Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module Specialist Report Country: Botswana Discipline: Wildlife

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June 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

BIOPHYSICAL SERIES

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module

Specialist Report

Country: Botswana

Discipline: Wildlife

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EXECUTIVE SUMMARY

The Okavango Delta supports a high diversity of wildlife ranging from those that are almost totally aquatic or semi-aquatic to animals completely independent of water except for drinking purposes. Animals of the Okavango Delta are linked to flows to a varying degree. This study set to assess and analyse potential responses of wildlife to selected flow categories which could be brought by development scenarios that affect flow variations within the Okavango River Basin. The study identified five key groups of wildlife indicators namely semi-aquatic species, frogs and river snakes, lower floodplain grazers, middle/upper floodplain grazers and outer floodplain grazers. Semi aquatic and aquatic species are likely to respond to flow variation immediately, especially the decline in flows which may lead to drastic reduction in water levels. On the contrary floodplain grazers, especially those that utilise the lower and upper floodplains would benefit from a reduce flow which leads to less or short duration of flooding. On the hand, floodplain grazers would be negatively affected by a major increase in flows especially when such a flow would lead extended long duration flooding. Under such circumstances, seasonally flooded areas would be flooded longer than usual, resulting in reduced access to grazing resources which normally became available when floods recede. The outer floodplain grazers which are predominately terrestrial species that do not depend on water except for drinking, are unlikely to be negatively affected by immediately respond to variation in flows.

Literature revealed that seasonal flooding is the driving force behind the functioning of floodplain ecosystems in the Okavango Delta, resulting in seasonal shrinking and swelling of grazing resources as a result of seasonal flooding and receding of the floodplains. It is this seasonal variability in forage quality and quantity which makes the Okavango Delta a unique ecosystem. The dynamic forage resources, which may be limiting at certain times of the year, influence the community ecology of large grazers of the Okavango Delta. When water level changes with the flooding dynamics, species concentrate on high grounds or disperse onto the floodplains, the population densities of these species change. When the water level recedes from August - September, large terrestrial ungulates move in to feed on the grasses that established or resprouted in this zone, which is a reliable grazing resource during the dry season.

The study was challenged by lack of data to support arguments concerning potential response of different wildlife to changes in flows. Long term ecological monitoring data, and data that link different wildlife to flows, are essential in order improve predictions of wildlife potential response to flow variations. Although challenged by lack of empirical evidence, the study benefited from the specialist's existing knowledge of the system. The study provides a useful baseline that can be used for further in-depth analyses of the relationship between wildlife and flows which is key in the prediction of the response of different indictors to flow variation.

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ABBREVIATIONS

ABBREVIATION	MEANING
HOORC	Harry Oppenheimer Okavango Research Centre

ACKNOWLEDGEMENTS

Firstly, I would like to thank my colleague, brother, friend and mentor Prof Mazvimavi for introducing the concept of Environmental Flows Assessment to me and colleagues at the Harry Oppenheimer Okavango Research Centre (HOORC). I would like to sincerely express my sincere gratitude to all members of the Southern Waters Team particular Jackie King for her patience, tolerance and understanding. I would like to appreciate colleagues from Angola in Kevin and Carmen for maintaining email contact through out the whole project. Not forgetting the Botswana Team members for their cooperation. Lastly I would like to thank the Directorate of HOORC and Deputy Vice Chancellor for granting HOORC staff members to partake in this noble undertaking.

1. INTRODUCTION

1.1 Background

An Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project is being implemented under the auspices of the **Food and Agriculture Organization** of the United Nations (UN-FAO). One of the activities is to complete a transboundary diagnostic assessment (TDA) for the purpose of developing a Strategic Action Plan for the basin. The TDA is an analysis of current and future possible causes of transboundary issues between the three countries of the basin: Angola, Namibia and Botswana. The Okavango Basin Steering Committee (OBSC) of the Okavango River Basin Water Commission (OKACOM) noted during a March 2008 meeting in Windhoek, Namibia, that future transboundary issues 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 such possible developments. OBSC recommended at this meeting that an Environmental Flow Assessment (EFA) be carried out to predict possible development-driven changes in the flow regime of the Okavango River system, the related ecosystem changes, and the consequent impacts on people using the river's resources.

The EFA is a joint project of EPSMO and the Biokavango Project. One part of the EFA is a series of country-specific specialist studies, of which this is the Wildlife report for Botswana.

1.2 Okavango River Basin EFA Objectives and Workplan

1.2.1 Project objectives

The goals of the EFA are:

- to summarise all relevant information on the Okavango River system and its users, and collect new data as appropriate within the constraints of the EFA
- to use these to provide scenarios of possible development pathways into the future for consideration by decision makers, enabling them to discuss and negotiate on sustainable development of the Okavango River Basin;
- to include in each scenario the major positive and negative ecological, resource-economic and social impacts of the relevant developments;
- to complete this suite of activities as a pilot EFA, due to time constraints, as input to the TDA and to a future comprehensive EFA.

The specific objectives are:

- to ascertain at different points along the Okavango River system, including the Delta, the existing relationships between the flow regime and the ecological nature and functioning of the river ecosystem;
- to ascertain the existing relationships between the river ecosystem and peoples' livelihoods;
- to predict possible development-driven changes to the flow regime and thus to the river ecosystem;
- to predict the impacts of such river ecosystem changes on people's livelihoods.
- to use the EFA outputs to enhance biodiversity management of the Delta.
- to develop skills for conducting EFAs in Angola, Botswana, and Namibia.

1.3 Layout of this report

2. STUDY AREA

2.1 Description of the Okavango 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 (Figure 2.1). 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 Thamalakane and then Boteti Rivers, the latter eventually joining the Makgadikgadi Pans. The Nata River, which drains the western part of Zimbabwe, also joins the Makgadikgadi Pans. On the basis of topography, the Okavango River Basin thus includes the Makgadikgadi Pans and Nata River Basin (Figure 2.2). This study, however, focuses on the parts of the basin in Angola and Namibia, and the Panhandle/Delta/Boteti River complex in Botswana. The Makgadikgadi Pans and Nata River are not included.

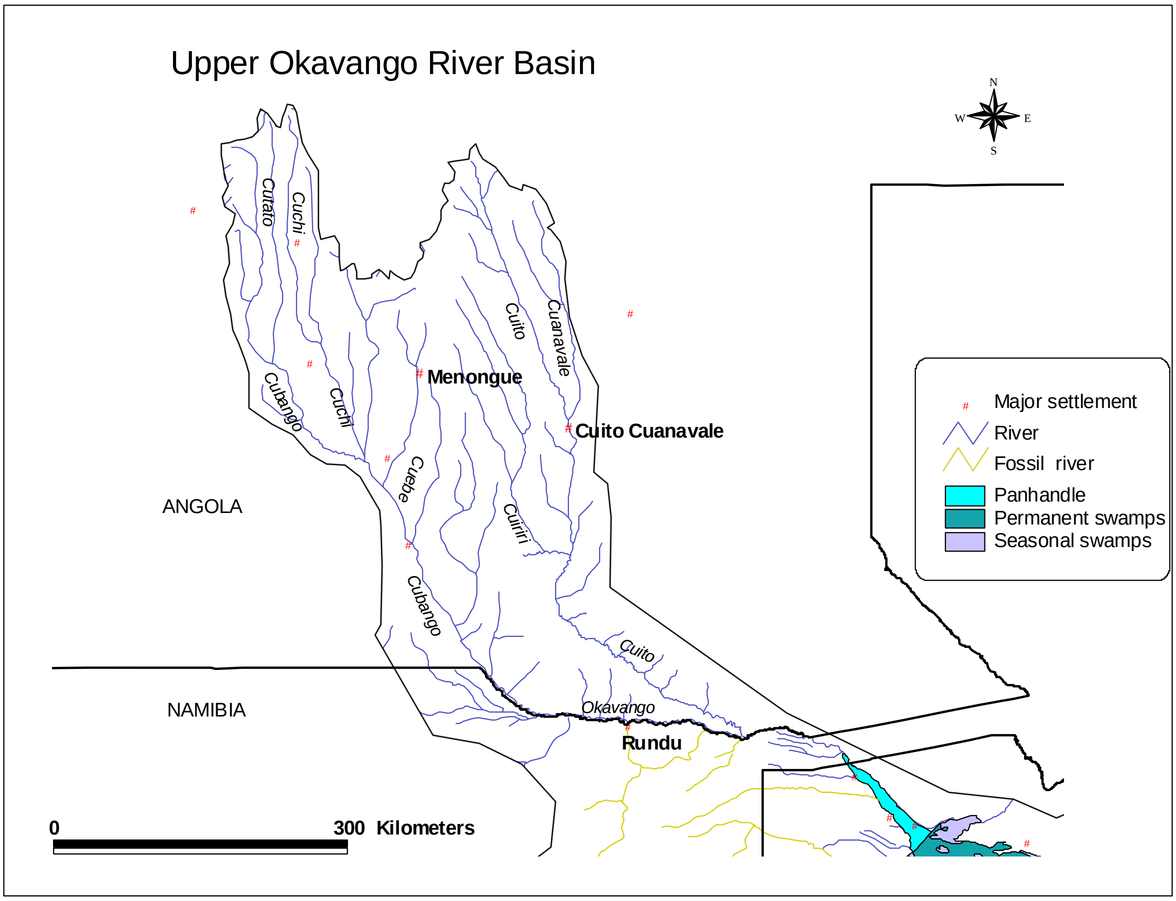

Figure 2. 1: Upper Okavango River Basin from sources to the norther end of the Delta

