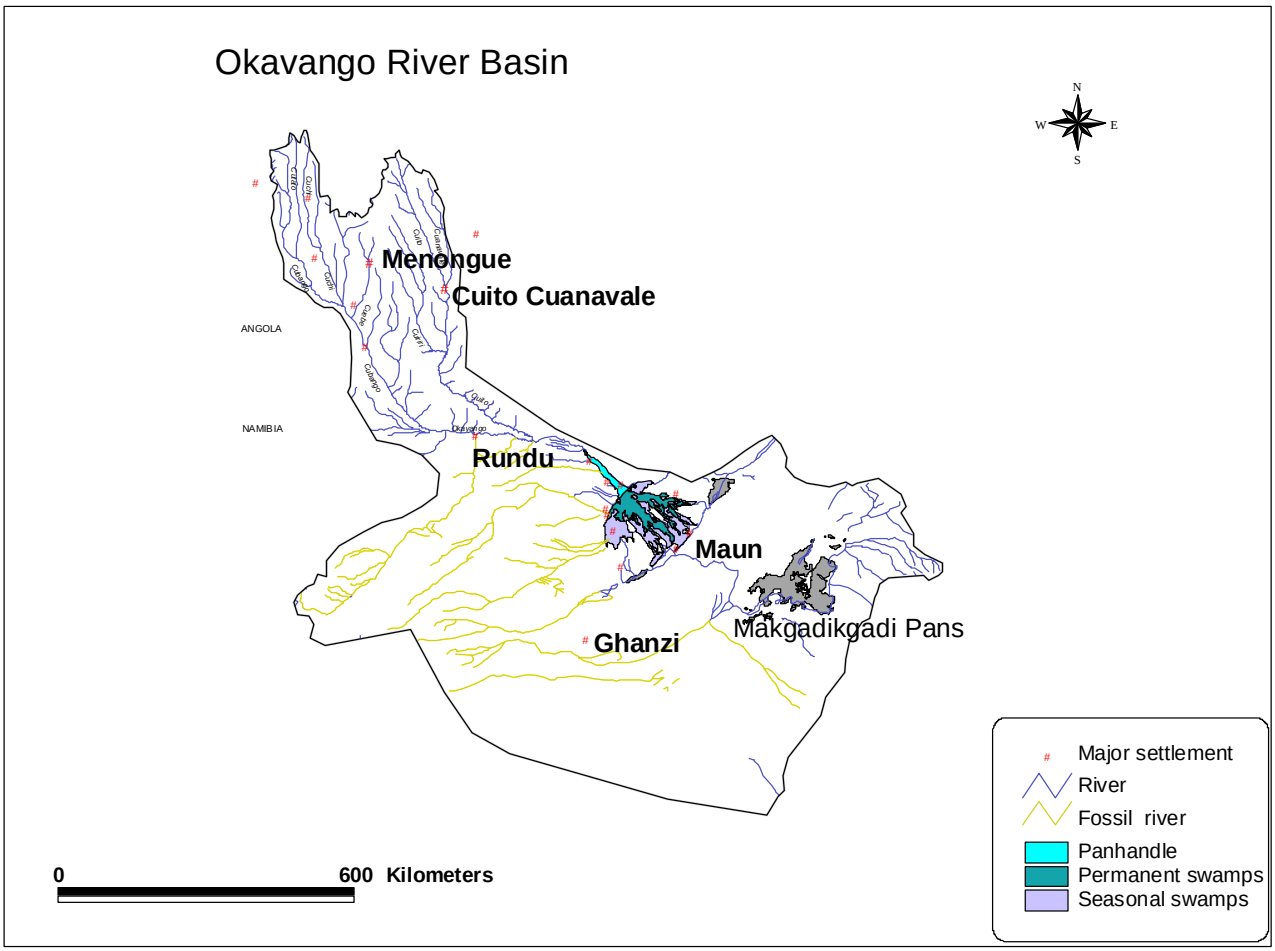

Figure 2-2 The Okavango River Basin.

2.2. Location in relation to political divisions and administrative boundaries

The Okavango River basin covers parts of the following six provinces of Angola; Bie, Cuando Cubango, Huambo, Huila, and Moxico, with Cuando Cubango covering the largest part of the basin (Figure 2-3 and Table 2-1). Menongue and Cuito Cuanavale are the only urban centres in the Angolan part of the basin. In Namibia, the basin covers parts of the Kavango Region, with Rundu located along the Okavango River being the regional centre. Within Botswana, the Okavango Basin is located within the Ngamiland District.

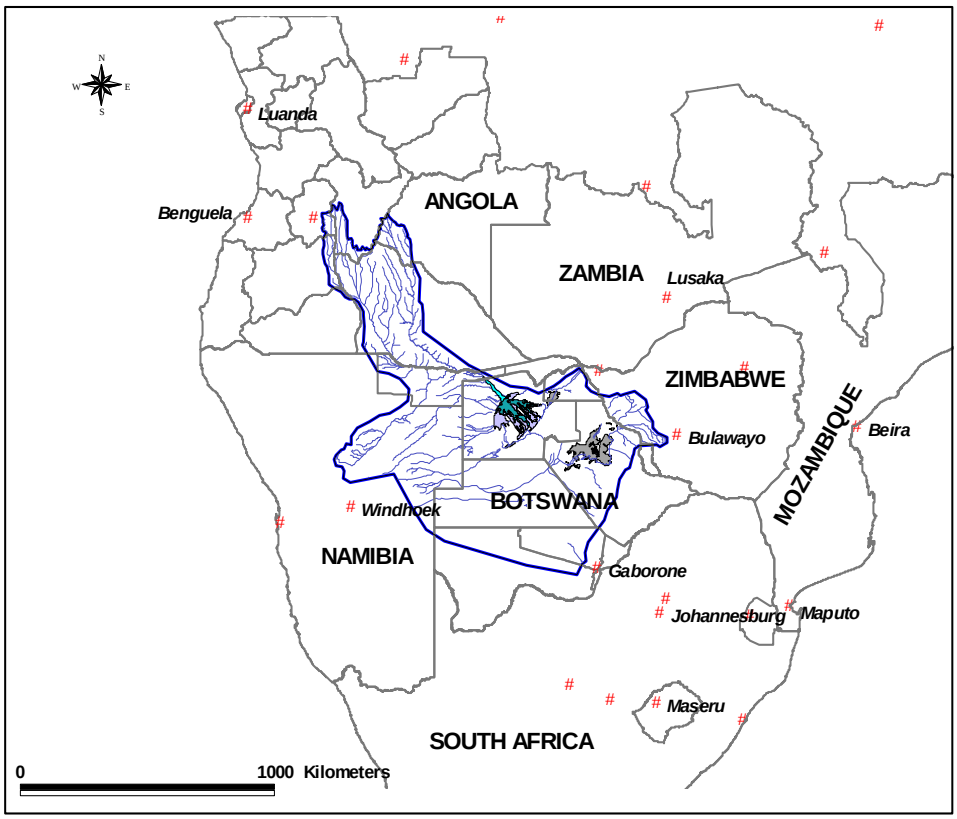

Figure 2-3 The Okavango River Basin in relation to political divisions and administrative boundaries of southern Africa

Table 2-1 Area of countries and districts occurring within the Okavango River Basin based on GIS data (Appendix C).

Country	**District**	**Area within Okavango R. Basin (km^2)**	**% contribution of each district to basin area**	**% contribution of each country to basin area**
Angola	Bie	13456	5.2	62.8
	Cuando Cubango	122144	46.9	
	Cunene	2210	0.8	
	Huambo	3295	1.3	
	Huila	8429	3.2	
	Moxico	13971	5.4	
Namibia	Kavango	41500	15.9	15.9
Botswana	Ngamiland	55374	21.3	21.3
Total Area		260379	**100**	**100**

Note:

- The inactive part of the basin drained by the fossil Omatako River has been included in estimating the area of the basin within the Kavango Region of Namibia.
- The area of the basin in Botswana was taken as the area of the Okavango Delta Ramsar Site (DEA, 2005)

2.3. Topography

The headwaters of the Okavango River are located between Huambo and Kuito at an altitude of 1700-1800 metres above sea level on the central Highlands of Angola. Steep gradients of about 1:1000 occur on the upper part of the Cubango, and then gradually decrease after the confluence of major tributaries such as Cuchi and Cuebe Rivers (1208 m) where the rivers exit from the Angolan Highlands. The Cuito River exits out of the highlands around Cuito Cuanavale. Once the rivers exit from the highlands region, they flow through an area with no significant topographic features on Kalahari sands.

The Okavango Delta is the most significant feature of the basin. The delta is in reality a conical alluvial fan on Kalahari sands with a gradient of 1:3300. Altitude decreases by 60 m along the 250 km from the upper to lower end of the delta. The delta is made up of active and inactive distributary channels, islands and floodplains.

The Okavango Delta drains into an internal depression, the Makgadikgadi Pans which is thought to be part of the paleo Makgadikgadi-Okavango-Zambezi basin (Figure 2-4). The south-western part of the basin has fossil rivers, such as the Omatako, which currently do not contribute flow.

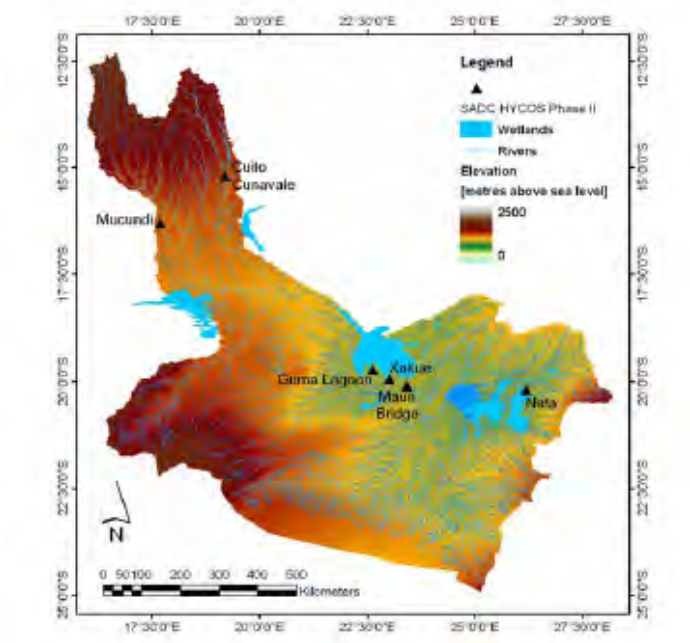

Figure 2-4 Topography of the Okavango River Basin derived from a digital elevation model (SADC HYCOS Phase II Network Design Report, 2007).

2.4. Climate

The Okavango Basin lies within the 12 to 21 degrees south latitude zone, which is characterised by rainfall in one distinct season, October to May, while the rest of the year is dry. The northern parts of the basin receive the highest rainfall during the December to January period, while the southern parts such as Maun have peak rainfall during January and February. Mean annual rainfall varies from about 1300 mm y^{-1} in the Huambo and Kuito areas in the headwaters of the basin, to 560 mm y^{-1} at Rundu, 550 mm y^{-1} at Mohembo, and 450 mm y^{-1} at Maun (Figure 2-5). Rainfall has a high inter-annual variability, with the coefficient of variation being 20% on the well-watered headwaters and 50% in the dry southern parts. There is a tendency for years to group, with above average rainfall for a while followed by generally years with below average rainfall. Due to the high inter-annual variability, years with extremely low rainfall occur frequently, particularly on the southern parts of the basin.

Average daily maximum temperatures range between 30-35°C from August to March in the Namibian and Botswana parts of the basin. Average minimum daily temperatures are in the 7-10°C range during the cool season, June to July. The average daily temperatures are greater than 20°C throughout the basin.

A-pan evaporation increases from the north to south in line with increasing temperatures. The mean annual A-pan evaporation increases from about 1900 mm y^{-1} at Menongue, to about 2010 mm y^{-1} for Maun. Highest evaporation rates occur during the August to November period, e.g. 300 mm m^{-1} in October at Maun (Figure 2-6). The average monthly evaporation rate is greater than monthly rainfall for all months in the middle to southern parts of the basin. Thus most of the Okavango River basin lies within a semi-arid zone.

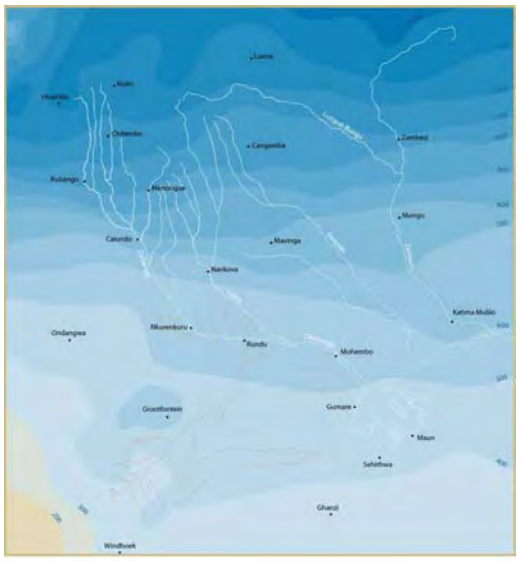

Figure 2-5 Rainfall map of the Okavango River Basin (Source: Mendelsohn and el Obeid, 2004).

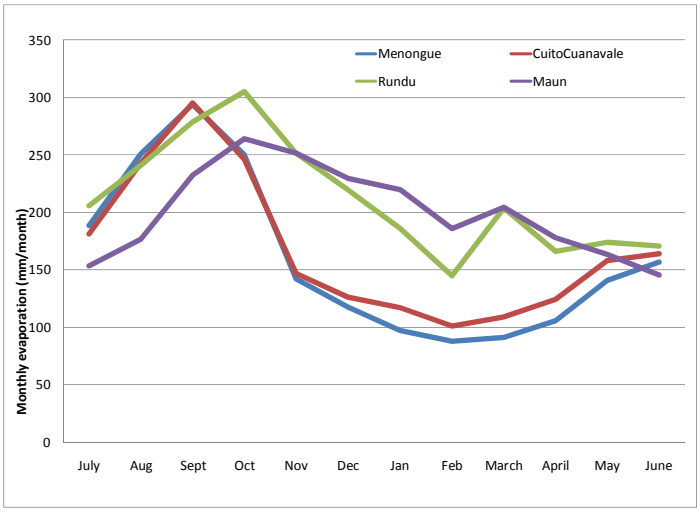

Figure 2-6 Monthly evaporation at selected locations within the Okavango River basin

2.5. Rivers and wetlands

The following river formations occur along the Okavango River,

- incised valleys
- valley marshlands
- floodplain valley
- panhandle
- permanent swamps
- seasonal swamps (Mendelsohn and el Obeid, 2004).

