Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Environmental Flow Assessment EFA Process Report Report No: 02/2009

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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
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Report 07/2009:	Scenario Report: Ecological and social predictions (3 Volumes)
Report 08/2009:	Final Project Report

Other deliverables:
DSS Software
Process Management Team PowerPoint Presentations

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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 2 in the report series for the EFA. It outlines the process used for the assessment, including the sequence of team activities from field visits to specialist reports; the workshops and meetings at key points of the process, and the Decision Support System used to capture knowledge and produce predictions of development-driven change to the river ecosystem and its users.

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Acronyms and abbreviations

DWAF	Department of Water Affairs and Forestry
EFA	Environmental Flow Assessment
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
Ha	hectare
HOORC	Harry Oppenheimer Okavango Research Centre
IUA	Integrated Units of Analysis
PD	Present Day
SAP	Strategic Action Programme
TDA	Transboundary Diagnostic Analysis

1. Introduction

1.1. Project background

The origin of the project is described in Report 01/2009: Project Initiation Report. Essentially, the project was an initiative of OKACOM, the Okavango River Basin Commission. Titled the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) project, it was approved by the United Nations Development Program (UNDP), to be executed by the United Nations Food and Agriculture Organization (FAO). The long-term objective of the EPSMO Project was to achieve global environmental benefits through concerted management of the naturally integrated land and water resources of the Okavango River Basin.

The project would follow a standard process used by all GEF funded International Waters projects: an objective assessment - the Transboundary Diagnostic Analysis (TDA) – followed by the development of a Strategic Action Programme (SAP) of joint management to address threats to the basin's linked land and water systems. The SAP would package initiatives that address issues raised by the TDA and would aim to overcome barriers to regional co-operation and thus help ensure that development of the basin would be sustainable and equitable. In the case of the Okavango Basin, the traditional approach, designed for rehabilitating degraded rivers, would have to be modified because of the near-pristine nature of the river ecosystem. It was suggested that this be done by incorporating an Environmental Flows Assessment as a major part of the TDA.

In 2008 EPSMO therefore collaborated with the BIOKAVANGO Project at the Harry Oppenheimer Okavango Research Centre (HOORC) of the University of Botswana, to jointly conduct a preliminary basin-wide Environmental Flows Assessment (EFA) for the Okavango River system.

1.2. Objectives of the EF assessment

There were two main objectives.

- Complete a basin-wide EFA of the Okavango River system as a major part of the wider Technical Diagnostic Analysis. This would be done through several subsidiary objectives:
    - Collate all existing hydrological data on the river system and set up a basin hydrological model that could simulate flows under various possible future development scenarios
    - Reach agreement with the three riparian governments on the scenarios to be explored
    - Bring together specialists in a range of relevant disciplines from across the basin to share knowledge and data, and reach consensus on the:
        - relationships between flow and a series of biophysical indicators of the river system
        - relationships of the condition of the ecosystem and social indicators

  - Develop a DSS that would capture these relationships and produce predictions of ecological and social change for each scenario that would complement the macroeconomic predictions emanating from a separate exercise
  - Incorporate the EFA findings in the TDA document.
- Promote basin-wide communication and collaboration, and build capacity in collaborative basin-wide Integrated Water Resource Management in all disciplines in all three countries. This was done by appointing a full biophysical and socio-economic team from each of the three countries, with planning, coordination and training done by a Process Management Team.

1.3. Layout of the report

Chapter 2 outlines the EF process adopted for this EPSMO-Biokavango project, and the sites and indicators chosen. Chapter 3 introduces the team and Chapter 4 describes the timing and purpose of the main activities. In Chapter 5 the work done by the specialists is outlined, which culminated in their specialist discipline reports. Finally, Chapter 6 describes the Decision Support System (DSS) built for and used in the EF process to produce predictions of potential development-driven ecological and social change. This is an early report in the report series and outlines several activities documented in more detail in later reports.

2. Outline of the EPSMO/BIOKAVANGO EF process

The basic workplan for the EPSMO/BIOKAVANGO EF process was as follows:

1. Divide the basin into homogeneous units and select representative sites.
2. Set up basin hydrological and hydraulic models and describe Present Day hydrology/hydraulics for each site.
3. Divide the flow regime into ecologically-relevant flow categories and produce summary statistics for each.
4. Visit sites and set up data collection programmes.
5. Select indicators and collect data as appropriate.
6. Develop three scenarios of future water use for assessment.
7. Analyse data, review world literature and write specialist reports.
8. Capture knowledge in the form of flow-indicator Response Curves.
9. Set up the Okavango EF DSS and populate with the Response Curves.
10. Use the DSS to predict the ecological and socioeconomic outcomes of the chosen water-use development scenarios.

The EF team comprised (see Section 3):

- The Project Manager and Team Coordinators for each of Angola, Namibia and Botswana.
- An international process team.
- Hydrological, biophysical and social specialists from each country.
- Support staff for, for instance, GIS.

The process team was responsible for coordination of the process, review of the specialist reports, set up and population of the DSS and presentation of the scenario outcomes. In a series of team meetings and other activities (Table 2.1 and Section 4), the hydrological team developed a basin hydrological model and prepared for scenarios; the biophysical team identified biophysical indicators and sought for links with flow through field work, data analysis and literature reviews; and the social team identified social indicators and the links with the biophysical indicators. Country leaders coordinated the specialist activities within each of the countries, including field data collection and report writing.