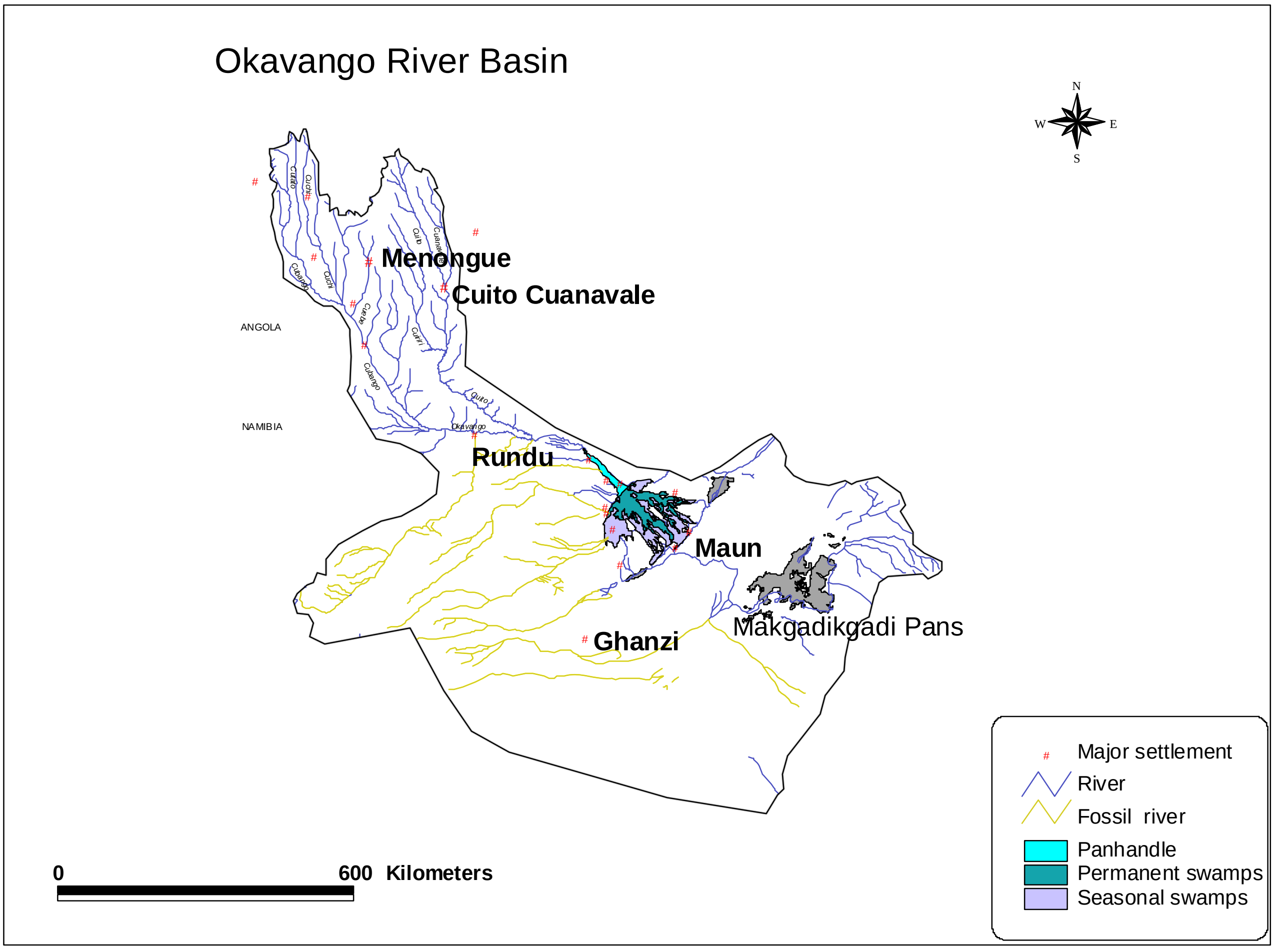

Figure 2. 2: The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans

2.2 Delineation of the Okavango Basin into Integrated Units of Analysis

Within the Okavango River Basin, no study could address every kilometre stretch of the river, or every person living within the area. Instead, representative areas that are reasonably homogeneous in character may be delineated and used to representative much wider areas, and then one or more representative sites chosen in each as the focus for data-collection activities. The results from each representative site can then be extrapolated over the respective wider areas.

Using this approach, the Basin was delineated into Integrated Units of Analysis (EPSMO/Biokavango Report Number 2; Delineation Report) by:
dividing the river into relatively homogeneous longitudinal zones in terms of:

- hydrology;
- geomorphology;
- water chemistry;
- fish;
- aquatic invertebrates;
- vegetation;

harmonising the results from each discipline into one set of biophysical river zones;

dividing the basin into relatively homogeneous areas in terms of social systems; harmonising the biophysical river zones and the social areas into one set of Integrated Units of Analysis (IUAs).

The 19 recognised IUAs were then considered by each national team as candidates for the location of the allocated number of study sites:
Angola: three sites
Namibia: two sites
Botswana: three sites.

The sites chosen by the national teams are given in Table 2.1.

EFA Site No	Country	River	Location
6	Botswana	Okavango	Panhandle at Shakawe
7	Botswana	Khwaei	Xakanaka in Delta
8	Botswana	Boteti	Chanoga

Table 2. 1: Location of the eight EFA sites

2.3 Overview of sites

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.

Zonation

The Okavango Delta was divided into the following five zones

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 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 up to Chanoga.

The eastern zone, central zone, and western zone have each perennial channels, seasonal floodplains and occasionally flooded areas and drylands occur. 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 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 Boteti River flowing into the Makgadikgadi Pans. The Gomoti, Santantadibe and Shashe have been dry since the 1990's. 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 on these rivers are derived from outflows from the delta. Another distinctive feature of these rivers draining the delta is the long-term variation of flows. The Thamalakane-Boteti River had very little to no flow during the mid-1990's, while high flows occurred during the 1970's and part of the 1980's.