2.5.1. Incised valleys

Incised valleys occur along almost all of the tributaries located on the north-western upper basin, such as Cubango, Cutato, Cuchi, Cacuchi, Cuelei and Cuebe Rivers. This part of the basin has exposed granitic and gneissic bedrock or shallow Kalahari sands. River channels tend to run in parallel. The valley bottoms have mostly permanent wet grasslands.

2.5.2. Valley marshlands

Valley marshlands are found along the main channels of the Cutato, Cuchi and Cacuchi Rivers. These are characterised by dense *Phragmites* reed beds and several ox-bow lakes and meanders.

2.5.3. Floodplain valleys

Floodplain valleys that are shallow and several kilometres wide occur along north-eastern rivers such as the Cuiriri, Cuito, and Cuanavale. The channel meanders within the floodplain valley.

There are no trees within the floodplain valley but short grass, with sedges and grass along the margins of the channel.

2.5.4. Panhandle

The panhandle is formed by two parallel faults within which the Okavango River meanders through a flat bottomed valley that is 10-15 km wide and 150 km long, and which terminates at the beginning of the broad alluvial deltaic fan. *Papyrus* and reeds dominate the valley. The main channel splits and rejoins at some locations. The panhandle drains into the delta, which is made up of meandering channels, floodplains and islands. The delta comprises several active and inactive distributary channels.

2.5.5. Permanent swamps

Permanent swamps cover an area of 2000-3000 km^2 and are mostly located on the central part of the Okavango Delta, and along the Maunchari, Mboroga, Jao-Boro, Nqogha, and Thaoga distributaries. Water flows through channels and also leaks through surrounding *Papyrus* and reedbeds onto the floodplain. Typical plant species are *Cyperus papyrus, Vossia cuspidata, Phragmites communis L., Typha capensis (*Mendelsohn and el Obeid, 2004).

2.5.6. Seasonal Swamps

The area under seasonal swamps varies annually from 4000-8000 km^2 depending on the magnitude of the inflow into the delta. Inflow into these swamps originates as water flowing onto the floodplains from the channels within the permanent swamps. The water is generally shallow and the vegetation highly variable, depending on the frequency and duration of flooding.

2.6. Vegetation

Eight vegetation types have been recognised for the Okavango River basin (Table 2-2 and Figure 2-7).

Table 2-2 Types of vegetation occurring within the Okavango River basin (Mendelsohn and el Obeid, 2004)

Vegetation Type	Characteristics
Planalto grasslands	Extensive grasslands dominated by Loudetia simplex occurring on the headwaters of the Cubango, Cutato and Cuchi rivers
Open Brachystegia woodland	Woody *Brachystegia* plants occurring in open grasslands. These occur on the upper parts of the Cubango, Cutato, Cuchi and Cacuchi Rivers.
Dense *Brachystegia* woodland	Occurs on upper parts of Cuelei, Cuebe, Cuito and Cuanavale. Species occurring are *Brachystegia* species, *Julbernadia paniculata, Pteleopsis anisoptera and Cryptosepalum pseudotaxus.*
Burkea-Brachystegia woodlands	Found south of the dense *Brachystegia* woodland and a transition to *Burkea* woodlands
Burkea woodland	Covers the basin from the middle part in Angola to the northern limits of the Okavango Delta. Common species are *Burkea africana, Pterocarpus*

	angolensis, Burkea plurijuga, Schinziophyton rautanenii, and *Guibourtia coleosperma.*
Valley woodlands and grasslands	Mixture of woodlands, grasslands and floodplain grasses. Found along the Cubango River
Floodplain valleys	Seasonally flooded grasslands. Occur along the Cuito, Cuanavale, and Cuirri Rivers.
Permanent swamps	Dominated by *Papyrus* and *Phragmites* in the delta.

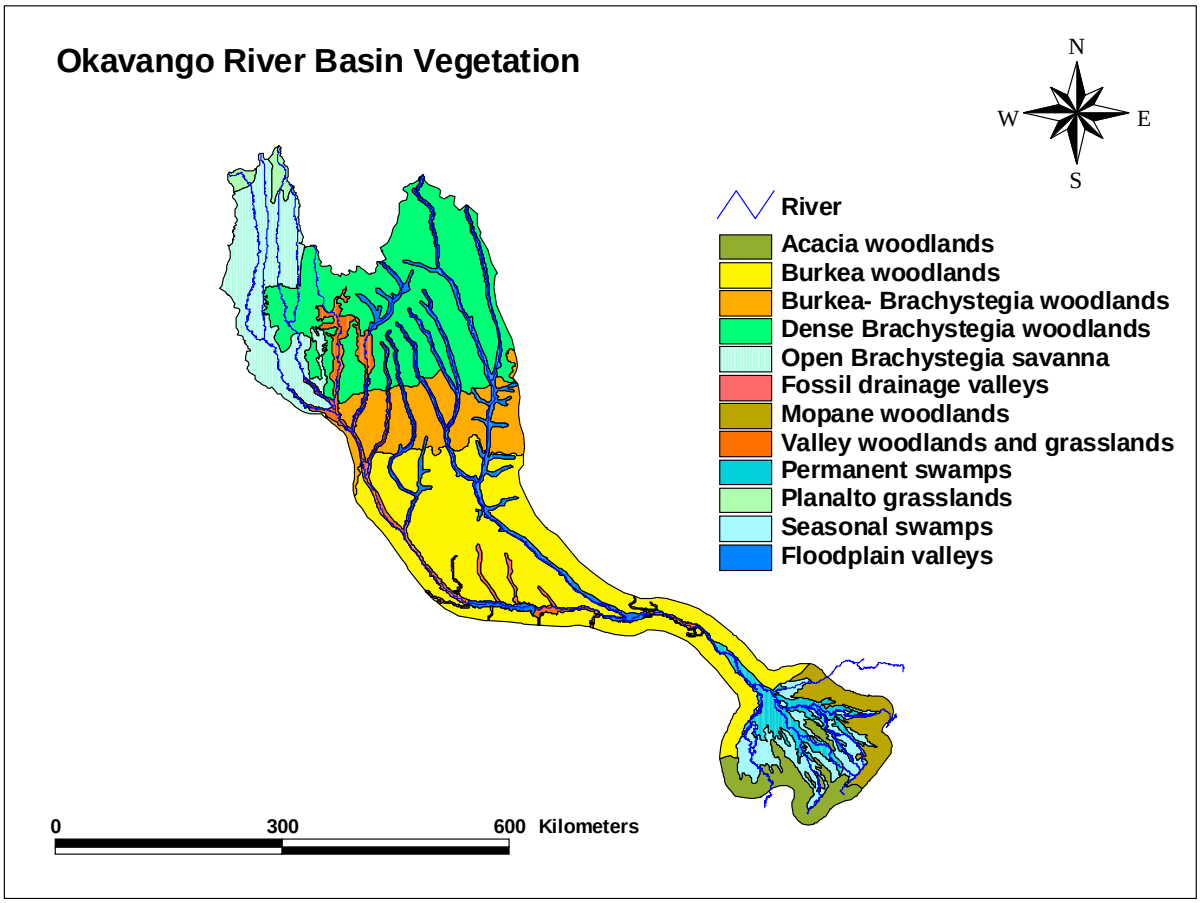

Figure 2-7 Map of the Okavango River Basin showing major natural features, vegetation types and land uses. Source: Mendelsohn and el Obeid, 2004.

3. ZONATION OF THE RIVER

3.1. Introduction

Rivers change from source to end in fairly predictable ways. They have steeper and often steep-sided valleys in mountainous areas, and low-gradient channels in wider valleys in flatter terrain. This affects the hydraulics of the system, the water quality and temperature, the riverbed bed and bank material, the in-channel and bankside habitats available for riverine life and thus the plants and animals that can exist in different sections of the river. All of this in turn influences where people can live along the river and how they use its resources. We cannot describe every section of a river and its biota, and every human user of the river. Instead, homogeneous river zones and social areas are delineated and representative sites chosen for each.

The length of the river can be zoned using a range of criteria: its hydrological, chemical, geomorphological or biological nature. In this project, river zones were delineated se perspectives and then harmonised into one summary set of zones. The details of this are described in Sections 3.2-3.6.

3.2. Hydrological and geohydrological zonation

The main objective of the hydrological and geohydrological zonation was to divide the river basin into areas with similar hydrological and hydrogeological characteristics.

Composition of the Hydrology team was as follows:

Angola

- Mr. Manuel Quintino (National Coordinator of the GEF EPSMO project/Water Engineer)
- Dr. Gabriel Luis Miguel (Faculty of Sciences of Agostinho Neto University/Hydrogeologist)
- Mr. Paulo Emilio Mendes (DNA/Hydrologist)

Botswana

- Ms. Kobamelo Dikgola (DWA/Assistant Water Engineering)
- Mr. France Tibe (DWA/ ssistant Water Engineering)
- Dr. Piotr Wolski (HOORC/Hydrogeologist)

Namibia

- Dr. Andre Mastert (NAMWATER/Manager/Hydrology)
- Ms. Aune-Lea Hatutale (NAMWATER/Hydrologist)
- Mr. Mathews Kajimune (DWAF/Hydrogeologist)

Process management

- Mr. Hans Beuster (Southern Waters/Hydrologist)

The river basin was divided into two major zones namely, (i) the Cubango sub-catchment with granitic soils and with most of the flows originating from surface runoff, and (ii) the Cuito sub-

catchment dominated by Kalahari sands and fed by both groundwater and surface runoff. The Cubango and Cuito sub-catchments were further subdivided into 13 sub-catchments. This division was a result of a larger group discussion involving biologists, socio-economists, hydrologists, geohydrologists and geomorphologists.

Table (Table 3-1) below shows the hydrological / geohydrological zones within the two Angolan catchments.

Table 3-1 Delineation of hydrological sub-catchments within the Angolan part of the Okavango Basin

Tally	Country	River	Description / Location	Hydrology subcatchment	Geohydrology zone
1	Angola	Cubango	Source		GeoH 1
2	Angola	Cubango	Source to Chinhama	Hydro 1	GeoH 1
3	Angola	Cubango	Chinhama to Kubango	Hydro 2	GeoH 1
4	Angola	Cutato	Source to Chinhama	No hydro	GeoH1
5	Angola	Cutato	Chinhama to confluence with Cubango	Hydro 3	GeoH1
6	Angola	Cubango	Kubango to Caiundo		GeoH 1
7	Angola	Cubango	Caiundo to Mucundi	Hydro 8	GeoH 2
8	Angola	Cuebe	Source to Menongue	Hydro 6	GeoH1
9	Angola	Cuebe	Menongue confluence with Cubango	Hydro 6	GeoH2
10	Angola	Cubango	Mucundi to Catambue	Hydro 9	GeoH 2
11	Angola	Cuito	Source to Cangoa	No hydro	GeoH2
12	Angola	Cuito	Cangoa to 14 Degrees Lat	Hydro 15	GeoH2
13	Angola	Cuito	14 Degrees Lat to Cuito Cuanavale	Hydro 17	GeoH2
14	Angola	Cuito	Cuito Cuanavale to Nankova	Hydro 19	GeoH2

3.3. Geomorphological zonation

3.3.1. Introduction

The main objective of the geomorphological delineation was to divide the main rivers within the Okavango River Basin into zones with similar channel characteristics. Channel patterns mainly depend on lithology, the existence of structural features such as faults, slope, and climate. Zones can be defined as stretches of river within which channel form is essentially homogeneous. Nested within zones can be a variety of channel types.

3.3.2. Approach used

The classification of the basins into geomorphological zones was done using lithology, drainage density, drainage pattern, existence of erosional or depositional features, and channel gradient. The basin was divided into lithological units and classification was then based on characteristics of the drainage network and channel slope.

The sources of information used for the geomorphological classification are given in Table 3-2. The main rivers considered in the classification are given in Table 3-3.

Table 3-2 The reports and maps that provided the bulk of the information used in the geomorphological delineation

Sources of Information for geomorphological classification
• Mendelsohn, J. and el Obeid, S. 2004. Okavango River: The flow of lifeline. Struik Publications, Cape Town. • Sharing water. Towards a transboundary consensus on the management of the Okavango River basin. 2005 Report prepared for the USAID • Classification of the Angolan part of the basin done by Angolan geomorphologist. • Google Maps

Table 3-3 Main rivers within the Okavango River Basin considered in the geomorphological zone analysis.

Country	**Main River**
Angola	Cubango, Cutato, Cuchi, Cacuchi, Cuelei, Cuebe, Cuiriri, Cuito, Cuanavale
Namibia	Okavango
Botswana	Panhandle, Maunachira, Khwai, Jao-Boro, Thaoga, Thamalakane,Boteti

3.3.3. Geology and dominant substratum

The upper part of the Cubango River in Angola has granites and gneiss. The rest of the basin is covered with Kalahari sands deposited over the basement complex during the last 63 million years.

3.3.4. Channel planform, valley form and the presence of floodplains

The upper part of the Okavango Basin occurring in Angola is characterised by rivers that run parallel to each other. The upper Cubango basin from the source to about Kubango is steep with incised valleys and high drainage density. The rivers can be classified as steep mountain streams (Table 3-4 and Figure 3-1). As the Cubango River descends from the highlands its valley becomes flat bottomed and wide and thus its is classified as a lower foothill river (Table 3-5). From Mucundi to Nzinze on the Angolan/Namibia border the channel is contained within a low-gradient, wide valley with depositional features. A lowland type of river with a low gradient dominated by depositional features occurs between Nzinze and Popa Rapids.