Table 2.1 Meetings and other team activities in the EF process

Date	Meeting	Location
July 2008	Planning Meeting	Pretoria, South Africa
September 2008	Delineation Workshop	Maun, Botswana
October 2008	Field trip to each of the eight EF sites	Angola, Namibia, Botswana
November 2008	EPSMO Project meeting and OBSC planning meeting for TDA and SAP	Maun, Botswana
December 2008	Hydrological Model Familiarisation and Training	Maun, Botswana
January 2009	Basin Hydrological Modelling	Maun, Botswana
March/April 2009	Knowledge Capture Workshop	Windhoek, Namibia
April 2009	Okavango Delta Modelling Workshop	Gaborone, Botswana
June 2009	Scenario Workshop	Cape Town, South Africa
August 2009	EF output incorporated into TDA document	Gobabeb, Namibia

2.1. Division of the basin into homogeneous units and selection of representative sites

Scenarios cannot address every part of the basin of concern, and instead routinely use the concept of representative sites. These are locations that, through a process of analysis, are deemed to be characteristic of relatively homogeneous lengths of river or areas of the basin. Data collection may focus on these sites, and the predictions of change are made for them and then extrapolated to the full river length or basin area that they represent.

For the EPSMO/BIOKAVANGO EF, eight representative sites were selected in a basin delineation exercise (Report 04 Basin Delineation) (Table 2.2), each of which corresponded to a wider, socio-economic Integrated Unit of Analysis (IUA; Figure 2.1).

The details of the delineation are provided in Report No. 03/2009: Basin Delineation Report.

Table 2.2 The Environmental Flow (EF) sites

EF Site	EF Site name	Country
1	Cuebe River @ Capico	Angola
2	Cubango River @ Mucundi	Angola
3	Cuito River @ Cuito Cuanavale	Angola
4	Okavango River @ Kapako	Namibia
5	Okavango River @ Popa Falls	Namibia
6	Okavango River @ Panhandle	Botswana
7	Okavango Delta @ Xaxanaka	Botswana
8	Boteti River	Botswana

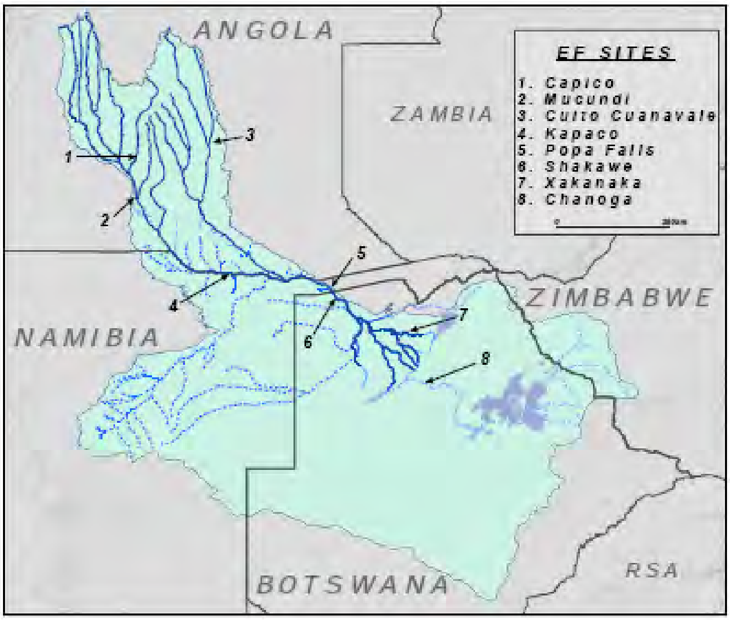


Figure 2.1 The EF sites and their corresponding socio-economic Integrated Units of Analysis (IUAs).

2.2. Set up of basin hydrological and hydraulic models and description of the present hydrology/hydraulics for each site.

A series of hydrological and hydraulic models have in the past been developed to reproduce flow conditions observed in the Okavango Basin and Delta. In order to provide the hydrological information required for the EFA, a suite of existing and new models were used. The models were selected and configured to provide current day (baseline) and scenario flow sequences at the eight EFA sites.

The models which were selected for use in the EFA are:

- **Catchment hydrology:** Estimates of naturalised (undeveloped) long-term runoff were obtained from an existing Pitman-based rainfall-runoff model developed as part of the EU funded WERRD project (Hughes *et. al.* 2006). The model was configured to provide runoff sequences at the outlets of 24 distinct sub-catchments upstream of the Delta.
- **Systems Model:** As part of this project, the monthly time-step WEAP systems model was selected and used to configure a reference (Present Day), Low, Medium and High Development scenarios. Inputs to the model include the undeveloped runoff sequences for 24 sub-catchments produced by the Pitman model, irrigation scheme and urban abstractions, in channel dams for irrigation water supply, inter-basin transfers, run-of-river and storage based hydropower schemes.
- **HOORC Delta Model:** A semi-conceptual model which was previously developed by the Harry Oppenheimer Okavango Research Centre (HOORC) (Wolski et. al. 2006) was used to model inundation frequencies and extents at the Delta EFA sites. The model operates on a monthly time step and includes a dynamic ecotope model that simulates the responses of vegetation assemblages to changes in hydrological conditions. Scenario inflows to the model are provided by the WEAP simulations of basin runoff.
- **DWA Delta Model:** A MIKE-SHE / MIKE 11 hydrodynamic model which was previously configured by Botswana DWA and DHI for the Okavango Delta Management (ODMP) project (IHM Report, 2005) was used to model flow velocities and depths at the Delta EF sites. Scenario flow sequences simulated with WEAP for Mohembo were used as inflow sequences for the Delta model, after disaggregating the monthly flow sequences to a daily time step.
- **Thamalakane/Boteti Model:** Delta outflows simulated by the HOORC model are routed along the Thamalakane/Boteti system with a linear reservoir spreadsheet model (Mazvimavi, 2008) to derive scenario flow sequences at the Boteti EF site. The model was incorporated into the HOORC Delta Model and improved to provide estimates of wetted river length and state changes of the system.
- **Disaggregation and Hydro-Statistics:** A custom utility was developed to disaggregate the simulated monthly WEAP flow sequences to daily flow sequences, to delineate flow seasons (dry, wet and transition) for each year of the 43 year long sequences, and to calculate ecologically relevant flow statistics (“flow categories”).