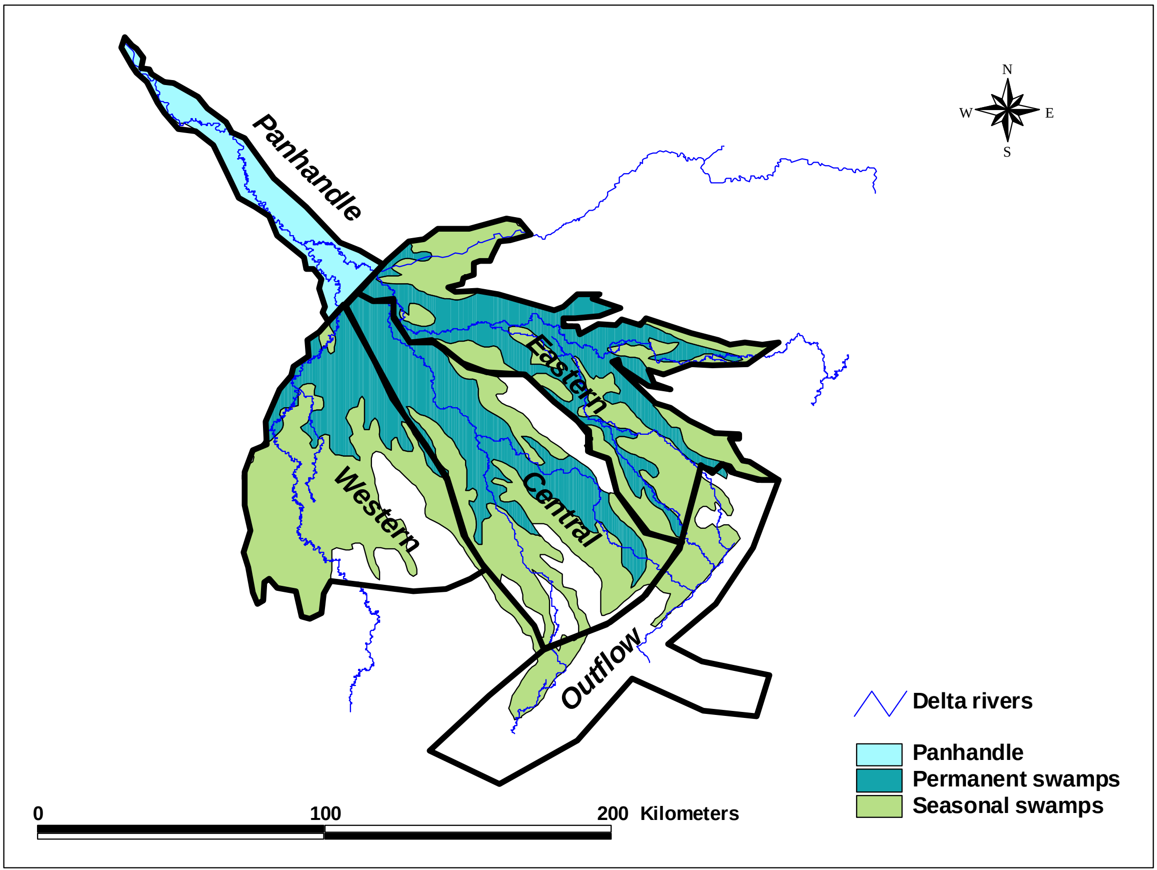

Figure 2. 3: Map of the Okavango Delta showing division into zones

2.4 Discipline-specific description of (Botswana) sites

Site 6: Panhandle at Shakawe

The Okavango River enters Botswana at Mohembo, having travelled some 1000km from its source, and it is channelled through a 15 km wide corridor between two secondary faults (Burchart 2000). After entering Botswana at Mohembo, the Okavango River meanders through papyrus and phragmites swamps (Figure 2.4) before it breaks into three main channel at Seronga.

Figure 2. 4: A photo showing Okavango River meandering through permanent swamps in the Panhandle

Dominant wildlife in the Panhandle area includes semi aquatic species such as hippo, crocodile, sitatunga and waterbuck. The permanent swamps flanking the river also provide suitable habitat for frogs, water snakes, terrapins, otters and water monitors. Terrestrial grazers such as wildebeest, buffalo, impala, tsessebe and lechwe are not common in the Panhandle area. High human presence in the Panhandle also contributes to the low numbers of other species.

Site 7: Eastern Delta around Xakanaxa

The Xakanaxa site on the eastern side of the Delta is typified by a permanent channel known as the Khwae River flanked by stretches of seasonally and occasionally flooded floodplains. The floodplains are themselves flanked by stretches of different woodland vegetation. The eastern side of the Delta supports almost all wildlife found in the whole Delta. Seasonally flooded floodplains and their associated islands (Figure 2.5) provides suitable habitats for semi aquatic and aquatic species, at the sometime providing suitable grazing sites for floodplain grazers when floods recede.

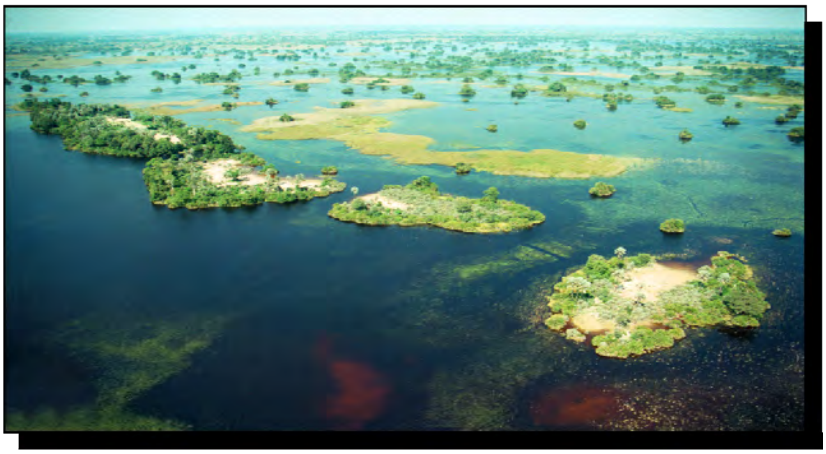

Figure 2. 5: Picture of seasonally flooded floodplains during peak floods

Occasionally flooded grasslands (Figure 2.6) of the eastern side of the Delta provides suitable habitat for terrestrial grazers such as zebra, buffalo, wildebeest and buffalo during years of high floods reflected in Figure 2.5.

Figure 2. 6: Picture of occasionally flooded areas found in the Xakanaxa area and other parts of the Delta

Site 8: Chanoga

The Chanoga site lie along the Boteti River which is part of the

3. IDENTIFICATION OF INDICATORS AND FLOW CATEGORIES

3.1 Indicators

3.1.1 Introduction

Biophysical indicators are discipline-specific attributes of the river system that respond to a change in river flow by changing in their:

- abundance;
- concentration; or
- extent (area).

Social indicators are attributes of the social structures linked to the river that respond to changes in the availability of riverine resources (as described by the biophysical indicators).

The indicators are used to characterise the current situation and changes that could occur with development-driven flow changes.

Within any one biophysical discipline, key attributes can be grouped if they are expected to respond in the same way to the flow regime of the river. By example, fish species that all move on to floodplains at about the same time and for the same kinds of breeding or feeding reasons could be grouped as Fish Guild X.

3.2 Indicator list for Wildlife

In order to cover the major characteristics of the river system and its users many indicators may be deemed necessary. For any one EF site, however, the number of indicators is limited to ten (or fewer) in order to make the process manageable. The full list of indicators was developed collaboratively by the country representatives for the discipline **–Wildlife** and is provided in Table 3.1. Further details of each indicator, including the representative species of each biological one, are given in Appendix 1and discussed fully in Chapter 4

Indicator Number	**Indicator name**	**Sites represented – no more than ten indicators per site**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Semi Aquatic						X	x	x
2	Frogs, river snakes						x	x	X
3	Middle floodplain grazers (upper floodplains)						x	x	
4	Outer floodplain grazers						x	x	
5	Lower floodplain grazers						x	x	

Table 3. 1: List of indicators for Wildlife and those chosen to represent each site

3.3 Description and location of indicators

Wildlife Indicator 1
Name: Semi Aquatic wildlife

Description:
Main channel and open water (lagoons and pools) dwellers that need sufficient low flow channel with and depth waters for protection.

Representative species:
Hippopotamus, crocodile

Other characteristic species:
Other aquatic reptiles, otters, terrapins

Flow-related location:
Found through out the Delta where permanent channels, backswamps and extensive floodplains exist.

Known water needs:
This indicator group require deep permanently flowing water and permanently moist vegetated channels margins for breeding, protection from high temperatures and predators.

Wildlife Indicator 2
Name: Frogs, river snakes

Description:
Wildlife species found in areas permanently inundated with rooted emergent plants, submerged plants and floating leafed plants, with margins or tree line dominated by riparian woodlands. They also require islands / sand bars / rocks for protection, feeding, resting and breeding sites

Representative species:
Water monitor, snakes, musk shrews and frogs

Other characteristic species:
Other aquatic reptiles and amphibians

Flow-related location:
Found through out the Delta in main channels, permanent swamps formed by backwaters.

Known water needs:
They require shallow to deep permanently to seasonally flowing water and permanently moist vegetated channel margins for breeding, protection from high temperatures and predators

Wildlife Indicator 3

Name: Middle floodplain (upper floodplain) grazers

Description:
Large mammalian floodplain grazers that utilise higher lying floodplains of grasslands elevated above the lower/primary floodplains by up to 1m. These floodplains are dominated by semi-aquatic grasses that become available when floods recede during the otherwise dry season.

Representative species:
Tsessebe, warthog, wildebeest, zebra, buffalo

Other characteristic species:
elephant, impala

Flow-related location:
Found through out the Delta but dominant in the fan part of the Delta where extensive floodplains exist.

Known water needs
This key habitat for floodplain grazers requires seasonal flooding for a period of 2-6 months in years of low flooding intensity and 4 -8 months in years of high rainfall and high flooding intensity. These floodplains provide water for drinking and high quality forage resources that become available when floods recede.

Wildlife Indicator 4
Name: Outer floodplain grazers

Description:
Grazers that utilise highest lying islands and grasslands which only flood in years of extremely high floods, and flood for a very short period of time if they ever flood.

Representative species:
Eland, roan antelope, sable antelope, elephants,

Other characteristic species:
small mammals

Flow-related location:
highest lying islands and grasslands which only flood in years of extremely high floods, and flood for a very short period of time if they ever flood.

Known water need
This habitat requires periodic short duration flooding.

Wildlife Indicator 5
Name: Lower floodplain areas

Description:
Floodplain grazers that utilise low lying floodplains which are the first to receive flood water over-spilling from the outlet channels in seasonal swamps, and are the last to recede..

Representative species:
reedbuck, lechwe, sitatunga, waterbuck

Other characteristic species:
Aquatic reptiles (crocodiles and water monitor lizards), Aquatic birds (wattle crane, African and lesser jacana) and painted frogs and other reptiles).