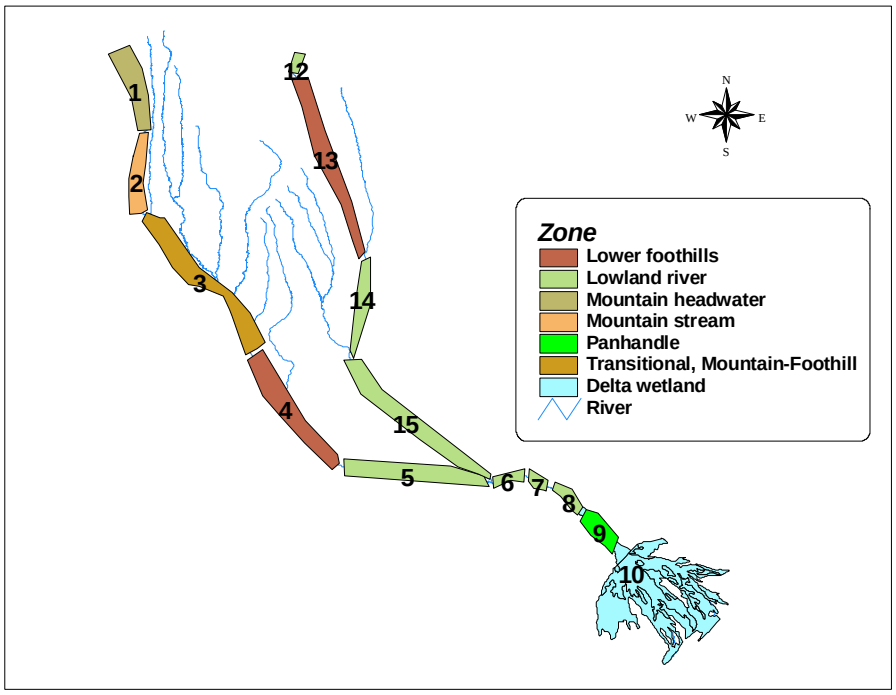

Figure 3-1 Geomorphological zones along the Cubango, Cuito and Okavango Rivers.

Table 3-4 Geomorphological delineation of the Okavango Basin river system

Reach No.	Zone # from Angolan data	River name	Coordinates demarcating the end of a reach				Length of reach	Altitude	Channel description	Slope	Depositional zone	Geomorphological zone	Geology
			Location	X	Y	Length from source (km)							
0		Cubango	Source			0		1772					
1	A	Cubango	Source to Chinhama	16.4	13.4	117	117	1605	Steep, incised. High drainage density. No floodplain.	0.0014	Erosional	Mountain headwater	Granites
2	A	Cubango	Chinhama to Kubango	16.5	14.6	360	243	1488	Steep, incised. Narrow stream bed. High drainage density. No floodplain.	0.0010	Erosional	Mountain stream	Granites
3	C	Cubango	Kubango to Mucundi	17.65	16.29	500	140	1331	Flat bottomed, wide streams.	0.0013	Erosional	Transitional (mtn foothill)	Kalahari Sands
4	E	Cubango	Mucundi to Nzinze	18.95	17.8	732	232	1201	Flat bottomed, wide streams. Low drainage density.	0.0011	Depositional	Lower foothill	Kalahari sands
5	E	Cubango	Nzinze to confluence with Cuito	19.12	17.82	1074	342	1093	Low gradient alluvial fine bed channel	0.0009	Depositional	Lowland	Kalahari Sands
6	E	Okavango	Confluence with Cuito to Andara	20.8	18.03	1261	187	1045	Low gradient alluvial fine bed channel	0.0004	Depositional	Lowland	Kalahari Sands
7	E	Okavango	Andara - Popa	21.35	17.99	1364	103	1020	Low gradient alluvial fine bed channel	0.0002	Depositional	Lowland	Kalahari Sands

Reach No.	Zone # from Angolan data	River name	Coordinates demarcating the end of a reach				Length of reach	Altitude	Channel description	Slope	Depositional zone	Geomorphological zone	Geology
			Location	X	Y	Length from source (km)							
8	E	Okavango	Popa Rapids to Mohembo	21.6	18.1	1402	38	1007	Low gradient alluvial fine bed channel	0.0001	Depositional	Lowland	Kalahari Sands
9	E	Okavango	Mohembo to Panhandle	21.73	18.17	1419	17	1000	Swamp	0.0001	Depositional	Lowland	Kalahari Sands
10	E	Okavango	Panhandle	22.4	19.04	1559	140	988	Meandering channel; floodplain	0.0001	Depositional	Panhandle	Kalahari Sands
11	E	Delta	Delta System	23.51	19.91	1734	175	952	Delta System	0.0003	Depositional	Lower land	Kalahari Sands
12	E	Cuito	Cangoa	18.38	12.87	30	30	1453	Low alluvial fine bed	.0006	Depositional	Lowland	Kalahari sands
13	E	Cuito	Cuito Cuanavale	19.19	15.14	477	447	1160	Lower gradient mixed bed alluvial channel	.0025	Depositional	Lower foothills	Kalahari sands
14	E	Cuito	Nankova	19.0	16.38	609	132	1129	Low gradient alluvial fine bed	.0002	Depositional	Lowland	Kalahari sands
15	E	Cuito	Dirico	20.77	18.00	921	312	1026	Low gradient alluvial fine bed	0.0009	Depositional	Lowland	Kalahari sands

Table 3-5 Geomorphological zonation of South African river channels (Rowntree and Wadeson 1999).

Longitudinal Zone	Characteristic Channel Features	
	Gradient	Description
Source zone	not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peat hydromorphic soils.
Mountain headwater stream (Mountain torrent)	>0.1	A very steep gradient stream dominated by vertical flows over bedrock with waterfalls and plunge pools. Normally first or second order. Zone types include bedrock fall and cascades.
Mountain stream	0.04 - 0.09	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Zone types include cascades, bedrock fall, and step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Mountain stream (transitional)	0.02 - 0.039	Moderately steep stream dominated by bedrock or boulder. Zone types include plane-bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited floodplain development.
Upper Foothills	0.005 – 0.019	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow floodplain of sand, gravel or cobble often present.
Lower Foothills	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Floodplains often present.
Lowland river	0.0001 – 0.001	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increased silt content in bed or banks.
Rejuvenated bedrock fall / cascades	>0.02	Moderate to steep gradient, confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid.
Rejuvenated foothills	0.001 – 0.02	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro-channel activated only during infrequent flood events. A limited flood- plain may be present between the active and macro-channel.
Upland flood plain	<0.005	An upland low gradient channel, often associated with uplifted plateau areas, as occur beneath the eastern escarpment.

The longitudinal profiles of the Cubango-Okavango River and Cuito River are given in Figure 3-2.

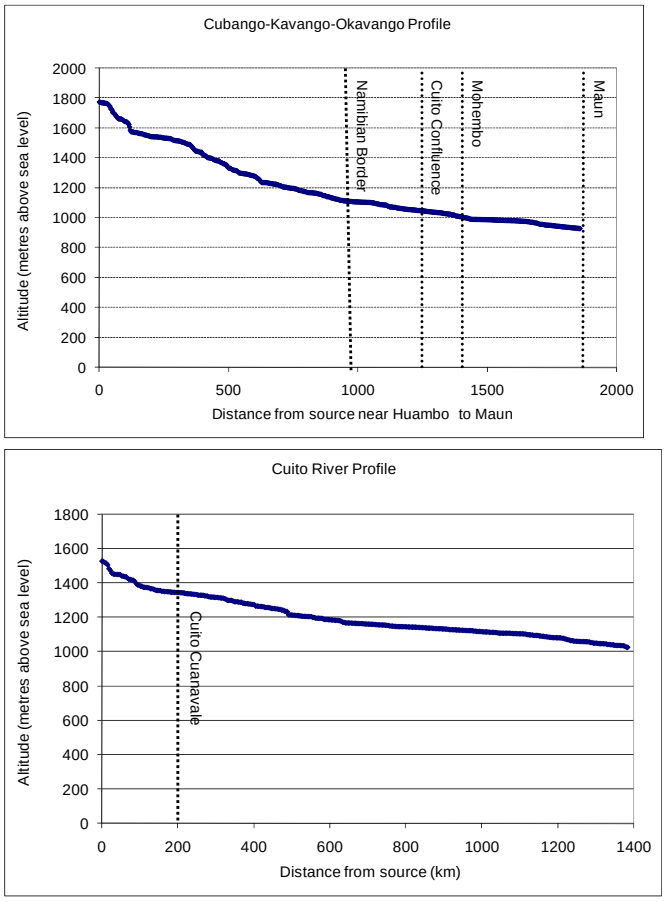

Figure 3-2 Longitudinal profiles of the Cubango-Okavango River and Cuito Rivers.

3.4. Chemical and thermal zonation

3.4.1. Introduction

The main objective of chemical and thermal delineation was to divide the main rivers within the Okavango River Basin into zones with similar water-quality characteristics. Zones were defined as stretches of the river within which water quality is essentially homogeneous. Urban centres were considered to be zones as it was felt that there would be significant localised effects of urban activities on the water quality. It was felt that within each chemical zone, the thermal characteristics would be similar.

3.4.2. Approach used

The water-quality team consisted of C. Ortmann and L. Namene (both from Department of Water Affairs,Namibia); Dr. C.N. Kurungudla (Department of Water Affairs, Botswana), Dr W. R.L. Masamba (Harry Oppenheimer Okavango Research Centre, University of Botswana, Botswana) and Carlos Andrade from Angola. The approach taken was to consider channel flow and human activities as the main basis for choosing chemical zonations. Three characteristics were used, and everywhere that one of these changes a new zone was assigned. The three characteristics were:

- zones characterised by:
    a. dominant instream flows
    b. low bank spills
    c. significant land use
- zones characterised by:
    a. several distributaries e.g. in Angola, Okavango Delta
    b. swamps and flood plains e.g. Namibia, Okavango Delta
    c. low to medium land use
- Towns and villages

The water quality zones were agreed on as follows (Table 3-6):
Angola
Zone 1:
- Headwaters of Cubango to Cubango- Cuebe confluence.
- Headwaters of Cuito River to Longa

Zone 2:
- From Cubango-Cuebe confluence to Caiundo
- From Longa to Cuito Cunavale

Zone 3:
- From Caiundo to Katwitwi on the Angola/Namibia border
- From Cuito Cunavale to Dirico

Angola and Namibia
Zone 4: along the Okavango River from Katwitwi to Kasivi/Bunya
Zone 5: along the Okavango River from Kasivi/Bunya to Mbambi
Zone 6: along the Okavango River from Mbambi to Popa Rapids
Namibia
Zone 7:along the Okavango River from Popa Rapids to Mohembo
Botswana
Zone 8: Mohembo to Seronga (Panhandle)
Zone 9: middle part of the Okavango Delta
Zone 10: lower part of the Delta

Zones 11 -15: urban areas at Rundu, Maun, Cuito Cuinavale, Menongue, Cuchi

These zones are plotted on Figure 3-3 and were later harmonised with other disciplines.

Table 3-6 Chemical zonation of the Okavango River system

Reach No.	River name	Description
WQ 1	Cubango	Source to Kubango
WQ 2	Cubango	Kubango to Mucundi
WQ 3	Cubango	Mucundi to Catambue
WQ 4	Okavango	Catambue to Rundu
WQ 5	Okavango	Rundu to Dirico
WQ 6	Okavango	Dirico to Mukwe
WQ 7	Okavango	Mukwe to Popa
WQ 8	Okavango	Popa to end of Panhandle
WQ 9	Okavango	Upper Delta
WQ 10	Okavango	Lower Delta
WQ 11	Cuito	Source to 14 degree Lat
WQ 12	Cuito	14 degree Lat to Cuito Cuanavale
WQ 13	Cuito	Cuito Cuanavale to confluence with the Okavango
WQ 2	Cutato	Whole river
WQ 2	Cuebe	Source to Mucundi
WQ 3	Cuebe	Mucundi to confluence with Cubango
WQ 14	Okavango	Maun (Urban)
WQ 15	Cuito	Cuito Cuanavale (Urban)
WQ 16	Cuebe	Menongue (Urban)
WQ 17	Cubango	(Cuchi (Urban)

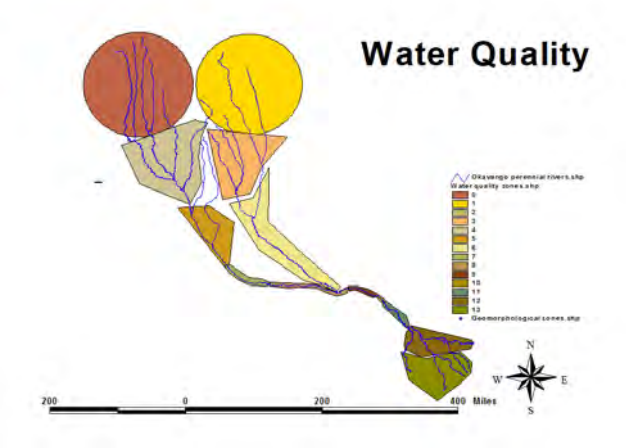

Figure 3-3 Water quality zones

3.5. Biological zonation

3.5.1. Introduction

Rivers are longitudinal ecosystems, with changing conditions from source to sea. Headwaters, if originating in highland areas, tend to have cooler, purer water, steeper channels, larger bed particles and more turbulent flow. The downstream ends of the systems are usually flatter, with warmer, less pure water, and finer bed particles because of the slower flow. In addition to these changes in altitude, rainfall across the Okavango River Basin steadily decreases from its

source to the Delta. These aspects of rivers have been covered in the three preceding physical and chemical zonation analyses.

Distribution of the living components of the ecosystem reflects these changes: the communities of plants and animals, in the channel, the floodplains and on the banks, differ along the length of the system. Usually there is no sudden transition from one community to another. Rather, species replace species along the river resulting in several overall changes from one recognisable community to another. Thus, for instance, a community of miombo woodland trees may occur along the upper catchment area of a river, to be gradually replaced by a more open tree community further downstream and then reeds, sedges and grasses along its lowest, slowest-flowing reaches. In the case of the Okavango River these vegetation zones reflect decreasing rainfall too. These recognisably different sections of a river may be seen as biological river zones. Such zones will also be apparent in the distribution of riverine fish, aquatic macro-invertebrates, amphibians, aquatic reptiles and river-dependent birds and mammals.