2.3. Division of the flow regime into ecologically-relevant summary statistics

One of the main assumptions underlying the EPSMO/BIOKAVANGO EF process is that it is possible to identify ecologically relevant elements of the flow regime and isolate them from the historical hydrological record (after King *et al*. 2003). Thus, one of the first steps in the process was for the country specialists to identify these ecologically important flow categories for the Okavango River.

The identification of such flow categories was started at the Preparation Meeting in Maun in September 2008 (Section 4.1) and finalized in discussion with the hydrological team once they had collected and synthesized the required hydrological data for the study.

On the basis of these discussions, the flow regime for the river sites (EF Sites 1-6) was divided into four seasons (Figure 2.2), *viz*. dry season; transition season 1; wet season and transition season 2 using the following rules (after Adamson 2006):

End of Dry Season:	2 to 6 x minimum dry-season discharge (site specific)
End of Transition 1:	First upcrossing of mean annual discharge
End of Flood Season:	Last downcrossing of mean annual discharge
End of Transition 2:	Recession rate over 15 days < 1.0 to 1.2 m^3s^{-1} day^{-1} (site specific) OR downcrossing of Dry season threshold.

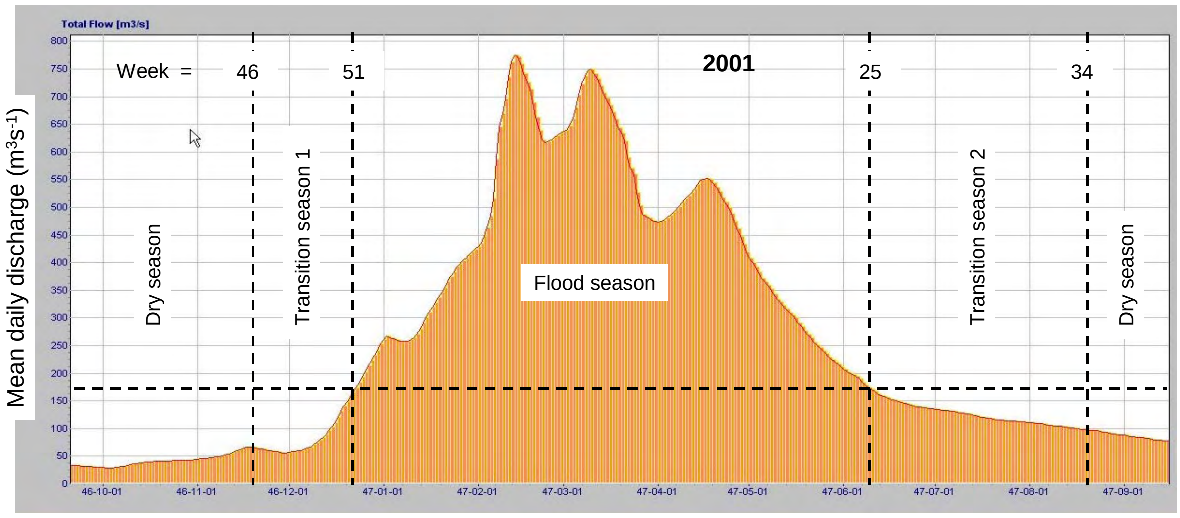


Figure 2.2 Example of seasonal division used: EF Site 4: Kapako 2001

From these eight flow categories were selected:

1. Annual dry- season onset by calendar week number
2. Annual dry-season minimum 5-day discharge in m^3s^{-1}
3. Annual dry-season duration in days
4. Annual flood-season onset by calendar week number
5. Annual flood-season 5-day peak discharge in m^3s^{-1}

6. Annual flood-season volume in MCMAnnual flood-season duration in daysAnnual transition 2: rate of decline.

Flow categories 5 and 6 were combined to create a single statistic called 'Flood Type'. At each site, flood types from 0 – 5 were identified on the basis oftheir peak discharge, their volume and, where applicable, the extent to which they inundated the associated floodplain. For instance, for EF site 4: Kapako, the following flood types were identified from the observed hydrological record (Figure 2.3):

Flood Type 0:	Drought years, no inundation of the floodplain.
Flood Type 1:	Very low peak and volume; 60% inundation of the floodplain.
Flood Type 2:	Low peak and volume; 70% inundation of the floodplain.
Flood Type 3:	Moderate peak and volume; 80% inundation of the floodplain.
Flood Type 4:	High peak and volume; 90% inundation of the floodplain.
Flood Type 5:	Very high peak and volume; 100% inundation of the floodplain.

Flow category 8: Transition 2: rate of decline was later discarded because it proved to be an unreliable statistic.