Flow-related location:
Found throughout the Delta where deep permanently flowing water and permanently moist vegetated channels margins provide breeding sites, protection from high temperatures and predators. Overspills of the main channels from the main channels create seasonal swamps dominated by emergent vegetation, floating leaved and submerged plants.

Known water needs
This key wildlife habitat (floodplain grazers in particular) require seasonal flooding for a period of 4-6 months in years of low flooding intensity and 6 -12 months in years of high rainfall. These floodplains are key fallback areas for all herbivores when the floods recede from July to October, providing green and highly nutritious forage during the flooding season when everything else in the nearby savannas is dry.

3.4 Flow categories – river sites

One of the main assumptions underlying the EF process to be used in the TDA is that it is possible to identify parts of the flow regime that are ecologically relevant in different ways and to describe their nature using the historical hydrological record. Thus, one of the first steps in the EFA process, for any river, is to consult with local river ecologists to identify these ecologically most important flow categories. This process was followed at the Preparation Workshop in September 2008 and four flow categories were agreed on for the Okavango Basin river sites:
Dry season
Transitional Season 1
Flood Season
Transitional Season 2.

Tentative seasonal divisions for river Sites 1-5 are shown in Figures 3.1 to 3.5. These seasonal divisions will be formalised by the project hydrological team in the form of hydrological rules in the hydrological model. In the interim they provide useful insights into the flow regime of the river system suggesting, along with the hydrographs, a higher within-year flow variability of the Cuebe River and a higher year-on-year variability of the Cubango River.

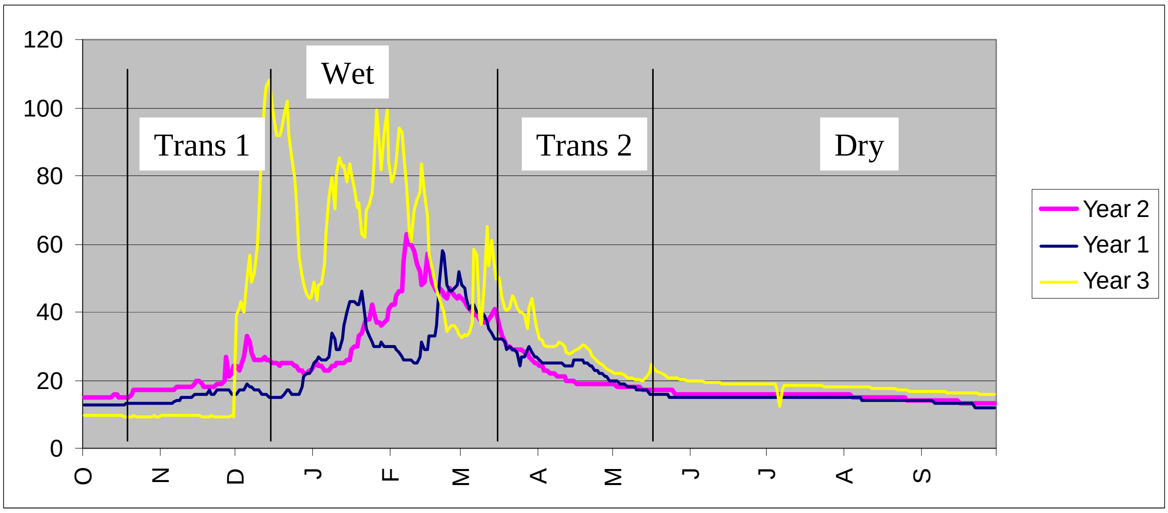

Figure 3. 1 Three representative years for Site 1: Cuebe River @ Capico, illustrating the approximate division of the flow regime into four flow seasons

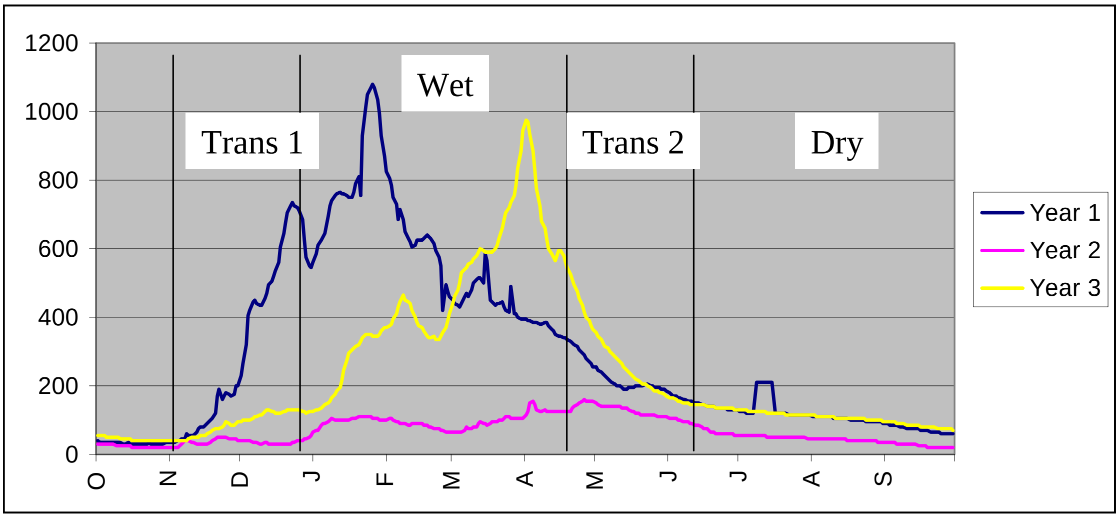

Figure 3. 2 Three representative years for Site 2: Cubango River @ Mucindi, illustrating the approximate division of the flow regime into four flow seasons

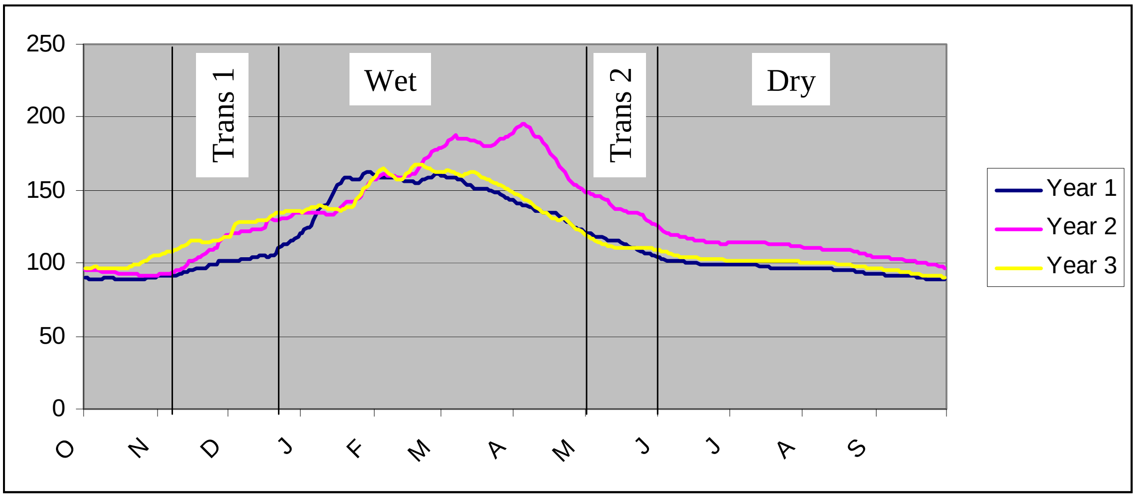

Figure 3. 3 Three representative years for Site 3: Cuito River@ Cuito Cuanavale, illustrating the approximate division of the flow regime into four flow seasons

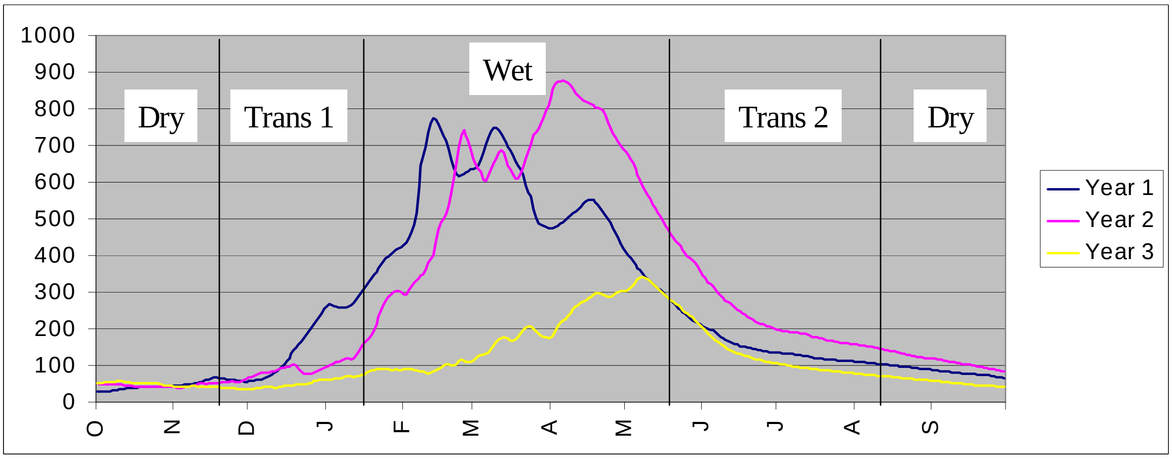

Figure 3. 4 Three representative years for Site 4: Okavango River@ Kapoka (hydrological data from Rundu) illustrating the approximate division of the flow regime into four flow seasons