The objective of the exercise reported in this section was to delineate river zones based on biological information – in other words to allow the river species to indicate by their distribution patterns which parts of the river are perceived by them as being different.

3.5.2. Approach used

On the first day, the biologists from the three countries formed a team to consider ecological delineation of the Okavango River Basin. The team included:
Angola: Luis Verissimo (Large mammals), Miguel Morais (General Biology), Carlos Andrade (General Biology/ Ecology)
Namibia: Kevin Roberts (Aquatic Ecology and Wildlife), Barbara Curtis (Vegetation Ecology), Shirley Bethune (Aquatic/Vegetation Ecology), Shishani Nakanwe (Aquatic Ecology), Christopher Munwela (Fisheries)
Botswana: –Casper Bonyongo (Wildlife ecology), Keta Mosepele (Fisheries ecology), Belda Mosepele (Aquatic Invertebrates), Kelebogile Mfundisi (Aquatic Vegetation) and Sekgowa Motsumi (General Ecology)

The team shared an overview of the basin as not all were familiar with parts of the basin in other countries. To start the more detailed discussions, the group listed the different habitats within the basin – aquatic, wetland and terrestrial, and agreed that the level of zonation would be broad habitats/vegetation zones, as determined by rainfall, altitude and soils, and within which they would distinguish distinct sub-basins. It was agreed that fauna should to some extent follow the vegetation zones and that they would test this concept within the group.

Using such intuitive biological zones based on rainfall and vegetation, each zone was then discussed per discipline, that is, by the specialists in aquatic invertebrates, fish, riverine reptiles, water dependent birds and mammals. Too little information was available to discuss the amphibians and it was agreed to group the reptiles with the mammals as wildlife for purposes of the discussions.

Starting in the north, the group distinguished 11 vegetation zones for the Cubango/Okavango and five for the Cuito basin, and recognised bands across the basins linked by rainfall and altitude. Within Angola, the same number was used for zones in the same band and within these the basins were designated as a) Cubango and b) Cuito – the two major sub-basins. For each of the 16 ecological zones thus identified within the Okavango River Basin (Table 3-7), the group listed the dominant species, gave the geographic location and a general ecological description. It was agreed to tabulate these vegetation zones and then link the main faunal zones across these.

Each country's specialists contributed information on broader characteristics and the occurrence of endemics of each faunal group for each identified zone. All discussed similarities with other zones. The team made use of maps, reference books such as Mendelsohn, Griffin, Ellery, as well as the ODMP, AquaRap and the Namibian pipeline preliminary environmental assessment reports (Table 3-8). It was agreed that Botswana's aquatic invertebrate, fish and bird specialists would give input during the next day as they were absent from the afternoon discussions.

On the second day, the team leader recapped on the previous day's work by discussing each zone as tabulated. All used the opportunity to add new information: on birds and vegetation species from Angola, fish, vegetation, and invertebrates in Botswana and fish zones as designated by fishery biologists in Namibia. The zones were reassessed based on the new information, mainly based on the Botswana AquaRap study results. The team agreed to divide (a) the Botswana panhandle zone into the upper and lower zones; (b) the permanent swamp into the Santantadibe/Maunachira arm and the Boro/Jao arm; and (c) that the 'seasonal swamp' should constitute the outflow channels, Thamalakane and Boteti, (d) that Lake Ngami should be a separate zone, thereby increasing the number of ecological zones to 13. The team was later instructed not to divide the zones in Angola into a) and b) but to give each identified ecological zone its own number, thus the four zones identified for the Cuito River Basin were added and moved to the end of the table as zones 14–18 (Figure 3-4).

The ecologists identified and agreed on eighteen zones, thirteen stretching from the source of the Cubango River to the outflow channels of the Delta and Lake Ngami, and four in the Cuito Basin parallel to rather similar zones in the adjacent Cubango River Basin.

Table 3-7 shows these 18 ecological zones and their vegetation characteristics.

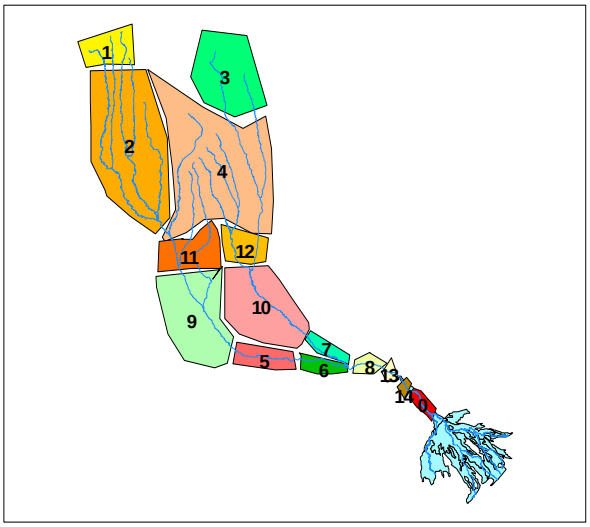

Figure 3-4 The 14 biological zones which were eventually increased to 18 zones.

Table 3-7 Ecological zones within the Okavango River Basin identified and agreed by biologists

Zone no	Veg zone and river	Location	Description	Dominant vegetation
1	Waterlogged grassland Cubango	From Vila Nova / Liuema to Sambo / Cachingues in the south	permanently wet grasslands at source, in small channels. Cubango, Cutato, Cuchi, Cacuchi tributaries; high human pressure	*Protea; Parinari; Syzygium; Helichrysum; Ctenium; Fimbristylis*
2	Miombo woodland Cubango	From Sambo / Cachingues to Caiundo / Mumbue	Cubango, Cuchi, Cuelei.	*Brachystegia* spp, *Brachystegia spiciformis, Julbernardia paniculata*
3	Miombo/Dry woodland transition area Cubango	From Caiundo to Mumbue		B*rachystegia* spp, *Burkea africana, Pterocarpus angolensis*
4	Dry woodland/ savannah mosaic Cubango	From Caiundo to Katuitui		*Burkea africana, Pterocarpus angolensis, Terminalia sericea, Acacia* spp
5	Mainstream River Reedbeds and Floodplains Okavango	Katwitwi to Mukwe Few floodplains east of Bunya More marked floodplains section Bunya to Mukwe	River flowing eastwards, heavily impacted by humans, Shallow water, sandy & rocky substrates; after Bunya well developed floodplains, large oxbow lakes & backwater habitats; below Cuito junction more:gentle gradient, meanders, wider, reedbeds, sedges & sandbanks Includes two distinct fisheries zones	*Ziziphus mucronata, Acacia* spp, *Dichrostachys cinerea, Terminalia sericea*
6	Rocky river section with well developed riparian and island woodlands Okavango	Mukwe - Popa rapids	Riparian woodland; rocky, braided with islands, rare fish: rapids, substratum sand and gravel, large boulders. Distinct fisheries zone	*Diospyros mespiliformis, Rhus quartiniana, Philenoptera violacea*
7	Riparian woodlands with floodplains Okavango	Below Popa Falls to Mohembo	: start of Panhandle - large floodplains, reedbeds, papyrus, protected area Distinct Fisheries zone	*T: Acacia nigrescens, Kigelia africana, Combretum imberbe, Diospyros mespiliformis. S: Croton megalobotrys, Combretum mossambicense*
8	Panhandle, riparian woodlands, permanent swamp Okavango	Mohembo to Sepopa "upper panhandle"	77 plant species-Meandering channel; floodplain, papyrus, reedbeds, Diospyros mespiliformis (different fish species and aquatic invertebrate fauna)	*Cyperus papyrus, Vossia cuspidata, Phragmites australis*
9	Permanent swamps Okavango	Sepopa/ Gumare to Serongo area "lower panhandle" with lagoons	131 plant species-Meandering channel; floodplain, papyrus, reedbeds, Diospyros mespiliformis Distinct aquatic invertebrate and fish communities	*Cyperus papyrus, Vossia cuspidata, Phragmites australis*

Zone no	Veg zone and river	Location	Description	Dominant vegetation
10	Seasonal swamps - central Jao/Boro channels	permanent swamp Central swamp and south east of Chief's island	108 plant species-f aquatic vegetation emergent and submerged species distinct aquatic invertebrate and fish communities	*C. papyrus, Vossia cuspidate*
11	Seasonal swamps Santantadiibe Maunachira. channels	Seasonal swamp North western Moremi and Xakananaxa lagoon	Papyrus, hippo grass, phragmites, lagoons,	*Phragmites australis, Mischantus junceus, C. papyrus*
12	occasionally flooded Thamalakane /Boteti outflows	Seasonal to occasionally flooded outflow channels south-west of Delta	Biologists distinguish three sub-zones here dependant on flooding duration. Primary secondary and tertiary	*Nymphae sp., Nymphoides, Marselia* Floodplain grasses
13	Ephemeral floodplain lakes Lake Ngami	Lake Ngami	Rarely flooded (low fish species diversity)	Usually dry, floodplain grasses and Acacia trees, when wet *Ludwigia* sp.
14	Headwaters Cuito	Source	High rainfall, gentler gradient, more meanders, wider valley. Few people	*Brachystegia spp,*
15	Miombo & floodplains Cuito	From Cango to 14 degrees Lat. Cuebe, Cueio, Cuatir, tributaries and floodplains		*Brachystegia spp,*
16	Miombo/Dry woodland transition Cuito	*From 14 degrees Lat to Cuito Cuanalae*		*Brachystegia* spp*, Burkea africana, Pterocarpus angolensis*
17	Dry woodland/savannah mosaic Cuito	From Cuito Cuanavale to Lumeta		*Burkea africana, Pterocarpus angolensis, Terminalia sericea, Acacia spp*
18	Permanent swamp at Cuito/Cubango confluence	From Lumeta to Mukwe		

Table 3-8 Literature searched for data on biological zonation of the Okavango River Basin

Country	Literature
Angola	Curtis, B. A and C.A. Mannheimer. 2007. Field guide to select trees of Kunado Kubango. The Okavango Integrated River Basin Management Project (IRBM), Windhoek.
	Mendelsohn, J. and S el Obied. 2004. Okavango River: the flow of a lifeline. Struik, Cape Town.
	Skelton, P. H. 1993. A complete quide to the freshwater fishes of Southern Africa. Southern Book Publishers, Halfway House.
	Verissimo, M.N. 2008. Guide to the larger mammals of Kuando Kubango. Okavango River Basin Management Project (IRBM), Windhoek.
Botswana	Alonso, L.E. and L-A Nordin (editors), 2003. A rapid biological assessment of the aquatic ecosystems of the Okavango Delta, Botswana: High Water Survey. RAP Bulletin of Biological Assessment 27. Conservation International, Washington, D.C.
	Butchart, D. 2000. Wildlife of the Okavango. Common Animals and Plants, Struik, Cape Town.
	Department of Environmental Affairs, 2008. Okavango Delta Management Plan, Gaborone.
	Ellery, K. and Ellery W. 1997. Plants of the Okavango Delta. Tsaro Publishers, Durban.225 pp.
	Mendelsohn, J. and S el Obied. 2004. Okavango River: the flow of a lifeline. Struik, Cape Town.

Country	Literature
Namibia	Bethune, S. 1991. Kavango River wetlands. *Madoqua.* 17 (2) : 77 – 112.
	Bethune, S. and K. S. Roberts. 1991. Checklist of the fishes of Namibia for each wetland region. *Madoqua.* 17 (2) : 193 – 199.
	Bethune, S.1992. An updated review of the limnological baseline survey of the Okavango River in Namibia 1984 – 1986. Research Division report RR/92/3. Department of Water Affairs, Windhoek.
	Bethune, S., D, Shaw, K.S. Roberts and the Wetland Working Group of Namibia. 2007. Wetlands of Namibia. Wetlands Working Group of Namibia, Windhoek.
	Chutter, F.M. 1997. A report on the application for the SASS4 method for the assessment of river water quality to the Zambezi, Okavango and Kwando/Linyanti/Chobe rivers in northern Namibia. Afridev consultants, Menlo Park.
	Curtis, B.A. 1991. Freshwater macro-invertebrates of Namibia. *Madoqua.* 17 (2):163 – 187.
	Curtis, B.A. and C.A. Mannheimer. 2005. Tree Atlas of Namibia. National Botanical Research Institute, Windhoek.
	Curtis, B.A., K.S. Roberts, M. Griffin, S. Bethune, C.J. Hay and H. Kolberg. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation.* 7: 447-466.
	Griffin M. and C.G. Coetzee. 2005. Annotated checklist and provisional national conservation status of Namibian mammals. Technical report 4 of Scientific Services, Ministry of Environment and Tourism, Windhoek.
	Hatutale, A. 1994. Investigation into the surface water resources of the Okavango Region with special reference to the Okavango River. Hydrology Division report 2500/3/1/H1 Department of Water Affairs, Windhoek.
	Hay, C.J., T.F. Naesje, J. Breistein, K. Harsaker, J. Kolding, O.T. Sandlund and B. van Zyl. 2000. Fish populations, gill net selectivity, and artisinal fisheries in the Okavango River, Namibia. Recommendations for a sustainable fishery. NINA-NIKU Project Report 010: 1- 105. Windhoek/Trondheim.
	Hines, C.J.H. 1986. The Birds of eastern Kavango, SWA/Namibia. *Journal of the SWA Scientific Society 1985/86, 1986/87.* 40/41 *:* 115 – 147
	Mendelsohn, J. and S el Obied. 2003. Sand and Water. A profile of the Kavango Region. Struik, Cape Town.
	Mendelsohn, J. and S el Obied. 2004. Okavango River: the flow of a lifeline. Struik, Cape Town.
	Paxton, M. (Editor) 2008. Bwabwata National Park, Special Edition. *Sandpaper* 10. SPAN project newsletter, Ministry of Environment and Tourism.
	Skelton, P.H. 1987. South African Red Data Book – Fishes. South African national scientific programmes report 137, Pretoria.
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Country	Literature
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3.5.3. Findings

Table 3-9 lists the 18 biological zones recognised and gives a general description of each.