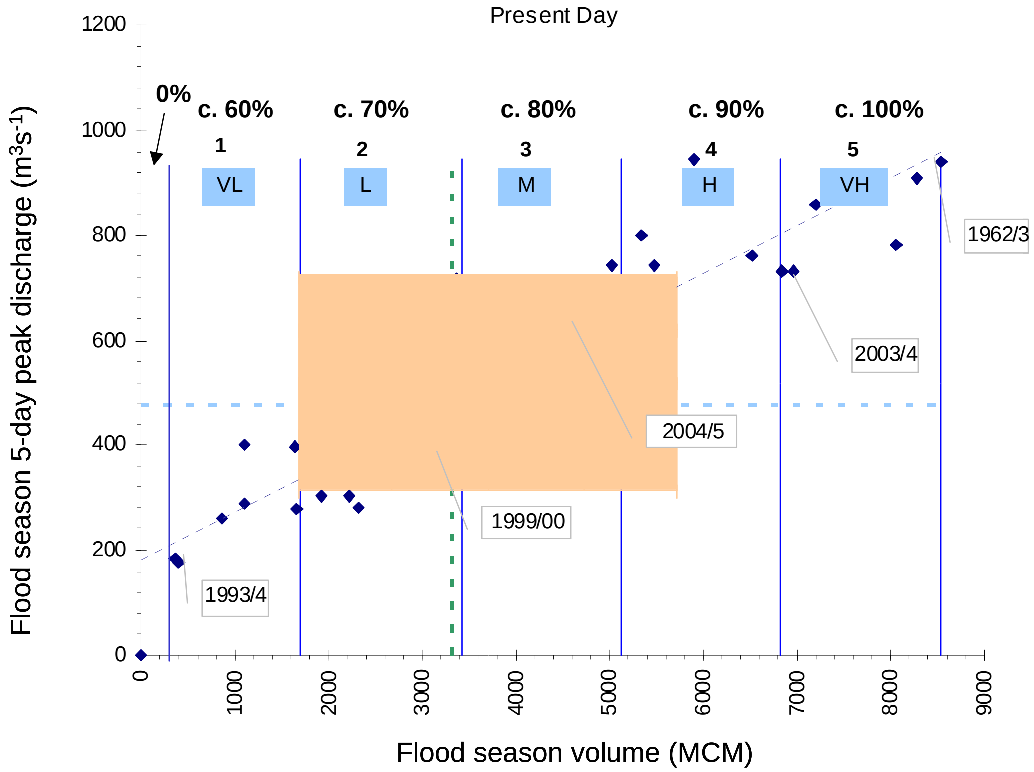


Figure 2.3 **Floods recorded over 43 years at EF Site 4: Kapako. The flood type is indicated**

The flow categories were used to translate daily-flow time series into ecological summary statistics for each year of record. This was done by moving through the time series and, for each year, sequentially recording the week of onset of the dry season, followed by minimum 5-day discharge of the dry season, followed by duration of dry season, followed by week of onset of the flood season, the flood type and the duration of the flood season (Figure 2.4).

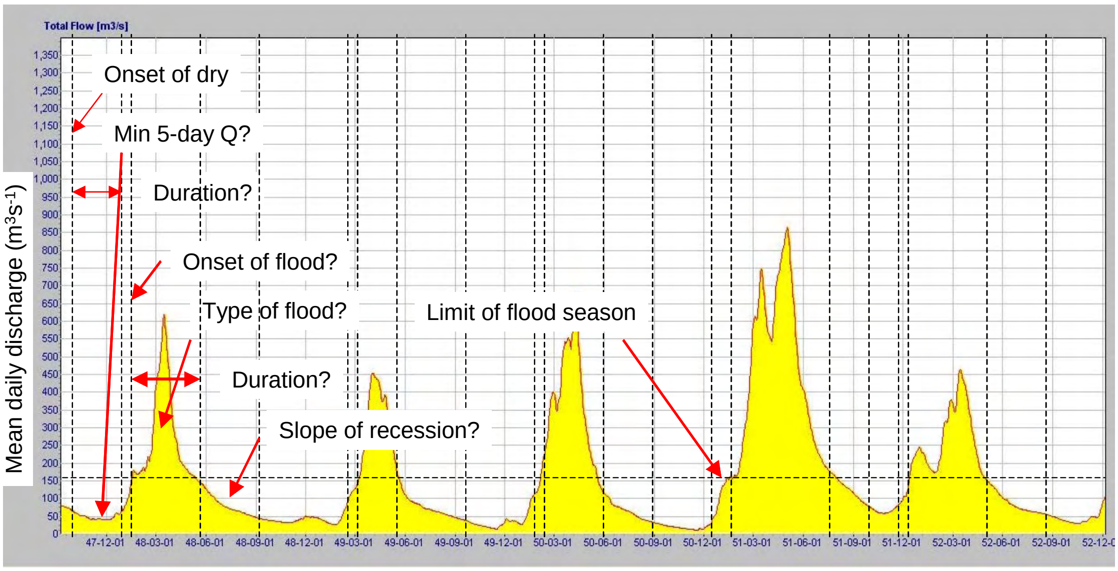


Figure 2.4 Ecological summary statistics extracted from the daily hydrological time series

The details for the selection of flow categories and calculation of the summary statistics are provided in Report 05/2009: Hydrology Report: Data and models.

2.3.1 EF Site 7: Xaxanaka and EF Site 8: Boteti

For EF Site 7: Xaxanaka and Site 8: Boteti, the processes used to assess flow changes were different from that used of the river sites. This was because hydrological time series data are not particularly useful indicators of actual conditions at these two sites. A dynamic ecotope model was developed in order to classify hydrological conditions in terms of hydro-ecological functionality. The model is based on assumption that vegetation assemblages observed at any given site change in response to varying hydrological conditions represented by duration of inundation. Vegetation is captured using four functional classes: aquatics, sedges, grasses and savanna (or permanent swamp vegetation, primary floodplains, secondary floodplains and dry floodplains). Channels, lagoons and floodplain pools were determined as a percentage of the main hydro-ecological classes. This was used for site 7.