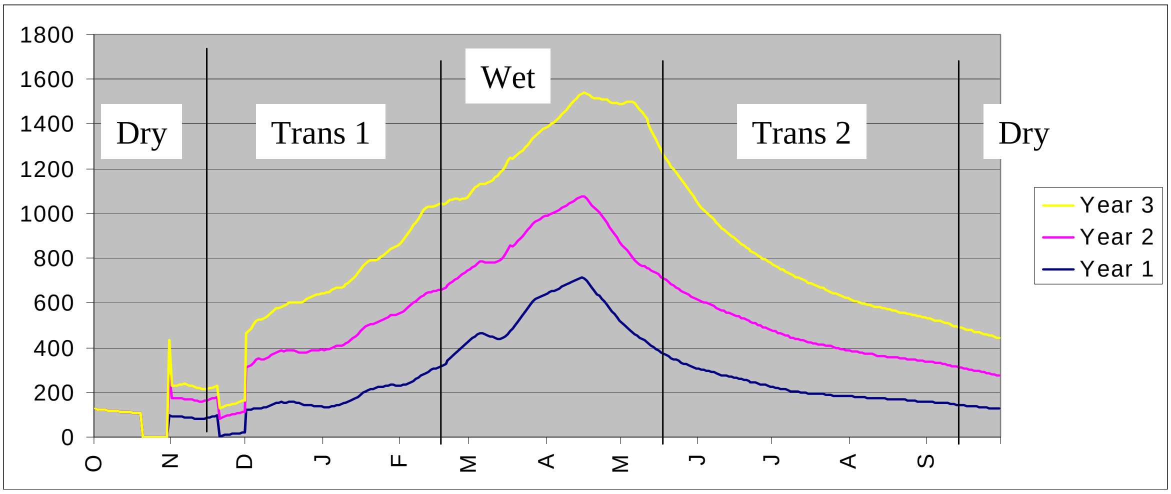

Figure 3. 5 Three representative years for Site 5: Okavango river @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

The literature review (Chapter 4) and data collection and analysis exercises (Chapter 5) are focused on addressing what is initially expected to be nine main questions related to these flow seasons (Table 3.2).

Question number	Season	Response of indicator if:
1	Dry Season	Onset is earlier or later than natural median/average
2		Water levels are higher or lower than natural median/average
3		Extends longer than natural median/average
4	Transition 1	Duration is longer or shorter than natural median/average - i.e. hydrograph is steeper or shallower
5		Flows are more or less variable than natural median/average l
6	Flood season	Onset is earlier or later than natural median/average – synchronisation with rain may be changed
7		Natural median/average proportion of different types of flood year changed
8	Transition 2	Onset is earlier or later than natural median/average
9		Duration is longer or shorter than natural median/average – i.e. hydrograph is steeper or shallower

Table 3. 2: Questions to be addressed at the Knowledge Capture Workshop, per indicator per site. In all cases, 'natural' embraces the full range of natural variability

3.5 Inundation categories – delta sites

The recognised river flow categories are not relevant in the Delta, where inundation is the major driver of ecosystem form and functioning. The main inundation categories recognised by the inundation model developed by the Harry Oppenheimer Okavango Research Centre (HOORC) are used here (Table 3.3).

Inundation category	Inundation category name	Description
Delta 1	Channel in permanent swamp	
Delta 2	Lagoons in permanent swamp	
Delta 3	Backswamp in permanent swamp	
Delta 4	Seasonal pools in seasonally flooded zones	
Delta 5	Seasonal sedgelands in seasonally flooded zones	
Delta 6	Seasonal grasslands in seasonally flooded zones	
Delta 7	Savannah – dried floodplain in seasonally flooded zones	
Boteti 1	Wet connected	
Boteti 2	Disconnected pools	
Boteti 3	Dry	

Table 3. 3: Inundation categories for the Okavango as recognised by the HOORC inundation model

4. LITERATURE REVIEW

4.1 Introduction

Literature highlighting the relations between wildlife and flows, and the impact of flow variation on specific wildlife species of the Okavango Delta is largely scattered, and unassimilated. However, available literature (e.g. Child 1976; Murray 1997; Rothert 1997; Bonyongo 1999, 2008; Butchart 2000; Mendelsonhn and Obeid 2004; Ramberg et al. 2006) has shown that a variety of large browsing and grazing mammals that occur on the open waters, floodplains and their fringing riparian vegetation, reflect the diversity of habitats and the high primary productivity facilitated by the pulsing seasonally flooding of the Okavango Delta. The high habitat diversity and the high primary productivity of are both clearly linked to seasonal and the long and short term patterns of the flooding of the Okavango Delta (Ellery and Ellery 1997). Due to the high habitat diversity, the Delta supports, a high diversity of wildlife ranging from those that are almost totally aquatic or semi-aquatic to animals completely independent of water except for drinking purposes (Bonyongo 2004).

The most conspicuous populations are found in the Moremi Game Reserve, and a number of controlled hunting areas adjacent to Moremi Wildlife Game Reserve. More than 400 species of birds (Kabii 1997, Ramberg 2006), 112 mammal species of 12 orders and 34 families (Ramberg et al 2006), 33 species of amphibians and 64 species of reptiles (Murray, 1997) have been recorded in the Okavango Delta. Most mammals of the Delta are small and often over looked (Ramberg, 2006). In the Delta, 12 reptile species including the Nile Crocodile and the Nile Monitor, python and five water snakes and four terrapins may be considered aquatic or near aquatic (Murray, 1997). These reptiles are restricted in their distribution to areas in or near potential surface water. The abundance and distributions of aquatic reptiles and amphibians is in the Okavango Delta highly likely to be affected by both natural and anthropogenic induced changes in water flows.

Large herbivores especially floodplain grazers, are among wildlife species that are wide spread throughout the Delta which are likely to be affected by anthropogenic changes of flows. It is highly probable that hydrological modification due to significant water abstraction upstream of the Okavango River would modify floodplain ecosystems leading to the decline of some ungulate species, particular the semi aquatic antelopes and other floodplain grazers. Decline of ungulates populations attributed to human induced changes in hydrological flows were reported in the Marromeu Delta following construction of three dams in the Zambezi River catchments (Funston 2006). Funston (2006) also reported that Kariba, Kafue and Cabora Bassa Dams significantly altered very large floodplains systems leading to loss of key habitats for both livestock and wildlife. It is therefore imperative to make reference to what happened to the Zambezi Delta and other systems when considering large scale developments such as damming and construction pipelines in the Okavango River basin.

Natural changes in hydrological regimes have been observed to influence populations of ungulates, especially floodplain grazers and semi aquatic species such as hippo and crocodile. Bonyongo and Ugutu (2009) hypothesized that in successive years of high floods and high rainfall which leads to prolonged flooding of floodplains, the population of large herbivores which use floodplains as fallback areas during the dry season will decline due loss of floodplain grazing resources. This is because under prolonged high floods, seasonally floodplains are converted into semi-permanently flooded swamps. Under those circumstances high quality palatable grasses give way to law quality unpalatable sedges. On the other hand the population of semi-aquatic and aquatic species will increase because extended flooding enhances the habitat quality for such species. Bonyongo and Ugutu (2009) showed that on 10 year moving average, the inflow at Mohembo exhibits 60 year cycle in which 30 years are of averagely high and increasing floods, while the other 30 years is of averagely low and declining floods (Figure 4.1).