Table 3-9 Biological zonation of the Okavango River system

Zone no	Biological zone	Location	General Description
1	Waterlogged grassland Cubango	From Vila Nova / Liuema to Sambo / Cachingues in the south	Permanently wet grasslands at river source, small channels. Parallel Cubango, Cutato, Cuchi, Cacuchi 68 wetland bird species Possibly sitatunga, eland, lechwe, reedbuck High human pressure
2	Miombo woodland Cubango	From Sambo / Cachingues to Caiundo / Mumbue	Cubango, Cuchi, Cuelei tributaries. Miombo woodland 85 wetland bird species few mammals, roan, eland , wildebeest
3	Miombo/Dry woodland transition area Cubango	From Caiundo to Mumbue	Transition vegetation between miombo woodland and dry woodland 85 wetland bird species Transition for mammals of zones 2 and 4
4	Dry woodland/savannah mosaic Cubango	Caiundo to Katuitui	Mosaic of dry woodland and savannah. 82 wetland bird species Historically the highest diversity and density of Mammals – elephant, buffalo, zebra, roan, sable.
5	Mainstream River Reedbeds and Floodplains Okavango River forming border of Namibia and Angola	Katwitwi to Mukwe Few floodplains east of Bunya More marked floodplains section Bunya to Mukwe	River flowing eastwards, heavily impacted by humans. Shallow water, sandy and rocky substrates. After Bunya well developed floodplains, large oxbow lakes and backwater habitats.Below Cuito junction more:gentle gradient, meanders, wider mainstream, reedbeds, sedges, and sandbanks Includes 3 distinct fishery zones: (i)Katwitwi – Kasivi; (ii) Kasivi – Mbambi; (iii) Mbambi- Popa High livestock numbers, little wildlife but high bird diversity in some sections
6	Rocky river section with well developed riparian and island woodlands Okavango	Mukwe - Popa rapids	Riparian woodland; rocky, braided with islands, rapids. Rare fish species in rapids. Rare bird species rocks and sandbanks. Substratum sand and gravel, large boulders. Distinct fisheries zone and endemic fish. *Simulium* , sponges and snails on rocks. Otters and rare rock pratincole
7	Riparian woodlands with floodplains Okavango	Below Popa Falls to Mohembo	Start of Panhandle – large floodplains, reedbeds, papyrus fringe. Protected area. Distinct Fisheries zone, greater diversity, numbers and larger fish than elsewhere in Namibia. Highest wildlife and bird diversity and mumbers Situtunga, waterbuck, hippo, elephants, reedbuck Rare birds : Pels fishing owl and African skimmers
8	Panhandle, riparian woodlands, permanent swamp Okavango	Mohembo to Sepopa "upper panhandle"	77 plant species-Meandering channel; floodplain, papyrus, reedbeds, *Diospyros mespiliformis.* Different fish species and aquatic invertebrate fauna. Ramsar site , human and livestock pressure

Zone no	Biological zone	Location	General Description
9	Permanent swamps Okavango	Sepopa/ Gumare to Serongo area "lower panhandle" with lagoons	131 plant species-Meandering channel; floodplain, papyrus, reedbeds, *Diospyros mespiliformis.* Distinct aquatic invertebrate and fish communities. Heavy human and livestock pressure. Ramsar Site
10	Seasonal swamps - central Jao/Boro channels	permanent swamp Central swamp and south east of Chief's island	108 plant species- aquatic vegetation; emergent and submerged species. Distinct aquatic invertebrate and fish communities. Protected area, high wildlife diversity and numbers Sitatunga, waterbuck, hippo, elephants, impala
11	Seasonal swamps Santantadiibe Maunachira. channels	Seasonal swamp North western Moremi and Xakananaxa lagoon	Papyrus, hippo grass, phragmites, lagoons,
12	occasionally flooded Thamalakane /Boteti outflows	Seasonal to occasionally flooded outflow channels south-west of Delta	Biologists distinguish three sub-zones dependant on flooding duration. Primary, secondary and tertiary No tigerfish. Ramsar site Tsessebe other floodplain grazers Livestock and human settlement
13	Ephemeral floodplain lakes Lake Ngami	Lake Ngami	Rarely flooded. Low fish species diversity. Ramsar site, wetland bird diversity. Livestock and human pressure – molapo farming.
14	Headwaters Cuito	Source	High rainfall, gentler gradient, more meanders, wider valley. Few people 68 wetland bird species Possibly sitatunga, eland, lechwe, reedbuck
15	Miombo & floodplains Cuito	Cango to 14 ° Lat	Cuebe, Cueio, Cuatir, tributaries and floodplains. Miombo woodland 85 wetland bird species Few mammals, roan, eland , wildebeest
16	Miombo/Dry woodland transition Cuito	14 °degrees Lat to Cuito Cuanavale	Transition vegetation between miombo woodland and dry woodland 85 wetland bird species transition for mammals of zones 15 and 17
17	Dry woodland/savannah mosaic Cuito	Cuito Cuanavale to Lumeta	Meandering river, oxbows, islands, sandbanks Little human activity Mosaic of dry woodland and savannah 82 wetland bird species Historically the highest diversity and density of mammals – elephant, buffalo, zebra, roan, sable.
18	Permanent swamp at Cuito/Cubango confluence	Lumeta to Dirico	Reduced flow, little gradient, islands and sandbanks Cuito/Cubango meanders, oxbows, High biodiversity value Papyrus, permanent swamp, submerged vegetation, elephants, otters, crocodiles, possibly sitatunga

3.6. Harmonised biophysical river zonation

3.6.1. Biophysical harmonisation exercise

Harmonization of river zones was done as part of a greater exercise of harmonising biophysical and socio-economic zones and is reported on in Section 7.

4. DELTA ZONATION

4.1. Delineation of upstream, downstream and lateral boundaries

The Okavango Delta was delineated on the basis of the duration and frequency of inundation, and the responses of the parts of the delta to inflow from upstream and local rainfall. Thus the delta can be divided into areas that are permanently flooded, seasonally flooded, occasionally flooded, and drylands. In addition, the presence of channels and floodplains was also used for delineating the delta.

4.2. Zonation

The Okavango Delta was divided into the following five zones (Figure 4-1 and Figure 4-2):

i. Panhandle, which stretches from Mohembo to the northern limits of the alluvial fan
ii. Eastern zone, fed by flows of the Nqoga River into the Maunchira, which the splits into the Mboroga and Khwai Rivers
iii. Central zone, mainly fed by flows of the Jao-Boro including the Boro and Xudum distributaries
iv. Western zone, with the Thaoge River
v. Outflow zone, with the Thamalakane-Boteti River to Chanoga.

The eastern zone, central zone, and western zone each have perennial channels, seasonal floodplains, occasionally flooded areas and drylands. These zones are differentiated by their responses to local rainfall and upstream inflows. Water levels in the eastern zone usually increase during the rainy season as a response to local rainfall, and then decline slightly at the end of the rainy season. This is followed by a subdued increase in flow as a response to inflows. The central and western zones have weak responses to local rainfall or minor increases in water levels during the rainy season, but a strong response or significant increase in water levels due to increase of inflows.

The outflow zone has distributaries draining the delta, such as the Gomoti, Santantadibe, Boro, Shashe, Kunyere. The Gomoti, Santantadibe, Boro and Shashe drain into the Thamalakane, which splits to form the Nhabe River flowing into Lake Ngami, and the Boteti River flowing into the Makgadikgadi Pans. The Gomoti, Santantadibe and Shashe have been dry since the 1990s. The Thamalakane-Boteti and Kunyere Rivers are characterised by the occurrence of high flows during the dry season, July to September. Almost all the flow of these rivers is derived from outflows from the delta. Another distinctive feature of the rivers draining the delta is the long-term variation of flows. The Thamalakane-Boteti River had very little to no flow during the mid-1990s, while high flows occurred during the 1970s and part of the 1980s.

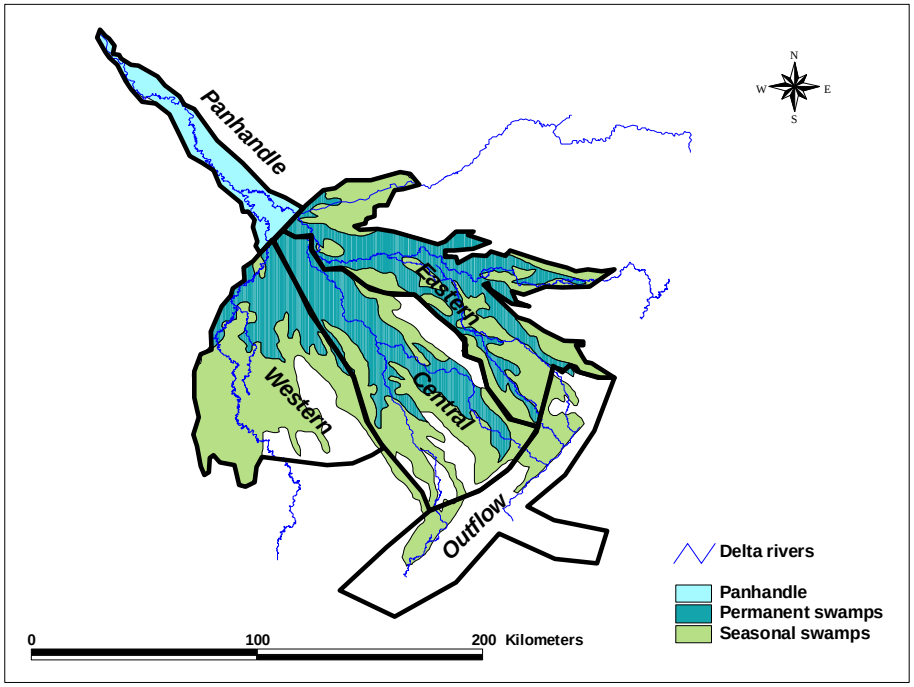

Figure 4-1 Zonation of the Okavango Delta

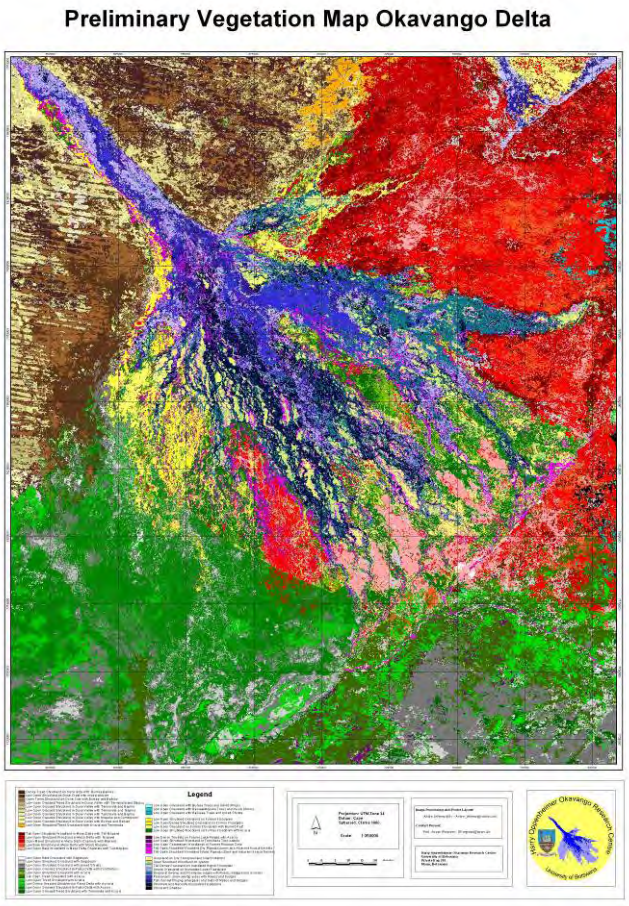

Figure 4-2 Vegetation and land use map of the Okavango delta

5. SOCIO-ECONOMIC ZONATION

5.1. Population

Mendlesohn and el Obied (2004) estimate that approximately 600 000 people live close to the Okavango River in the three countries. They used a distance of 20 km from the river for the Namibian estimates and a similar distance from the edge of the Delta for the estimates in Ngamiland. Both are based on the 2001 national population census counts in each country. No census has yet been conducted in Angola and the true figures may be very different there. Trends show that over the last 90 years annual growth has been about 3% in both the Namibian and Botswana sections of the Okavango Basin but that in the last 30 years this increased to 5% per year in Namibia due to the influx of immigrants from Angola.

The ODMP report (2008), however, gave a population figure for the entire Ngamiland as 124 712 according to the 2001 census and a similar growth rate of 2.8 % for the period 1991 to 2001. Many of the people included live more than 20 km from the Delta and were thus less likely to benefit directly from its wetland resources.

Table 5-1 shows the original population figures as given by Mendlesohn and el Obied (2004), and as used in the delineation process.

Table 5-1 Population figures in the Okavango River Basin taken from Mendlesohn and el Obied (2004)

	Rural	Urban	Total	Urban percentage
ANGOLA	300 000	50 000	350 000	14%
KAVANGO	121 000	42 000	163 000	26%
NGAMILAND	44 000	44 000	88 000	50%
TOTAL	465 000	136 000	601 000	23%

5.2. Land use

The only recent information on land use within the Okavango Basin was from the ODMP study for the Okavango Delta in Botswana. The ODMP map distinguished eight types of land use: ranch; national park/game reserve/commercial photographic area; commercial wildlife utilisation (leasehold); community managed wildlife utilisation in livestock area; community photographic area; community wildlife utilisation (leasehold) WMA; and a final catch-all category Pastoral/Arable/Residential. On closer inspection of the map (Figure 5-1) the area under discussion in this report does not include any ranches or community-managed wildlife utilisation in livestock area categories and shows clearly that the panhandle and edges of the delta fall within the pastoral/arable/residential land use category.