For EF Site 8: A model representing the Boteti River between Maun and Mopipi as a quasi-linear reservoir was developed. The model consistes of a surface water reservoir and a series of 5 independent groundwater reservoirs each representing groundwater at a reach of the river. The groundwater reservoirs are recharged from the surface water reservoir, and the recharge occurs only to these reservoirs which represent currently inundated reach of the river. Boteti flow changes were assessed using changes in inundation categories for the 200-km stretch of the Boteti. The categories used were:

- inundated, i.e., flowing
- isolated pools
- dry.

The details of the modelling for Sites 7 and 8 are provided in Report 05/2009: Hydrology Report: Data and models.

2.4. Sites visits and initial data collection

In October 2008, the process team (King, Brown, Beuster and Barnes) undertook a 17-day trip through the Okavango Basin (Table 2.3). In each country, the hydrological, biophysical and social specialists representing that country accompanied them. The trip had the following objectives:

1. To familiarise the process and national teams with the study area, in general, and the characteristics of the study sites in particular.
2. To visit the hydrological gauging stations used in the study.
3. To allow for team and discipline-specific discussion of EF data requirements and data collection techniques.
4. To collect data.
5. To undertake a habitat integrity assessment (Kleynhans 1996) for each of the EF sites.

Table 2.3 Itinerary for familiarisation and initial data collection trip to the Okavango Basin

Date	Day	Activity
10 October 2008	Friday	Travel to Maun
11 October 2008	Saturday	Travel: Maun-Popa Falls
12 October 2008	Sunday	Travel: Popa Falls - Rundu
13 October 2008	Monday	Travel: Rundu - Menongue
14 October 2008	Tuesday	Data collection: EF Site 3 – Cuito Cuanavale
15 October 2008	Wednesday	Data collection: EF Site 1 – Cuebe/Capico
16 October 2008	Thursday	Data collection: EF Site 2 - Mucundi
17 October 2008	Friday	Travel to Namibia
18 October 2008	Saturday	Namibia
19 October 2008	Sunday	Sunday - Day of rest
20 October 2008	Monday	Data collection: EF Site 4 – Kapako
21 October 2008	Tuesday	Data collection: EF Site 5 – Popa
22 October 2008	Wednesday	Travel: Popa - Panhandle
23 October 2008	Thursday	Data collection: EF Site 6 – Panhandle
24 October 2008	Friday	Data collection: EF Site 7 – Xaxanaka
25 October 2008	Saturday	Data collection: EF Site 8 – Boteti
26 October 2008	Sunday	Travel home

2.5. Selection of indicators and further data collection

For each biophysical and social discipline, the specialists identified the aspects of the river ecosystem for which flow-related change were predicted, known as indicators. These are items that respond to a change in river flow by changing in their:

- abundance;
- concentration;
- extent (area); or
- cover (vegetation only).

The indicators were chosen discipline by discipline, through an iterative process with all members of that discipline. The process team required that no more than ten indicators be chosen per discipline per site, although the overall number of indicators per discipline could be more than that. Each discipline had a leader who coordinated discussion among discipline team members and produced the final indicator list.

2.5.1 Biophysical indicators

The discipline-specific biophysical indicators chosen for the EPSMO/BIOKAVANGO EF process are listed in Table 2.4.

Table 2.4 Biophysical indicators used in the EPSMO/BIOKAVANGO EF process

Discipline	Sites	Indicators used
Geomorphology	1-6	Extent - exposed rocky habitat
		Extent - coarse sediments
		Cross-sectional area of channel
		Extent of backwaters
		Extent of vegetated islands
		Sand bars at low flow
		Percentage clays on floodplain
		Extent of inundated floodplain
		Inundated pools and pans
		Extent of cut banks
	7	Carbon sequestration
Water Quality	1-8	pH
		Conductivity
		Temperature
		Turbidity
		Dissolved oxygen
		Total nitrogen
		Total phosphorus
		Chlorophyll a
Vegetation	1-6	Channel macrophytes
		Lower Wet Bank (hippo grass, papyrus)
		Upper Wet Bank 1 (reeds)
		Upper Wet Bank 2 (tree, shrubs)
		River Dry Bank
		Floodplain Dry Bank
		Floodplain Residual Pools
		Lower floodplain
		Middle floodplain (grasses)
		Upper floodplain (trees, *rhus*)
	7	Open waters
		Permanent swamps
		Lower floodplain
		Upper floodplain
		Occasionally flooded grassland
		Sporobolus Islands
		Riparian woodland, trees
		Savanna and scrub
	8	Open water
		Riparian woodland, trees
		Wet bank
Macroinvertebrates	1-8	Channel: submerged vegetation
		Channel: marginal vegetation
		Channel: fine sediments
		Channel: cobbles, boulders
		Channel: rapid, fast flowing
		Channel: pools
		Floodplain: marginal vegetation

Discipline	Sites	Indicators used
		Floodplain: pools, backwaters
	Plus for 7	*Mopane* woodland: pools
Fish	1-8	Fish resident in river
		Migrating to floodplain: small fish
		Migrating to floodplain: large fish
		Sandbank dweller
		Rock dweller
		Marginal vegetation dweller
		Backwater dweller
Wildlife	1-8	Semi Aquatics (hippos, crocodiles)
		Frogs, river snakes
		Lower floodplain grazers
		Middle floodplain grazers
		Outer floodplain grazers
Birds	1-8	Piscivores: open water
		Piscivores: shallow water
		Piscivores: and invertebrate feeders
		Specialists: floodplains
		Specialists: water lilies
		Specialists: fruit trees
		Breeders: reedbeds and floodplains
		Breeders: overhanging trees
		Breeders: banks
		Breeders: rocks, sandbars

2.5.2 Social indicators

Social indicators were used that responded to changes in river condition, such as household incomes from reeds, fish and tourism; potable water; and wellbeing.