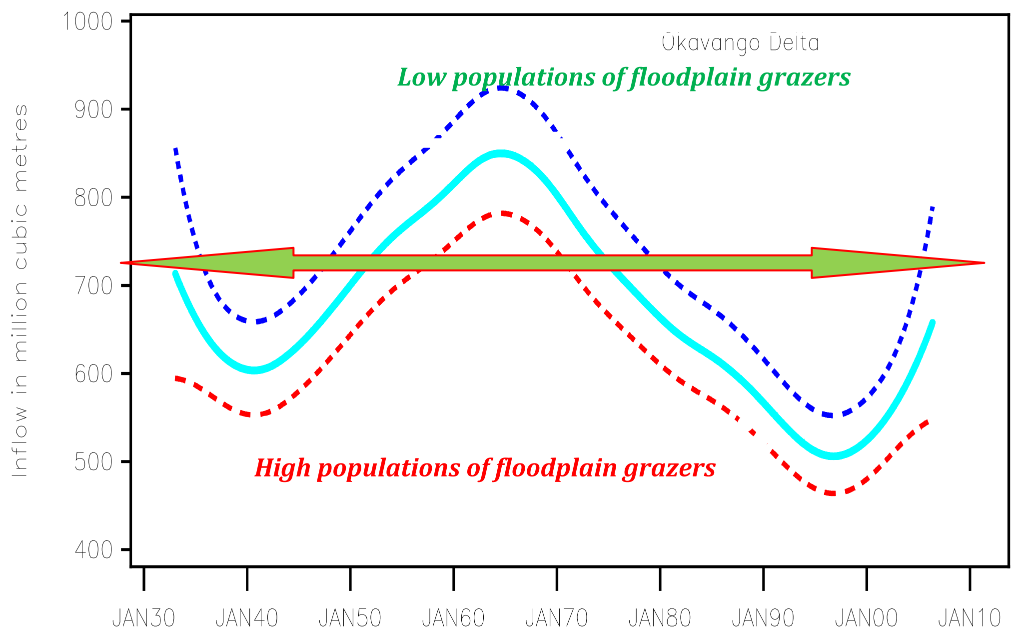

Figure 4. 1 A 10 year moving average of inflow at Mohembo from 1933 to 2005. Source (Bonyongo and Ugutu 2009: unpublished manuscript

Natural changes in flooding regime demonstrated in Figure 4.1 serve as a natural regulator of wildlife population in the Okavango Delta. Bonyongo and Ugutu (2009) modeled the influence of rainfall on the population trends of the large herbivores in the Okavango Delta, and found no relationship between trends in rainfall and trends in wildlife populations. Rather, a density dependent feedback was predicted. This suggests that the shrinking and expanding of floodplains as result of variation in flooding frequency, intensity and duration form part of the major drivers of wildlife population in the Okavango Delta.

4.2 Indicator 1: Semi-aquatic

4.2.1 Main characteristics of Indicator 1

The main species that inhabit channels/open water are hippopotamus and crocodile. Hippopotamus and crocodiles are confined to areas of open waters from where they venture in short distances to feed on grasses on the higher ground and floodplains at night (Butchart 2000; Mendelsonhn and Obeid 2004). Hippos are an important component of any wetland/floodplain system. They play a crucial role in the creation and maintenance channels through out the Okavango Delta. This indicator species is widely distributed throughout the Okavango Delta with an estimated population of about 3000 (DWNP 2000). They are usually found in small herds of 10-12 (Burchart 2002). They forage short grasses thus maintaining grazing lawns for small grazers such as lechwe, reedbuck, impala and warthog.

Species	Relationship to flows
Hippopotamus	Require deep (**deep enough to submerge**) slow flowing to stagnant waters of lagoons and main channels for protection and breeding. Hippo population would immediately decline with drastic reduction in inflows but would remain stable with increase in flows. Establishment of new sites of deep water would possible lead to an increase population.
Crocodile	Require deep water to submerge. Crocodiles spend most of their time in open waters. They are very sensitive to drop in water levels. Reduced flows are likely to lead to the disturbance of crocodile nesting sites.
Okavango Hinged Terrapin,	It occurs in permanent water of rivers, channels, lagoon lagoons where it feeds on small fish (Butchart 2000**).**
Water monitor	Massive aquatic lizard with an elongated snout. Highly depended in water and would decline in numbers if places of permanent water would dry up**.**
Various aquatic snakes and frog	Various snakes and frogs residing in permanent open water would decline in numbers if flows decline significantly significant

Table 4. 1: Table showing the semi-aquatic indicator species

Currently the hippo population in the Okavango Delta is believed to be stable although Child (1976) reported population declines. Child (1976)'s assertion is doubtful because there is not evidence that shows it was supported by any form of empirical data. In mid 1970s few animal surveys were conducted in Botswana. Based on data from Department of Wildlife and National Parks (DWNP) dating from 1989 to 2006, Bonyongo (2004) reported that currently the population of hippos in Delta are steadily increasing. However, it is important to note that population of hippos are extremely difficult to ascertain due to their aquatic and nocturnal behaviour. Although the Okavango Delta still supports a descent population of hippos, their population is reported to be declining in other similar ecosystems notably the Kafue and the Zambezi Delta (Builfus and Brown 2006).

Crocodiles are widely spread out through out the Okavango Delta. Their populations are extremely difficult to ascertain although is widely believed that in the 1970 to late 1980, their population declined due excessive illegal hunting. Current population dynamics information on crocodiles including hatching survival rate is lacking (Murray 1997).

Life cycle attributes of Indicator 1: Semi-aquatics

Hippopotamus spends the day resting near water through out the year to keep cool, protect their skin from sunburn and avoid biting insects (Kingdon 1997; Apps 2000; Butchart 2000). Hippo leaves water to sunbath on the banks especially during the overcast cool weather in summer. At dusk, it leaves out of water to feed to feed for 7-8 hours. Because it has a unique skin which loses water several times the rate of other mammals, a hippo out of water in hot weather risks rapid dehydration and overheating (Kingdon 1997).

Crocodiles also spend most the time basking near water during the day for protection. Terrapin also spend time near water during the day basking on logs, and sometimes of the backs of hippos. Various aquatic reptiles also spend most of their time near water for protection feeding and nesting.

Links to flow

All the species of indicator 1 are entirely dependent on water to varying degrees. They require deep permanently slow flowing water and permanently moist vegetated **(emergent, floating and submerged vegetation)** channels and lagoon margins for breeding/nesting/spawning, resting, feeding, protection from high temperatures and predators all year round. For example hippos need water up to 1.5m to submerge during the day and feeds 2-3km from water (Kingdon 1997; Butchart 2000). Development near water would deprive hippos of feeding sites. Crocodiles also require deep permanent waters to submerge during the day. These indicator species would decline immediately when flows are reduced drastically. Rapid increase in water levels is also likely to disturb the ecology of this indicator group.

4.2.2 Main characteristics of Indicator 2 – Frogs and River snakes

This indicator comprises of species which need to spend time near permanent waters of main channels with small islands of sandbars and vegetated islands. Vegetated islands are used by this indicator group are also found in backswamps. Members of this indicator group use these islands for nesting and feeding or resting on exposed sand islands and rock out crops. Near by water could be swallow or deep but permanent depending on the flooding season. The islands may be completely covered by water during peak floods and exposed during low floods. It is during the low floods that crocodiles, otters, water monitors would use sandbars for resting (Butchart 2000). In the Okavango Delta system, rock outcrops and extended rock beds are common in the Boteti River.

Life cycle attributes of Indicator 2

The life cycle attributes of indicator are similar to those of indicator 1 because they spend sometime in water and sometime outside water either to feed, nest or rest.

Links to flows

The links to flows of indicator 2 are similar to those of indicator 1. Therefore the reader is referred to indicator 1. These species are sensitive to changes in flows. Some of them may survive the absence of surface water for sometime as long as moist soils exist. This is particularly so for frogs who may burry themselves in moist soils for protection when there no water for them to submerge.

4.2.3 Main characteristics of Indicator 3:

Middle floodplain (Upper floodplain grazers) This indicator comprises mainly of terrestrial grazers which use seasonal floodplains when floods recede. Species in this indicator group retreat to terrestrial habitats adjacent to floodplains during the rainy season to benefit from annual grasses that grow in terrestrial habitats when it rains. These species use large home ranges which enable them to utilise a variety of habitats types given the mosaic and patchy nature of the Okavango Delta habitats

Upper floodplain grazers	Link to flows
buffalo, elephant, impala, zebra waterbuck, tsesebe, wildebeest, steenbok, duiker, bushbuck, waterbuck.	This indicator group require seasonally flooded grasslands to provide grazing and resting places. Smaller islands surrounded by active floodplains require horizontal below ground flows to raise the ground water table which results improved development of the herb layer. Larger islands with a higher diversity of grasses and forbs are grazed by most large grazers of the Okavango Delta in periods of high floods.

Table 4. 2: Table showing terrestial grazers which utilise seasonal floodplains

Life cycle attributes of Indicator 3

On a large scale, both temporally and spatially, dispersal of wildlife through out the Delta is influenced by fluctuations in water level and food availability will be reflected by the different population densities of floodplain grazers over years and seasons (Bonyongo 2004).

Links to flows

When water levels change with the flooding dynamics, species of this indicator group concentrate on high grounds or disperse on floodplains. When the water level recedes from August - September, large terrestrial ungulates of this indicator group move in to feed on the grasses that established or resprouted in upper floodplains. The upper seasonal floodplains flooding dynamics are to a large extent an influential factor determining the amount of floodplain grazers found in the Okavango Delta.