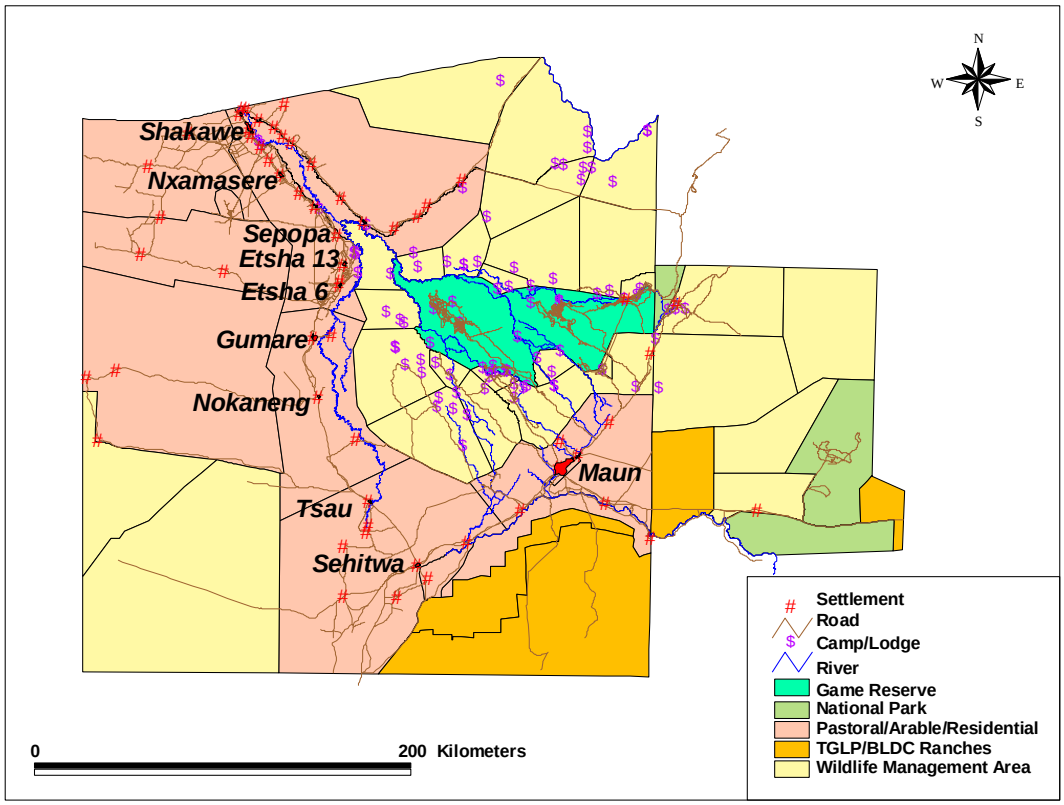

Figure 5-1 Land use categories around the within the Okavango Delta region.

Four broad, existing, land use categories were identified by the ODMP integrated land use plan for the Okavango Basin in Botswana. They were: communal areas (settlements, arable and pastoral agriculture), game reserves and national parks, wildlife management areas and wetlands (outside the protected areas) e.g. in the Panhandle (Department of Environment Affairs, 2008).

Using these broad categories it was assumed that three of them occurred in the Namibian section of the river, Communal Areas alongside most of the river, where the main activity is livestock farming (cattle and goats) and millet growing with some “molapo’ gardening. This area stretched from Katwitwi in the west up to the Muhango and Buffalo Core areas of the Bwabwata National Park. This protected area made up the second broad land use category while the wetlands or river itself and its floodplains within both these areas could possibly be seen as a third category. A fourth land use category in Namibia was then the commercial irrigation farms set at intervals alongside the river. The area under commercial irrigation was expected to expand. Currently there were irrigation schemes at Shitemo, Shadikongoro, Vungu-Vungu, Musese and Bagani Tourism was a possible fifth category as the number of lodges alongside the river was steadily increasing.

No detailed information was available for Angola, other than Mendlesohn and el Obied’s observation (2004) that agriculture is dominated by maize, cassava, millet and vegetable growing and that cattle numbers are relatively low except for alongside the lower Cubango and on the northern bank of the river section shared with Namibia.

5.3. Use of water

Mendlesohn and el Obied (2004) pointed out that, other than for domestic use, little water was used from the Okavango River in Angola. There were no large scale irrigation schemes,

although several are planned, and only one small dam on the tributary of the Cuebe River at Menogue.

Accurate estimates of the amount of water abstracted from the Okavango River in Namibia were available from the Department of Water Affairs (Hatutale,1994, Mendelsohn and el Obied 2003, 2004). The total amount of water abstracted annually in Namibia from this river was 22 Mm^3, which was less than 0.25% of the volume of water reaching Mohembo. Irrigation of about 1,200 ha used about 74% of the water abstracted, while 15% was for livestock watering, and 11% for the Rundu urban area. The villages of Nkurenkuru and Divundu were soon to be upgraded to towns, which would increase their water consumption. The area under irrigation was also expected to expand by a further 7,400 hectares. This could increase the total amount of water abstracted from the Okavango River in Namibia to 134 Mm^3 per year amounting to some 4% of the average annual volume that enters the Panhandle (Mendlesohn and el Obied, 2004).

According to the ODMP report (Department of Environmental Affairs, 2008) the Okavango River annually delivered about 10,000 Mm^3 of water to Botswana at Mohembo and this volume can range from 7,000 to 15,000 Mm^3 depending on rainfall in Angola. The report gives a table of water abstraction within the Okavango Delta Ramsar Site (Table 5-2).

Table 5-2 Water use/abstraction in the Okavango Delta Ramsar Site in 2004. Based on the ODMP report (DEA, 2008)

Scheme	Villages supplied	Amount ($Mm^3 y^{-1}$)
Maun water supply	Maun	2.69
Private licensed abstraction	Within delta (lodges)	No data
Gumare water supply	Gumare, Etsha, Nokaneng, Habu, Tsau	0.62
Sepopa/Ikoga integrated rural village water supply	Sepopa, Mowana, Ikogo	0.12
Kauxwi/Xakao integrated rural village water supply	Kauxwi, Xakao, Mohembo-east, Goa, Jejedoa, Sekondomboro, Sechenje	0.17
Shakawe water supply	Shakawe	0.24
Total		**3.84**

Thus the total amount of water abstracted based on the 2004 figures was 3.84 Mm^3 a year. This was however expected to increase to about 11.04 Mm^3 by 2020-25 i.e. 1% of the total flow received at Mohembo (DEA, 2008).

5.4. Household use of aquatic resources

To better appreciate the value of wetlands it is useful to give monetary values to wetland resources and services. This was done in 2005 for the Okavango Delta Ramsar site and some of the interesting values found for wetland resources in the Okavango Delta are given in Table 5-3. Values are divided into direct use and indirect use values (J. Barnes in Bethune *et al.* 2007).

Table 5-3 Direct uses of delta resources

Resource use	Estimated contribution to the Gross National Product in Botswana at 2005 (million Pula)
Tourism (wildlife viewing and hunting)	363
Natural resources harvesting (fish, wood, reeds etc.)	12

Natural resources processing (crafts, foods)	4
Livestock, mainly cattle	1
Crops (maize and millet)	1
TOTAL	**381**

Indirect use values were estimated for 2005 to be:

- Wildlife refuge: 60 – 80 million Pula
- Groundwater recharge: 12 – 20 million Pula
- Water purification: 12 – 20 million Pula
- Carbon storage: 50 - 250 million Pula
- Scientific and educational value: 12 – 20 million Pula

The researchers also estimated the wages and other income earned by the households living in and around the delta from the use of delta resources. In 2005, these households earned 19.8 million Pula from agricultural production and natural resource harvesting within the Ramsar site. They also earned P107 million in the form of salaries and wages for working with tourism operators in the wetland. Note that the Okavango Ramsar site extends beyond the Okavango Basin in Botswana to include the Kwando/Linyanti/Chobe wetlands too.

No similar work has yet been undertaken in either Namibia or Angola.

5.5. Delineation of the basin into socio-economic zones

The following account describes the process of basin delineation, as it emerged at the workshop. The team agreed that socio-economically the first level for distinguishing different zones was political, that is, by national boundaries as this has an overriding influence on social as well as economic activities and values.

In Botswana, the team recognised that clear socio-economic zones had already been determined as part of ODMP/Ramsar IUCN study within its “Economics of the Delta” component. The same five zones were thus designated as homogenous zones for this exercise. The five zones are:

1. Central Wildlife and Tourism core area (within buffalo fence): includes the Moremi National Park as well as communal land leased to concessionaires/community trusts and local/traditional authorities
2. Panhandle: Mohembo to Serongo
3. West of Delta: Etsha to Gumare and westwards to the edge of the Ramsar site
4. South west: Mainly cattle country south of Gumare; the Thaoge channel excluding its fossil drainage and including Lake Ngami, which is included within the Ramsar site, up to the buffalo fence in the east.
5. South east of Buffalo fence: Toteng to Xudum channel and the Thamalakane to Toteng. From the buffalo fence to Shorobe in the east.

A possible sixth zone, Maun Urban, was suggested for inclusion given the very different water use and supply, the much higher human population and the increased potential for water pollution.

The team agreed on the following two zones in Namibia with Rundu Urban as a possible third zone.

1. Conservation area: Mohembo to Popa/Bagani Bridge, including the Bwabwata National Park with the Buffalo and Mahango Core Areas as well as the emerging Conservancies in the vicinity, such as Kamatjonga
2. Rest of the river in Namibia: The heavily settled area alongside the river typified by linear infrastructure, irrigation, degraded riverbank and floodplains. Essentially a zone shared by Angola on the opposite bank, although the Angolan side is less degraded.

Rundu Urban.was considered for possible inclusion as a new zone given the very different water use and supply, the much higher human population and increased potential for water pollution.

Within Angola, the team distinguished two different river basins: the Cubango with distinctly seasonal flows, a heavily settled catchment that is degraded in the north west, and the Cuito with its less variable flow and more pristine environment. Mirroring the ecological analysis, the social team identified three parallel sub-basins within each basin. These are from the south:

1. Thick Kalahari sand zone also classified as the inactive basin with low rainfall.
2. The Miombo woodland or active basin around Menongue, Cushi to Cuito Cavenale.
3. Upper bogs/sponges or the head waters of each basin. They recognised that the upper Cuito supports different crops, manioc.

Thus the team identified six zones in Angola, three for the Cubango basin and three parallel ones for the Cuito basin. Some of the team members consulted geohydrologists and hydrologists to obtain more input on the situation in Angola to gain some local knowledge inputs and to discuss the different hydrological zones.

On the second day, the group consulted more widely. They then adapted the table and zone delineation slightly as suggested, especially for the Namibian and Angolan sections and took the opportunity to add characterisation.

Using the Mendelsohn/Ward map of the basin, the social group marked out their delineated basins indicating broad socio-economic zones. They identified 13 zones with the option of adding zones to cover the main urban areas, Menongue, Cushi, Rundu and Maun. Of these, six zones where in Angola, two in Namibia with one of them being shared with Angola, and five in Botswana in keeping with the ODMP/IUCN sites (Figure 5-2).

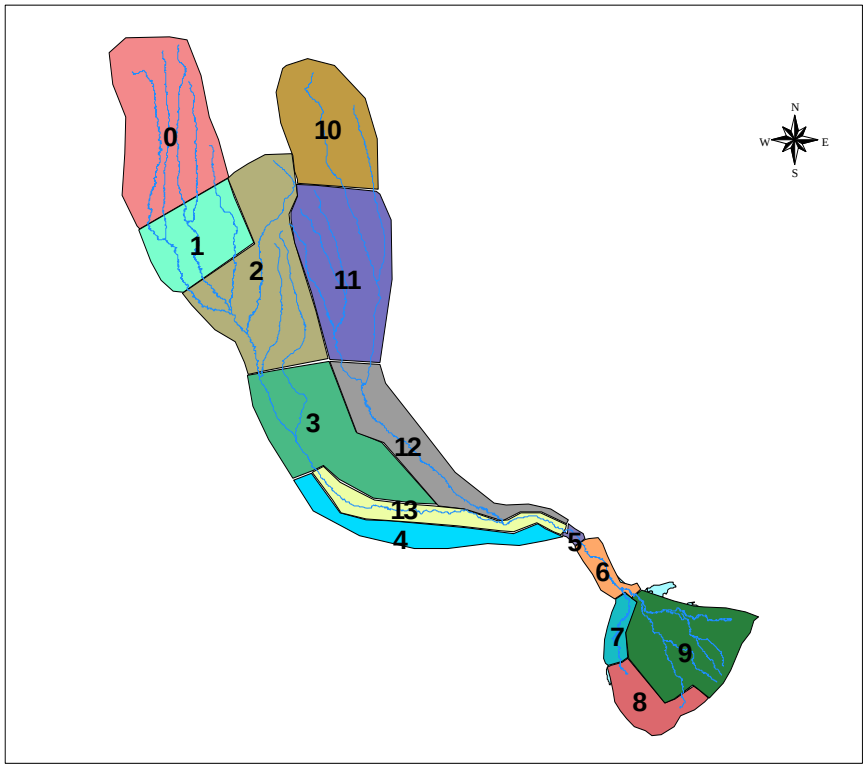

Figure 5-2 Preliminary delineation of socio-economic sub-zones within the Okavango River Basin, in relation to rivers, major dams and lakes, and villages and towns.

These zones were presented in a plenary session at the workshop where it was agreed to exclude the three urban sites. In later discussion with the Namibian ecologists the social team conceded that the resource use in river sections with floodplains was likely to differ from resource use in the rocky, braided section of the river with numerous islands. Although broadly similar activities are practiced, the detail is likely to differ, for example floodplain fishing is very different to fishing in faster flowing mainstream areas and there is less habitat suitable for "molapo" farming in the more rocky reaches of the river. It was therefore agreed to identify three zones within Namibia, the first, longest reach from the border near Katwitwi to Mukwe shared with Angola on the opposite bank, the second rocky reach from Mukwe to the boundary of the Mahango National Park at Kamatjonga, and the final short protected stretch within the Mahango National Park to the border with Botswana at Mohembo.

Table 5-4 describes 13 zones within the basin, identified as being homogeneous socio-economically. A 14th zone, urban areas, was included but not as a spatial entity.