2.6. Development of scenarios of future water use

The water-use scenarios assessed in the EPSMO/BIOKAVANGO EF process are simply ways of exploring possible management options. None of the scenarios, as laid out in this study, will necessarily happen but they can inform negotiations on cooperative basin development. The scenarios were chosen through an iterative process of discussion between project staff, OKACOM and government representatives. The most important of these meetings took place in Maun in November 2008 when two major decisions were made:

1. The scenarios would be development-based rather than sector-based. In other words they would explore a progressive growth in water use through various kinds of development, rather than exploring the implications of maximising basin-wide hydropower generation or basin-wide irrigated crops.
2. The scenarios would represent three levels of potential water use in the basin: Low, Medium and High. The Low water-use scenario would equate approximately to the three countries' present short-term (i.e. 5-7 years) national plans. The Medium water-use scenario would reflect possible medium term (approx 10-15 years) national plans, and the High water-use scenario possible long-term (>20 year) plans.

It was also decided that the major water uses to be included in the scenarios would be hydropower generation; agriculture, including irrigated crops and livestock; mining and industrial; human demographics including urban growth and tourism; and inter-basin transfers.

The details of where to place individual potential developments within the basin hydrological model was done by the hydrological team after consultations within their respective countries. Such a placement does not imply that the development will happen or, if it happens, that it will be in the location indicated in the model. Modification of the site of a development, or its design or operating rules, could affect the consequent flow regime and thus the predicted ecological and social impacts.

The creation of a DSS for this project addresses this problem, by enabling many permutations of development projects to be explored in terms of their ecological and social impacts, not just the three created in the project.

2.7. Specialist reports

In parallel with the discussions on scenarios, the specialists reviewed relevant international literature, completed additional visits to the EF sites and analysed any available data to glean relationships between their indicators and the flow/inundation regime. Each contracted specialist then wrote a report, using a template provided by the process team. The purpose of the reports was five-fold.

- To acquaint the specialists with what was essentially for almost all of them a new topic and a new way of collecting and analysing their data.
- To help them develop a mindset that would allow them to create a realistic list of indicators and analyse the relationship of each indicator to flow.
- To prepare them for the Knowledge Capture Workshop (Section 4.2) where they would create Response Curves (next section) that captured their best understanding of the indicator-flow relationships.
- To prepare them for the Scenario Workshop (Section 4.4) where they would assess the prediction of impacts of the scenarios created by the DSS using their Response Curves, and modified these predictions if necessary.
- To provide a permanent record of the present state of knowledge of the ecological and social aspects of the Okavango River system.

The reports were submitted as drafts prior to the Knowledge Capture Workshop, reviewed by the process team at that stage, revised after the Knowledge Capture and Scenario Workshops, and submitted as final specialist reports in June 2009. They were not reviewed again at the final submission. The Angolan biophysical reports were reviewed by an outside bilingual scientist, Dr Sharon Pollard, who also wrote short summaries of each for use in compiling the TDA Report.

2.8. Knowledge capture and the construction of Response Curves

Response Curves are a means of capturing information and understanding, from in-depth scientific data through international and national knowledge to local wisdom. They are created by EF specialists with a working knowledge of the river ecosystem and its users; are graphic and explicit with supporting explanations; and are amenable to adjustment as knowledge increases.

In the EPSMO/BIOKAVANGO EF process, the biophysical and social specialists created Response Curves for each of their indicators at the week-long Knowledge Capture Workshop (Section 4.2).

The starting point of a response curve is Present Day (PD) flow conditions, which equate to zero value for the indicator. Thus, in Figure 2.5, the circle represents PD median dry season

5-day minimum discharge (30 m^3 s^{-1}), and the value of the indicator under PD conditions, which would be zero (0). A Response Curve is always zero at Present Day conditions. Other information was also provided to assist the specialists, such as the standard deviation in a flow category over the historical (present-day) record, and its historical full range of values (Figure 2.5).