In successive years of high floods and high rainfall which leads to prolonged flooding of upper floodplains, the area floodplain grazers venture to graze can be reduced by as much as 50%. Ultimately the population of middle/upper floodplain grazers will decline due loss of floodplain grazing resources. Prolonged high floods convert upper floodplains into semi permanently flooded lower floodplain type of vegetation at the expense of semi aquatic grasses which are key to floodplain grazers of this group. Under those circumstances, high quality palatable grasses give way to low quality unpalatable sedges. This will result in prolonged nutritional stress which leads to low conception rates, high rates of miscarriage, stillborns, and ultimately decline populations. This phenomenon is considered natural population regulation mechanisms (Bonyogo and Ugutu 2009). On the other hand the population of semi-aquatic and aquatic species increases during high intensity flood extended flooding enhances the habitat quality for such species.

4.2.4 Main characteristics of Indicator 4 Outer/tertiary floodplain grazers

This indicator comprises of large mammalian herbivores which are not water dependent except for drinking. They utilise highest lying islands and grasslands which only flood in years of extremely high floods, and flood for a very short period of time if they ever flooded.

Outer floodplain grazers	Link to flows
gemsbok, eland, hartebeest, giraffe, kudu, roan antelope, sable antelope, ostrich, springbok, rhinoceros	These are not water dependent except for drinking, therefore are not linked to flows.

Table 4. 3: Outer floodplain grazers which do not depend on water except for drinking

Life cycle attributes of Indicator 4

Species of this indicator group generally spend most of their time grazing in open woodlands but my spend time in the ecotones where outer floodplains merge with the woodlands. They drink in floodplains and floodplain residual pools during the fry season. After drinking, they may spend time grazing in the upper floodplains.

Links to flows

Species in this indicator group are not directly linked to flows except for drinking water. These species do not necessarily have to drink regularly though. They are therefore unlikely to be affected by low to medium decline in flows. Naturally they utilise large home ranges which enable them to utilise a high diversity of habitats. They also utilise lower and upper floodplains whenever they are available but are not dependent on floodplains. However, in years of high floods which lead to flooding of outer or tertiary floodplain, they benefit from enhanced growth of grasses due to increased soil moisture**.**

4.2.5 Main characteristics of Indicator 5: Lower floodplain areas

This indicator comprises mainly of semi-aquatic antelopes which need to graze near water either because they need water to escape from predators or they need to drink regularly. They include lechwe, reedbuck, sitatunga and water buck (Kingdom 1997). Semi-aquatic and aquatic antelopes are generally found in lower floodplains bordering semi-permanant and permanent swamps. The lower floodplains are generally flooded longer but provide very nutritious forbs, sedges and grasses when the floods recede.

Floodplain grazers	Link to flows
lechwe, reedbuck, sitatunga waterbuck	Require seasonally flooded floodplains with grasses and sedges which keep growing in swallow water.

Table 4. 4: Table showing floodplain grazers

Life cycle attributes of Indicator 5

Sitatunga is a swamp dwelling antelope with feet adapted to wet terrain. In the Okavango Delta, it is found mainly in the Panhandle where stretches of papyrus and phragmites permanent swamps exist. It is an elusive aquatic antelope confined to the papyrus swamps and adjacent land (Burchart 2000). Sitatunga feeds on aquatic vegetation as well as on leaves and grasses of lower and upper floodplains. It is a slow swimmer which uses regular pathways through the papyrus reeds (Kingdon 1997; Butchart 2000). Sitatunga is active from daylight to about 11:00am and to about 17:00h when they may emerge to feed on open grasslands or forests under the cover of darkness (Kingdon 1997). The sitatunga's dependence on swamps for food and cover favours dispersed social organisation and makes it hard to observe.

Water buck is highly water dependent because it needs to drink regularly. It grazes on open grasslands within close proximity of water. Lechwe prefer floodplains bordering permanent swamps. When water level changes with the flooding dynamics, species concentrate on high grounds or disperse onto the floodplains, the population densities of these species change. On a large scale, both temporally and spatially, dispersal through out the Delta result of fluctuations in water level and food availability will be reflected by the different population densities over the years and seasons (Bonyongo 2004).

Links to flows

Waterbuck is the most water dependent of the aquatic antelopes found in the Okavango Delta. It is highly susceptible to dehydration during the dry hot days therefore requires to be near water all the time. Sitatunga is the most aquatic antelope followed by lechwe (Kingdon 1997; Burchart 2000). Most aquatic antelopes use water as an escape route when threatened by predators. Waterbuck also use water to escape from predators although it generally prefers dry high ground. Due to the dependence on water as a refuge from predators, aquatic antelopes cluster together along the shore lines or floodplain edges before dark descends (Kingdon 1997). Being the most aquatic, sitatunga is so specialised such that it occurs only in swamps or permanent marshes dominated by sedges (Kingdon 1997). Most terrestrial predators cannot handle prey efficiently in water; hence floodplains with deep water and permanent swamps form an important habitat for aquatic antelopes. However, lions, leopards, spotted hyenas and wild dogs have been observed hunting aquatic antelopes in water.

Semi-aquatic antelopes depend on the abundant and highly nutritious grasses growing in inundated floodplains. Such areas are not accessible to most terrestrial grazers which also utilize floodplains. Therefore high intensity flooding gives competitive advantage to aquatic antelope over non aquatic floodplain grazers such wildebeest and tsessebe.

Semi-aquatic antelopes are likely to respond to flow variation to a varying degree since their dependency in water is slightly variable. Lechwe, waterbuck and reedbuck are likely to respond quickly to a reduction in flow that would lead to a reduction in seasonally flooded areas. Lose of lower floodplains would immediately led to the decline in lechwe population. Waterbuck would not respond immediately to lose of floodplains as long as there is sufficient drinking water from the main channel or residual pools. Permanent swamps are generally more robust than floodplains which suggest that sitatunga would not be immediately affected by a reduction in flows.

5. DATA COLLECTION AND ANALYSIS

No new data was collected. However, based on literature, and existing knowledge of the of Okavango Delta, the distribution of key wildlife indicators was established. Large semi-aquatic species, frogs and water snakes are common and widespread throughout the Delta. Hippos and crocodiles are particularly common in all areas where deep flowing and/or stagnant waters are found. Hippos and crocodiles are among the animals which course death in many parts of Delta since deep waters they inhabit are also used by human beings to for various livelihoods activities which include fishing, tourism and transport. Hippos and crocodiles can be described as abundant in the Panhandle and the Okavango Delta. In the Boteti River, they can be described as rare to common although the situation is changing due to the current high floods.

Semi aquatic antelopes are abundant throughout the Okavango Delta but rare to common in the Panhandle. Their numbers are relatively low in the Panhandle area due to the presence of human beings who hunted them for bush meet in the past. Sitatunga is common in the permanent swamps in the Panhandle region. Lechwe is probably the most abundant semi-aquatic antelopes while waterbuck and reedbuck are the list abundant throughout the Delta

Floodplain grazers are generally wide spread throughout the Delta, particularly in the lower Delta where seasonal flooded floodplains are abundant. Outer floodplain grazers are particularly common in the Chiefs Island where they travel short distances from the woodlands to floodplain especially when floods recede. During the rainy season, most of the upper and outer floodplain grazers spend most of their time in the woodlands benefit from the green flush and seasonal ponds for drinking water.

5.1 Methods for data collection and analysis

This study was predominantly desktop based with minimal fieldwork because long-term observation and sampling were beyond the scope of this study. The analysis of potential impacts of flow variation on different wildlife, and the potential response of various wild species benefited from existing literature and the experience accrued by the specialist over time while working in the Delta. Key literature will include Fleming (1976), Patterson (1976), Fleming (1976) Robel and Child (1976) Kingdon (1997), Apps (2000), Butchart (2000), Bonyongo (1999; 2000; 2004) Sites selected during the preparation workshop were visited mainly to appreciate the similarities and differences in habitats.

5.2 Results

Based on literature and personally knowledge of the Okavango Delta and its wildlife, 5 key wildlife indicators were identified. They are semi – aquatic species, frog and river snakes, lower floodplain grazers (mainly aquatic antelopes), upper floodplain grazers and the outer floodplain grazers. A summary of present understanding of the predicted responses of all wildlife indicators to potential changes in the flow regime is presented in section 5.3.

5.3 A summary of present understanding of the predicted responses of all wildlife indicators to potential changes in the flow regime

The following tables summarize predicted response of the wildlife indicators to potential flow dynamics.