Table 5-4 Description and characteristics of original socio-economic zones

Zone	Country	River	Description	Basic characteristics	Additional features
1	Angola	Cubango	Upper Cubango reaches from source to line between Kubango and Mumbué	Dense population, dryland maize dominated subsistence production few livestock	-
2	Angola	Cubango	Central Cubango from Kubango to line between Mucundi and Machai	Moderate population maize and millet few livestock. Some fish use, charcoal production.	Several urban zones, irrigation potential, direct water use
3	Angola	Cubango	Lower Cubango from Mucundi to riverine zone below Catamoué	Inactive basin low population millet some livestock	-
4	Angola	Cuito	Upper Cuito from source to 14^0 latitude	Low population, mandioca production no livestock.	Some timber potential
5	Angola	Cuito	Central Cuito from 14^0 latitude to 16^0 latitude	Low population, millet and few livestock.	Some urban development, timber potential.
6	Angola	Cuito	Lower Cuito from16^0 latitude to confluence with Cubango	Low population millet few livestock some timber potential. Flood attenuation. Some timber production	Some tourism potential
7	Angola/ Namibia	Cubango/Okavango	Immediate terraces of river in Angola and Botswana from Catamoué to Divundu	110,000 people. Dense population in riparian strip. Millet production with livestock fishing (53% of people) and some plant use. Irrigation development. Aquaculture.	One large urban centre (Rundu) and associated tourism. Trans border movement.
8	Namibia	Okavango	Protected areas, Mahango Game reserve, Bwabwata National Park and conservancies	Tourism, biodiversity protection, Some use of upland and wetland plant resources.	Tourism potential
9	Botswana	Okavango	Panhandle from Mohembo to Seronga. Permanently flooded wetlands	25,000 people. Wetland plants use (20%) and fish use (11%) important in natural resource use. Dryland millet production (9%), livestock (45%) and upland plants use (15%) also important.	River- based tourism (mainly angling) fairly important. Potential for wildlife –based tourism.
10	Botswana	Okavango Delta	Western edge of Delta, west of Buffalo fence, from Ikoga to 10km south of Nokaneng.	17,000 people. Wetland plants use (9%), Molapo crop production (6%) fairly important in Natural resource use. Livestock (74%) and upland plant use (10%) important.	Some Delta-based tourism.
11	Botswana	Okavango Delta	South western edge of Delta SW from Buffalo fence, between 10km south of Nokaneng to 10 km west of Komana.	9,200 people. Limited wetland resource use Wetland plants (4%) Molapo crops (1%), mainly in Xudum, Thamalakane channels. Livestock (81%) very important, upland plants (11%) fairly important.	-
12	Botswana	Okavango Delta	South eastern edge of Delta from 10km west of Komana to the Buffalo fence in north west and north.	53,500 people (including Maun). Wetland plants (12%) and fish (1%) and Molapo crops (2%) of natural resources use. Livestock important (64%) and upland plants (17%) fairly important. Tourism directed at Delta very important.	Includes urban centre of Maun.

13	Botswana	Okavango Delta	Central Delta north and east of the Buffalo fence.	1,500 people. Delta based tourism extremely important. Small human population makes important use of wetland resources. Fish (26%), Wetland plants (20%), Molapo crops (5%). Use of upland wild resources (38%) fairly important and livestock (8%) unimportant.	Community-based natural resource use (CBNRM) important.

6. INTEGRATED UNITS OF ANALYSIS

The various homogeneous zones were then harmonised. Firstly the biophysical zones (hydrology,geohydrology, water chemistry, and ecology/biology) were harmonised and these were then harmonised with the socio-economic zones to produce Integrated Units of Analysis (IUAs). Where there was doubt on boundaries, the IUA was defined primarily by the socio-economic area rather than the biological zone, with the result that some IUAs contained more than one biological zone. The IUAs were discussed in plenary session, some adjustments were made and they were then used as the basis for selection of representative sites.

The general feedback from the teams was that they would have preferred more time and a more inclusive process for this step in future.

Overnight the Namibian biologists conferred with the social economists to find out if the resource use in floodplain sections of the river was likely to differ from resource use in the rocky, braided section. They agreed that although broadly similar activities are practiced, the detail is likely to differ, e.g. floodplain fishing is different to fishing in the rapids and there is no “molapo” farming in the more rocky reaches of the river. They agreed that there should thus be three integrated units of analysis within Namibia: one from Katwitwi to Mukwe shared with Angola on the opposite bank, one from Mukwe to Kamatjonga and one for the protected area within the Bwabwata National Park including the Mahango and Buffalo core conservation areas and conservancies to Mohembo. This was agreed by the meeting the next morning.

The final result was a set of 12 IUAs that can be described primarily in socio economic terms. Angolan IUAs 1 to 4 were delineated in the Cubango arm of the basin. Here, floodplains are rare and river courses are relatively incised. The basement geology has mostly been exposed, leaving little Kalahari sand cover. The IUAs here were delineated on the basis of topography, ecology, population density, urbanisation and the future likely water use developments. Thus, IUA 1 covered the high rainfall, high altitude upper reaches where parallel tributaries drain an open upland savanna, the soils are medium textured, and there is a high density of people. Rainfed crop production with maize is the most important land use. IUA 2, including the town of Cuchi, was similar but lower, less incised, slightly drier, slightly less densely settled and it contains small areas of Kalahari sand woodlands. It contained field study site 2, at Mucundi. IUA 3 was specific to the Cuebe river catchment and included the city of Menongue. Here the situation was similar to that of IUA 2 but there were some water quality issues surrounding the city, and there was some irrigation of crops and plans for much more. The field study site 1 at Capico was included here.

Angolan IUAs 5 to 7 were delineated for the Cuito arm of the basin. These were relatively uninhabited, pristine, and occupied by Kalahari sand woodlands. Floodplains were more significant here than in the Cubango arm, and water flow variation was much more seasonally stable. The three IUAs here were separated on the grounds of rainfall (from humid to semi-arid), on the basis of crops grown (cassava is the main crop grown in the upper part), the presence of an urban area (Cuito Cuanavale) and on the basis of future water use developments (likely to be in the lower reaches). Field study site 3 at Cuito, was situated in IUA 6.

Two IUAs, each with two subdivisions, were defined for Namibia, based on the presence or absence of a floodplain, flooding regime, and whether or not there was a human population. IUA 8 covered the river along the Angolan border, where human population density was high and a moderate floodplain was present. It contained the urban area of Rundu, and field study site 4 at Kapako. It was subdivided between the parts above and below the Cuito junction, which differed slightly in terms of seasonal flow regime. IUA 9 covered the river below Mukwe, where a floodplain was mostly absent and some rocky exposures occurred in the river bed.

IUA 9 was subdivided into that section with a resident human population and that which was protected as Bwabwata National Park. It contained field study site 5 at Popa

Three IUAs were defined for the Botswana part of the basin, based primarily of flooding patterns. IUA 10 formed the panhandle with a fairly wide, mostly permanently flooded plain and a moderately dense, relatively ethnically distinct human population. It contained field study site 6 at Mohembo. Fishing, and non-floodplain crops were characteristic. IUA 11 covered most of the Delta with a complex pattern of seasonal, permanent, frequent, and occasional flooding. It contained two subdivisions; moderately dense human settlement in the west, and natural protected areas used mostly for tourism in the north east. Field study site 7 at Xakanaka was in the latter subdivision. IUA 12 covered the most distal part of the active basin and as such contained ephemeral channels and more restricted, less commonly flooded floodplain. Fairly dense human settlement was present here including the urban centre of Maun. It contained field study site 8 at Boteti.

IUAs 13 to 17 were retained, to refer to larger urban areas, in case these could be of use in the EFA process. These were embedded within the other IUAs and not delineated spatially. The location of study sites, as described below, within the IUAs is also shown in Table 6-1. The spatial layout the final 13 IUAs is shown in Figure 6-1.

Table 6-1 Final Integrated Units of Analysis, showing relationships between IUAs and corresponding zones for each discipline

Tally	Country	IUA	EFA Site	River	Description/Location	Hydrology subcatchment	Geohydrology zone	Geomorphology zone	Chemistry zone	Biology zone	Social-zone
1	Angola	1		Cubango	Source		GeoH 1	Geo 0	WQ 1	Bio 0	Socio 1
2	Angola			Cubango	Source to Chinhama	Hydro 1	GeoH 1	Geo 1	WQ 1	Bio 1	Socio 1
3	Angola			Cubango	Chinhama to Kubango	Hydro 2	GeoH 1	Geo 2	WQ 1	Bio 2	Socio 1
4	Angola			Cutato	Source to Chinhama	No hydro	GeoH1	To be done	WQ 2	Bio 1	Socio 1
5	Angola			Cutato	Chinhama to confluence with Cubango	Hydro 3	GeoH1	To be done	WQ 2	Bio 2	Socio 1
6	Angola	2	2	Cubango	Kubango to Caiundo		GeoH 1	Geo 3	WQ 2	Bio 2	Socio 2a
7	Angola			Cubango	Caiundo to Mucundi	Hydro 8	GeoH 2	Geo 3	WQ 2	Bio 3	Socio 2a
8	Angola	3	1	Cuebe	Source to Menongue	Hydro 6	GeoH1	To be done	WQ 2	Bio 3	Socio 2b
9	Angola			Cuebe	Menongue confluence with Cubango	Hydro 6	GeoH2	To be done	WQ 3	Bio 3	Socio 2b
10	Angola	4		Cubango	Mucundi to Catambue	Hydro 9	GeoH 2	Geo 4	WQ 3	Bio 4	Socio 3
11	Angola	5		Cuito	Source to Cangoa	No hydro	GeoH2	Geo 12	WQ 11	Bio 12	Socio 4
12	Angola			Cuito	Cangoa to 14 Degrees Lat	Hydro 15	GeoH2	Geo 13	WQ 11	Bio 13	Socio 4
13	Angola	6	3	Cuito	14 Degrees Lat to Cuito Cuanavale	Hydro 17	GeoH2	Geo 13	WQ 12	Bio 14	Socio 5
14	Angola			Cuito	Cuito Cuanavale to Nankova	Hydro 19	GeoH2	Geo 14	WQ 13	Bio 14	Socio 5
15	Angola	7		Confluence	Swamp at confluence between Okavango and Cuito	Hydro 11, plus Hydro 20	GeoH 2	Geo 12	WQ 13	Bio 5c/16	Socio 6
16	Angola			Cuito	Nankova to Lumeta	Hydro 20	GeoH2	Geo 15	WQ 13	Bio 15	Socio 6
17	Angola			Cuito	Lumeta to Dirico	Hydro 20	GeoH2	Geo 15	WQ 13	Bio 16 (see above)	Socio 6
18	Angola/Namibia	8a		Cubango	Catambue to Katwitwi	No hydro	GeoH 2	Geo 4	WQ 4	Bio 5a	Socio 7
18	Namibia			Okavango	Katwitwi to start of floodplain at Bunya	No hydro	GeoH 2	Geo 4	WQ 4	Bio 5a	Socio 7
19	Namibia		4	Okavango	Bunya to confluence with Cuito	Hydro 11	GeoH 2	Geo 5	WQ 4	Bio 5b	Socio 7
20	Namibia	8b		Okavango	Cuito confluence to Mukwe	Hydro 12	GeoH 2	Geo 6	WQ 6	Bio 5c/16	Socio 7
21	Namibia	9a	5	Okavango	Mukwe to Popa Falls	Hydro 12	GeoH 2	Geo 7	WQ 7	Bio 6	Socio 7
22	Namibia	9b		Okavango	Popa Falls to Mohembo	Hydro 13	GeoH 2	Geo 8	WQ 8	Bio 7	Socio 8

23	Botswana	10	6	Okavango	Panhandle	Hydro 14	GeoH 3	Geo 10	WQ 8	Bio 8b	Socio 9
16	Botswana	11a	7	Okavango	Permanently inundated	Hydro 14	GeoH 3	Geo 11	WQ 9 - Upper delta (different definition)	Bio 9	Socio 13
17	Botswana	11b		Okavango	Occasional West	Hydro 14	GeoH 3	Geo 11	WQ 10 - Lower delta (different definition)	Bio 10 a	Socio 13 and 10 (from 11 b)
18	Botswana	12		Okavango	Occasional East	Hydro 14	GeoH 3	Geo 11		Bio 10 b	Socio 13
19	Botswana		8	Okavango	Outflows	Hydro 14	GeoH 3	Geo 11			Socio 11&12
30	Urban	13		Cuebe	Menongue (Urban)				WQ 16		Socio 14 (Urban)
31	Urban	14		Okavango	Rundu (Urban)	Hydro 10	GeoH 2	Geo 5	WQ 5	Bio 5b	Socio 15 (Urban)
32	Urban	15		Delta	Maun (Urban)	Hydro 14	GeoH 3	Geo 11	WQ 14		Socio 16 (Urban)
33	Urban	16		Cuito	Cuito Cuanavale (Urban)	Hydro 17	GeoH2	Geo 13	WQ 15	Bio 14	Socio 17 (Urban)
34	Urban	17		Cuchi	(Cuchi (Urban)				WQ 17		Socio 18 (Cuchi)