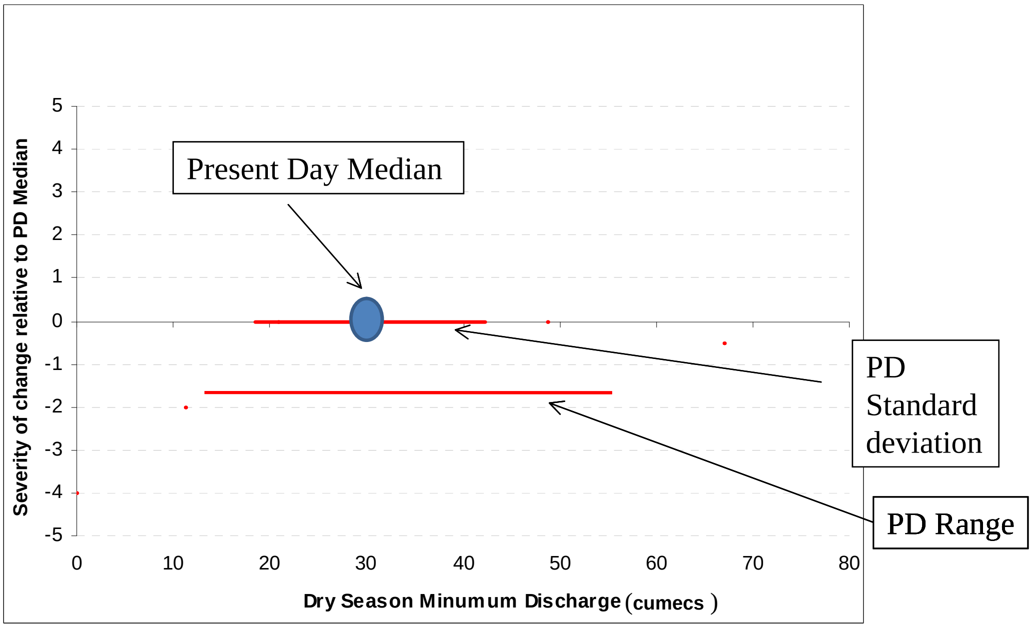


Figure 2.5 Example of a Response Curve template – minimum dry-season flows in a year

Response Curves were created by the specialists at the Knowledge Capture Workshop using the DSS Data Entry files, which provided them with, among other things, the opportunity to assess how each indicator could change with time. They used this to calibrate the present-day situation for that indicator (Figure 2.6).

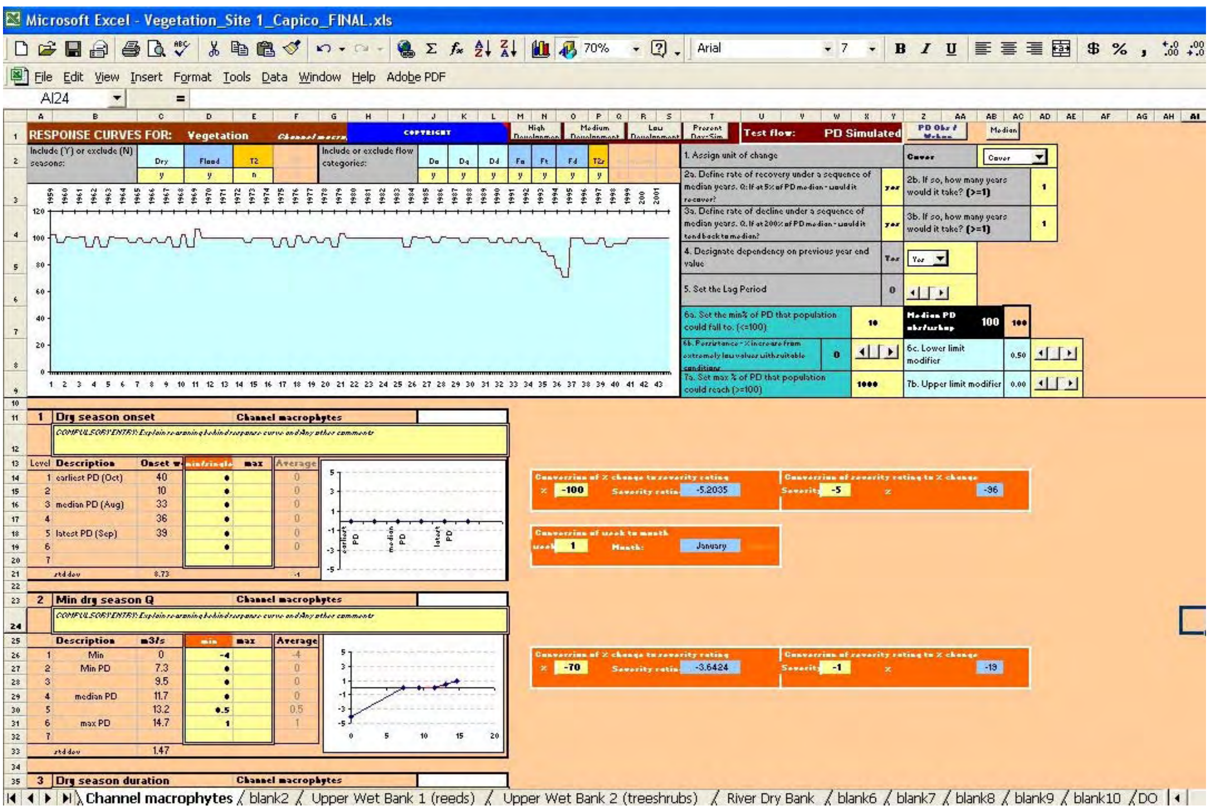


Figure 2.6 Example of an indicator data entry sheet in the Okavango-DSS

The specialists followed a 13-step process:

Step 1. Assign unit of change (eg. abundance - for animals, area – for sandbank, and so on)

Step 2. Define rate of recovery under a sequence of median years

Step 3. Define rate of decline under a sequence of median years

Step 4. Designate dependency on previous year end value

Step 5. Set the Lag Period

Step 6. Select relevant seasons

Step 7. Select relevant flow categories within selected season(s)

Step 8. Complete the Response Curves for the selected flow categories

Step 9. Test extreme drought flow regime:

Step 10. Test extreme wet flow regime

Step 11. Test Present Day (observed) flow regime

Step 12. If further adjustment still required, return to Step 9, and repeat

Step 13. Move to next indicator and repeat Steps 1-12.