5.3.1 Indicator (Semi aquatic)

Table 5. 1 Predicted responce to possible changes in the flow regime of Semi Aguatic species in the Okavango River Ecosystem

Question number	Season	Possible flow change	Response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Dry season onset would not affect semi aquatic species as long as permanent water bodies exist within the system. Whether it comes late or early, it is of no consequence as long as sufficient water needed to facilitate the life cycles of aquatic species is available.	medium
2		Water levels are higher or lower than natural	High water levels would enhance the quality of semi aquatic wildlife habitats which may in turn lead to an increase population. On the other hand, water levels lower than natural would lead to the decline in the amount of permanent water bodies which are key habitats for semi aquatic species.	High
3		Extends longer than natural	Long dry season would definitely have a negative impact since will lead to reduction in water levels and lose of permanent waters in lagoons and back swamps	High
4	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Early flood onset might have a slight positive impact especially when it follows years of low floods. However, if it follows years of high floods, it might not have any significant impact. Late floods could have a negative impact because that could mean an extended dry season especially if it follows years of low floods.. Water levels could drop beyond minimum thresholds for species such as hippo which need to submerge at certain times of the day.	high
5		Natural proportion of different types of flood year changed	Short flood season would result in negative impacts since it could lead to lose of key habitats, while long flooding season would enhance the quality if the habitats which could lead to increase in population of semi aquatic species	High

5.3.2 Indicator 2 (Frogs, River snakes)

Table 5. 2: Predicted responce to possible changes in the flow regime of Frogs, River Snakes in the Okavango River Ecosystem

Question number	Season	Possible flow change	Response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The onset of the flooding season would not affect the Frogs, Rivers Snakes (as well as other small reptiles and amphibians) as long as the river system and its associated floodplains have enough water to meet their minimum requirements	High
2		Water levels are higher or lower than natural	Water levels higher than natural will lead to the establishment of more aquatic environment suitable for species of this indicator group. Water levels lower than natural will definitely affect the habitat quality which my in turn lead to the decline in numbers	High
3		Extends longer than natural	Extended dry season will results in loss of aquatic habitats which will lead to the decline in population small aquatic amphibians and reptiles.	High
4	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Early floods would benefit small reptiles and amphibians particularly after a period of prolonged droughts because it would immediately make the environment conducive for growth and development. However, if the onset is later than usual, this group would suffer especially if water levels go down to an extent where some water ways dry up.	medium
5		Natural proportion of different types of flood year changed	Low floods will definitely affect the quality of the habitat negatively but, contrarily, high floods would enhance the habitat for small reptiles and amphibians leading prosperity.	

5.3.3 *Indicator 3 (Middle Floodplain Grazers)*

Table 5. 3: Predicted response to possible changes in the flow regime of Middle Floodplain Grazers in the Okavango River Ecosystem

Question number	Season	Possible flow change	Response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Dry season on set would not affect the middle/upper floodplain grazers because these group is not directly water depended.	medium
2		Water levels are higher or lower than natural	High dry season volume would also not affect this group except in situation where it would lead to prolonged flooding of the middle/upper floodplains. Lower dry season volume would not affect middle floodplain grazers for reasons given above.	medium
3		Extends longer than natural	As long as is drinking water either in the channel or residual floodplain pools, longer dry periods would not affect these group of grazers negatively. In fact they may benefit slightly since prolonged dry season results in more unflooded floodplains to venture on for grazing	medium
4	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Floods that come earlier than natural may negatively affect this group of grazers because floodplains might flood at the time when grazers still depend on them. If floodplains of the Delta flood during the rainy season, it is highly likely that seasonal floodplains will be turned in semi permanent swamps which are not of any value to floodplain grazers.	high
5		Natural proportion of different types of flood year changed	Prolonged flooding season will affect the middle floodplain grazers negatively because that means floods won't recede on time to enable grazers to access the green flush which becomes readily available when floods recede. Under this circumstances, sedges of low quality increase at the expense of high quality grasses. This group of animals then became nutritionally stressed leading low conception rate and miscarriages.	high

5.3.4 Indicator 4 (Outer floodplains)

Table 5. 4: Predicted response to possible changes in the flow regime of Outer floodplain grazers in the Okavango River Ecosystem

Question number	Season	Possible flow change	Response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	This group of grazers will not be affected by the onset of the dry season since they do not depend on regular flooding.	medium
2		Water levels are higher or lower than natural	This group of grazers will benefit from water level higher than natural because that will ensure that the outer elevated floodplains also get flooded leading to improved forage productivity in those otherwise dry areas.	medium
3		Extends longer than natural	Extended dry season will not affect this group of grazers since they do not depend directly on flooding.	medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	This group of grazers will not be affected by the onset of the flooding season since they do not depend on regular flooding. As long as there is drinking water either in the floodplain residual pools or in the channel, they will be fine	medium
7		Natural proportion of different types of flood year changed	If the flooding season is longer than natural, this is likely to benefit this group of grazers because such can only happen in years of very high floods. Under such circumstances the outer floodplains will afford to get flooded leading to better quality of forage.	medium

5.3.4 Indicator 5 (Lower floodplain grazers)

Table 5. 5: Predicted response to possible in the flow regime of Lower floodplain grazers in the Okavango River Ecosystem

Question number	Season	Possible flow change	Response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	This group of floodplain grazers will not be affected in any way by early floods, but are likely to be affected by late floods. Late floods would deprive species such as lechwe of the much needed flooded lower floodplains which they use as escape routes when predators charge.	medium
2		Water levels are higher or lower than natural	Water level which are higher than natural are unlikely to affect this group of grazers negatively but water levels which are lower than natural will lead to loss of floodplain ecosystems., much to the detriment of lower floodplain grazers/ Their population will decline under such circumstances.	medium
3		Extends longer than natural	An extended dry season would mean floodplains remain unflooded for a long period of time meaning that semi aquatic antelopes which use lower floodplains will lose their preferred habitat, thus exposing them to predators.	medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	An early onset will be of benefit to lower floodplain grazers especially if that follows a year of lower floods. Late floods would negatively affect the habitats of the semi aquatic antelopes	medium
7		Natural proportion of different types of flood year changed	If the flood season is longer than normal, semi aquatic antelopes will benefit since such circumstances will lead to improved habitats..	medium

5.4 Conclusion

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APPENDIX A: FULL DESCRIPTIONS OF INDICATORS

Habitat	Indicator/ habitat type	Major wildlife	Flow requirement and major ecological role
Semi Aquatic Wildlife **Frogs, river snakes**	**Open water** – flowing deep and permanent channel flanked predominantly by papyrus and phragmites reeds	Hippopotamus, crocodile and other aquatic reptiles, cape clawless otter, aquatic birds.	Requires deep permanently flowing water and permanently moist vegetated channels margins for breeding, protection from high temperatures and predators, and foraging
	Permanent swamps - areas permanently inundated with rooted emergent plants, submerged plants and floating leafed plants, with margins or tree line dominated by riparian woodlands.	Hippopotamus, crocodile, water monitor lizard, otters, terrapins, aquatic birds (wattle crane) and aquatic antelopes (reedbuck, lechwe, sitatunga, waterbuck)	Requires permanently slow flowing water with depth varying seasonally. Vegetation provides protection and breeding sites. Emergent, floating and submerged vegetation also provides food to various forms of wildlife.
Lower floodplain grazers	i). **Primary floodplains / Lower floodplains** – low lying floodplains which are the first to receive flood water from the outlet channels in seasonal swamps, and are the last to recede. Domintated by sedges, aquatic grasses and aquatic forbs. Depth and duration of flooding to vary depending on the annual rainfall intensity and the annual inflow at Mohembo.	Aquatic reptiles (crocodiles and water monitor lizards), Floodplain grazers which include hippopotamus, lechwe, reedbuck, elephants, and in some cases buffalo and zebras have been observed grazing in water	Requires seasonal flooding for a period of 4-6 months in years of low flooding intensity and 6 -12 months in years of high rainfall and high flooding intensity. Key fall back area for all herbivores when the floods recede from July to October. Provides green and highly nutritious forage during the dry season when everything else in the nearby savannas is dry and of low quality.

Middle/Upper floodplain grazers	ii). **Secondary floodplains/Upper floodplains –** higher lying floodplains of grasslands elevated above the primary floodplains by up to 1m. Dominated by semi-aquatic grasses. Composition varies in accordance with accordance with flooding frequency, duration and grazing intensity.	Large mammalian floodplain grazers mainly impala, lechwe, wildebeest, zebra, tsessebe, buffalo, warthog, elephants, small mammals, and amphibians	Requires seasonal flooding for a period of 2-6 months in years of low flooding intensity and 4 -8 months in years of high rainfall and high flooding intensity. Provide forage for all grazers of the Okavango Delta during the dry season, after the floods recede. Availability and accessibility of secondary floodplain grasslands determine the amount of wildlife found in the adjacent woodlands.
Outer floodplain grazers	iii). **Tertiary floodplains and Island grasslands** – highest lying islands and grasslands which only flood in years of extremely high floods, and flood for a very short period of time if they ever flooded.	The smaller islands grasslands dominated by *Sporobolus sp*. are predominantly grazed by hippopotamus, lechwe, impala and warthog.	Provide grazing and resting places for floodplain grazers. Smaller islands surrounded by active floodplains require horizontal below ground flows to raise the ground water table. Larger islands with a higher diversity of grasses and forbs are grazed by most large grazers of the Okavango Delta in periods of high floods.

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 Trans-boundary 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)*
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Environmental protection and sustainable management of the Okavango River Basin

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