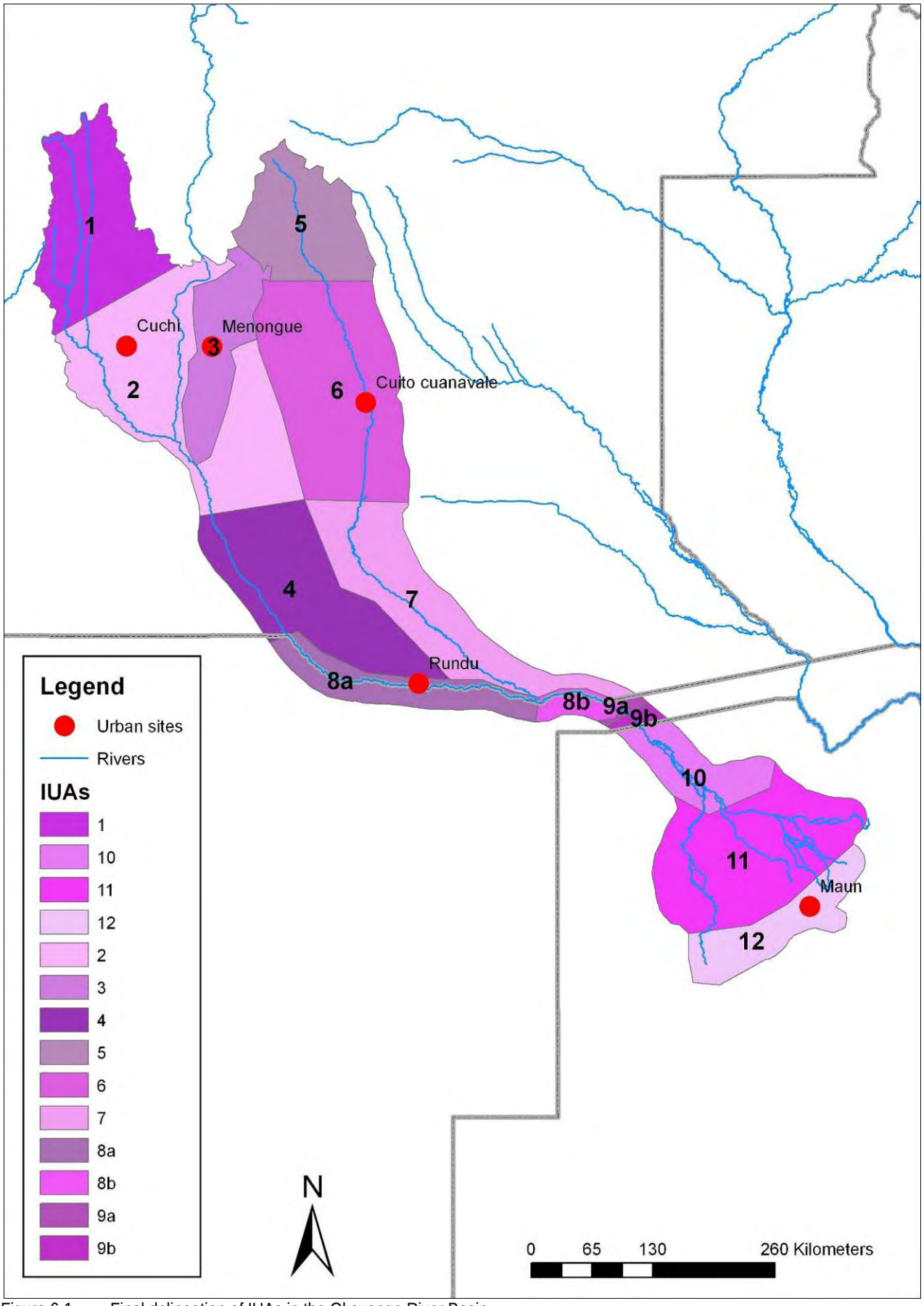

Figure 6-1 Final delineation of IUAs in the Okavango River Basin.

7. STUDY ZONES AND SITES

7.1. Biophysical sites

As described above, 17 IUAs were selected in total. Of the spatially defined ones in Figure 6.1, seven were in Angola, two were in Namibia (both subdivided and one shared with Angola), and three in Botswana. Then there were five urban IUAs (Table 6.1). The IUAs were used to select representative study sites that would be used for hydrological modelling, field visits, data analysis and the predictions produced in the scenarios (Table 7-1). Sites were chosen in Angola with due consideration of landmines and safety concerns. Flood dynamics in the Delta played an important role in selection of the Botswana sites. BIOKAVANGO chose additional sites for their own research needs (Table 7-2).

Angola selected three sites, namely Capico within the Hydro Zone 6 (from Menongue to the confluence with Cubango River), Mucundi within the Hydro Zone 9 (from Mucundi to Catambue and Cuito Cuanavale within the Hydro Zone 19 (from Cuito Cuanavale to Nankova). Namibia was divided into four hydrological and geohydrological zones. The selected zones were located between Bunya to the confluence with Cuito River within the Hydro Zone 11, and Popa Falls to Mohembo within the Hydro Zone 13. The Botswanan sites were in the eastern side of the Delta and in its outflow. Table 7-1 also shows in which IUAs the chosen study sites were located.

Table 7-1 EF sites within the Okavango River Basin selected for the TDA

EF Site Number	Country	River	Location	Latitude, longitude
1	Angola	Cuebe	Capico	15° 33’ 05” S 17° 34’ 00” E
2	Angola	Cubango	Mucundi	16° 13’ 05” S 17° 41’ 00” E
3	Angola	Cutio	Cuanavale	15° 10’ 11” S 19° 10’ 06” E
4	Namibia	Okavango	Kapako	17° 49’ 07” S 19° 11’ 44” E
5	Namibia	Okavango	Popa Falls	18° 07’ 02” S 21° 35’ 03” E
6	Botswana	Okavango	Panhandle, Shakawe	18° 21’ 16” S 21° 50’ 13” E
7	Botswana	Khwai	Xakanaka: mix of permanent, seasonal and occasionally flooded areas	19° 11’ 09” S 23° 24’ 48” E
8	Botswana	Boteti	Chanoga; delta outflow	20° 12’ 51” S 24° 07’ 37” E

Table 7-2 Additional biophysical study sites within the Okavango River Basin selected for BIOKAVANGO studies

EF Site Number	Country	River	Location
9	Botswana	Boro	Nxaraga
10	Botswana	Thaoga	Etsha

7.2. Social sites

The social survey followed the same pattern as the biophysical visits, in that the same sites were visited. With social survey, however, any uneven spatial patterns of natural resources

use were determined, and field and desk work was tailored to cover a wider area. Thus socio-economic field sites were the same as those in Tables 7.1 and 7.2.

8. CONCLUSIONS

The delineation exercise used a structures process to divide the basin into homogeneous units. Each river site could now represent a greater length of river and a surrounding social are in the data collection and scenario creation exercises to follow. These later activities are reported on in Reports 05 to 08 in the EFlows Report series.

9. REFERENCES

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10. APPENDIX 1.1: LIST OF PARTICIPANTS AT THE BASIN DELINEATION WORKSESSION

ANGOLAN TEAM

Name	Institution	Area of expertise
Carlos Andrade		Ecology
Paulo Emilio Mendes		Hydrology
Gabriel Miguel		Hydrogeology
Helder de Andrade Sousa		Geomorphology
Miguel Morais		Biology
Manuel Quintino		Water Resources
Luis Verissimo		Ecologist

NAMIBIAN TEAM

Name	Institution	Area of expertise
Shirley Bethune	Wetlands Working Group of Namibia	Wetland ecologist
Aune Hatutale	NamWater	Hydrologist
Andre Mostert	NamWater	Hydrologist/ Hydraulic modeller
Mathews Katjimune	Geohydrology Div. DWAF	Geohydrologist
Cynthia Ortmann Laura Namene	Water Environment Div. DWAF	Water Quality & Pollution
Barbara Curtis	Polytechnic of Namibia	Vegetation ecologist
Shishani Nakanwe	Water Environment Div. DWAF	Aquatic invertebrates
Christopher Munwela	Freshwater Fisheries Div, MFMR	Aquaculturist
Kevin Roberts	Water Environment Div. DWAF	Wetland biologist
Dorothy Wamunyima	Namibia Nature Foundation	Social scientist

BOTSWANA TEAM

Name	Institution	Area of expertise
Nkobi Moleele	Biokavango National Coordinator	Biokavango National Coordinator
Belda Mosepele	Biokavango Fishery Coordinator	Biokavango Fishery Coordinator
Dominic Mazvimavi	HOORC	Project Coordinator
Piotr Wolski	HOORC	Hydrology
Casper Bonyongo	HOORC	Wildlife & Terrestrial Ecology
Kelebogile Mfundisi	HOORC	Aquatic ecology
Keta Mosepele	HOORC	Fish and Fisheries
Wellington Masamba	HOORC	Water Quality
Gagoitseope Mmopelwa	HOORC	Natural Resources Economics – Livelihoods
Joseph Mbaiwa	HOORC	Tourism
Cornelis Vanderpost	HOORC	Demographics
Lapo Magole	HOORC	Governance
Barbara Ngwenya	HOORC	Social anthropology
Masego Dhliwayo	HOORC	GIS
Tracy Molefi	Ministry of Minerals, Energy & Water Resources	International Waters Unit
C.N. Kurugundla	Dept of Water Affairs	Aquatic ecology
Kobamelo Dikgola	Dept of Water Affairs	Hydrology
Francis	Dept of Water Affairs	Hydrology
Sekgowa. Motsumi	Dept of Environmental Affairs	Ecology

OTHER PARTICIPANTS

Name	Institution	Area of expertise
Chaminda Rajapakse	GEF/EPSMO	Project Manager
Jacob Burke	GEF/EPSMO	FAO Senior Water Policy Officer
Eben Chonguica	OKACOM Secretariat	OKACOM Executive Secretary
Jackie King	Water Matters	EFA Project leader
Cate Brown	Southern Waters	EFA Technical co-ordinator
Hans Beuster	Beuster and Associates	EFA Basin hydrologist
Jon Barnes	Design and Development Services	EFA Natural resources economist
Gregory Thomas	Natural Heritage Institute, USA	President

11. APPENDIX 1.2: AGENDA FOR BASIN DELINEATION WORKSHOP; MAUN, BOTSWANA

Monday: 22nd September 2008				
Time	Activity		Responsible person	
INTRODUCTORY SESSION				
08h00	Welcome		Chaminda Rajapakse and Nkobi Moleele	
08h20	Introduction of delegates			
08h30	Concept of Environmental Flows		Jackie King	
09h30	Overview of the TDA: EF Process		Jackie King	
10h15	Introduction to guidelines and templates		Cate Brown	
10h30	TEA			
BASIN DELINEATION				
11h00	Introduction	Steps	Cate Brown	
		Example of outputs		
		Template for report		
11h30	Discipline Group Sessions	Step 1: Basin location and characteristics	National Project Leaders	GIS team to provide information to all
		Step 2.1: Hydrological zones	Hydrologists	
		Step 2.2: Groundwater zones	Geohydrologists	
		Step 2.3: Geomorphological zones	Geomorphologists	
		Step 2.4: Chemical and thermal zones	Aquatic chemists	
		Step 2.5: Biological zones	Ecologists	
		Step 3.1: Socio-economic areas	Socio-economists	
13h00	LUNCH			
14h00	Discipline Group Sessions continued		Same groups	
15h00	TEA			
15h30	Parallel sessions	Discipline Group Sessions continued	Same groups	
		Scenario discussion	Jackie King, Project Leaders, National Team Leaders	
17h00	SESSION CLOSES			

Tuesday: 23rd September 2008			
Hydrologists follow own agenda			
Time	**Activity**		**Responsible person**
BASIN DELINEATION: CONTINUED			
08h00	Feedback on progress		Jackie King
08h30	Discipline Group Sessions continued		Same groups
10h30	***TEA***		
11h00	Discipline Group Sessions continued		Same groups
13h00	***LUNCH***		
14h00	Discipline Group Sessions	Step 2.6: Harmonisation of river zones	Biophysical specialists
		Step 3.2: Adjusted socio-economic areas	Socio-economists
15h00	***TEA***		
15h30	Step 4: Identification of Integrated Units of Analysis		Cate Brown Report writing by National Project Leaders
17h00	***SESSION CLOSES***		

Wednesday: 24th September 2008			
Hydrologists follow own agenda			
Time	**Activity**		**Responsible person**
BASIN DELINEATION: SITE SELECTION			
08h30	Feedback on progress		Jackie King
09h00	Country Group Sessions	Step 5: Select zones and sites	Angola Team
			Namibia Team
			Botswana Team
10h30	***TEA***		
11h00	Country Sessions continued		
12h00	Angola feedback on site selection		Angola Project Leaders
12h20	Namibia feedback on site selection		Namibia Project Leaders
12h40	Botswana feedback on site selection		Botswana Project Leaders
13h00	***LUNCH***		
INDICATORS			
14h00	Introduction	Steps	Jackie King
		Example of outputs	
		Reporting	
14h30	Discipline Group Sessions	Identification biophysical indicators by discipline and by site	Biophysical discipline groups
		Identification socio-economic indicators by Socio-economic area	Socio-economic group
15h00	***TEA***		
15h30	Parallel sessions	Discipline Group Sessions continued	Same groups
		Scenario discussion	Jackie King, Project Leaders, National Team Leaders
17h00	***SESSION CLOSES***		

Thursday: 25th September 2008			
Hydrologists follow own agenda			
Time	**Activity**		**Responsible person**
LINKED INDICATORS			
08h00	Feedback on progress		Jackie King
08h15	Discipline Group Sessions	Identification of links to driving indicators	Discipline groups
10h30	***TEA***		
11h00	Discipline Group Sessions continued		Discipline groups
13h00	***LUNCH***		
LINKS TO FLOW REGIME			
14h00	Introduction to flow categories		Jackie King
14h15	Discipline Group Sessions	Identification of links between biophysical indicators and flow regime	Biophysical discipline groups
		Identification of links between socio-economic indicators and flow regime	Socio-economic group
15h00	***TEA***		
DATA FLOW			
15h30	Data flow session		Cate Brown
17h00	***SESSION CLOSES***		

Friday: 26th September 2008			
Time	**Activity**		**Responsible person**
08h00	Summary of workshop to date		Cate Brown
08h30	Hydrological and hydraulic model feedback		Dominic Mazvimavi
SCENARIO IDENTIFICATION			
09h00	Introduction to the concept and use of scenarios		Jackie King
09h30	Presentation of Preliminary Long List of Scenarios		Chaminda Rajapakse
10h00	Discussion of Long List of Scenarios		Nkobi Moleele
10h30	***TEA***		
11h00	Rationalisation of Long List of Scenarios		Hans Beuster
13h00	***LUNCH***		
THE WAY FORWARD			
14h00	Plenary session: Next steps in the TDA: EF process	Field Trip	Dominic Mazvimavi
		Data collection and analysis	Jackie King
		Purpose of Specialists Report and Deadlines	
		Hydrological Configuration Workshop	Hans Beuster
		Knowledge Capture Workshop	Cate Brown
		Technical Scenario Analysis Workshop	Jackie King
		Responsibilities	
15h00	***TEA***		
15h30	Next steps: continued		As above
16h45	Workshop closure		Nkobi Moleele and Chaminda Rajapakse
17h00	***SESSION CLOSES***		

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*
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Environmental protection and sustainable management of the Okavango River Basin

EPSMO

Boteti River shoreline, Botswana

Republic of Botswana

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