The predicted severity of the response of an indicator to a change level of a given flow category was rated on a scale of 0-5, using a standard format (after King *et al*. 2003), as described in Table 2.5. In the construction of a Response Curve, the impact on an indicator of change in any one flow category was considered in isolation, that is, as if only that category would change and the rest of the flow regime would stay at Present Day levels. This was important because sometimes two or more categories of flow can fulfill a similar function. For instance, both small and big floods may move sediment, but big floods may move more. Thus a loss of big floods will not mean that no sediment is moved, only that much less is moved. Similarly, a loss of small floods may not greatly affect sediment movement.

Table 2.5 Severity ratings used to construct Response Curves (after King *et al.* 2003)

Severity rating	Severity of change	Equivalent loss (abundance retained)	Equivalent gain
0	None	No change	No change
1	Negligible	80-100% retained	1-25% gain
2	Low	60-79% retained	26-67% gain
3	Moderate	40-59% retained	68-250% gain
4	Large	20-39% retained	251-500% gain
5	Very large	0-19% retained	501% gain to up to pest proportions

An example of a completed Response Curve is shown in Figure 2.7. In total the specialists created approximately 3000 Response Curves (e.g., 8 sites x 8 disciplines x 8 indicators x 6 flow categories = 3072 Response Curves), which were stored in the custom-built Decision Support System.

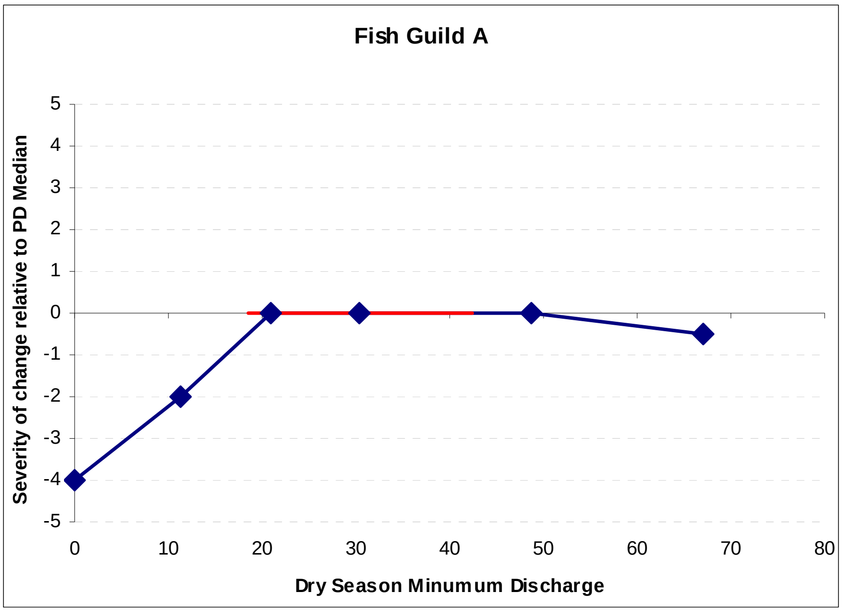


Figure 2.7 Example of a Response Curve – the response of one indicator to minimum dry-season flows in a year

2.9. Set up and population of the Okavango EF DSS

A more detailed description of the DSS is provided in Chapter 6.

The Okavango EF DSS is arranged hierarchically. The main folder (1 OKAVANGO DSS) contains nine subfolders and a file (*Okavango Scenario Interface.xls*), which is the summary and information processing file. The nine subfolders consist of a Hydrology folder and a folder for each site (e.g. SITE 2 Mucundi).

The site folders each contain nine files. Eight of these are data entry files: one for each biophysical discipline (geomorphology, water quality, vegetation, invertebrates, fish, wildlife, birds) and one for socio-economics. Data entry files are named according to a strict naming convention by site number, site name, discipline, followed by 'FINAL' e.g. *Wildlife Site 2_Mucundi_FINAL.xls*. The ninth file is a site summary file (e.g. *SITE 2 Mucundi Summary.xls*).

The Hydrology folder contains nine files: one hydrological file for each site (e.g. *Site 2 Mucundi hydro.xls*) and one (*Input hydrology.xls*), which includes summary information for all sites.

Information is linked from the files in the Hydrology folder to relevant data entry file for each discipline at each site. The site summary files gather the information together from the different disciplines and provide the relevant biophysical information to the socio-economics data entry file. All of the information contained in the Site summary files is also passed to the main file *Okavango Scenario Interface.xls*.

The file *Okavango Scenario Interface.xls* therefore gathers together all information from all sites and disciplines and provides various summaries by discipline and by site.

The specialists can enter data within their site level discipline file and view the effects of different scenarios on their chosen indicators.

Scenarios can also be run and operated from the site summary file for that site and from *Okavango Scenario Interface.xls* for all sites.

2.10. Prediction of the ecological and socioeconomic outcomes of chosen water-use scenarios

Once steps 1-9 of the EPSMO/BIOKAVANGO EF process had been completed, the calibrated DSS was used to predict of the ecological and socioeconomic outcomes of chosen water-use scenarios (Figure 2.8). In the DSS, for any one scenario, the expected daily flows were simulated for each EF site for a 42-year period. These were then analysed to produce a set of annual ecological flow statistics, e.g., dry season onset, flood season duration, and so on. The Response Curves were then used to describe a time series of the response of each indicator to the simulated flow changes (Figure 2.9), which was then summarized for the whole flow regime and for all indicators to provide summary responses by discipline and for the ecosystem as a whole. These were then used, again via the social Response Curves, to describe the social responses. The outputs may be linked with the macroeconomic analysis of each scenario (which is part of the wider TDA process) to provide the TRIPLE BOTTOM LINE for each scenario (Figure 2.8).

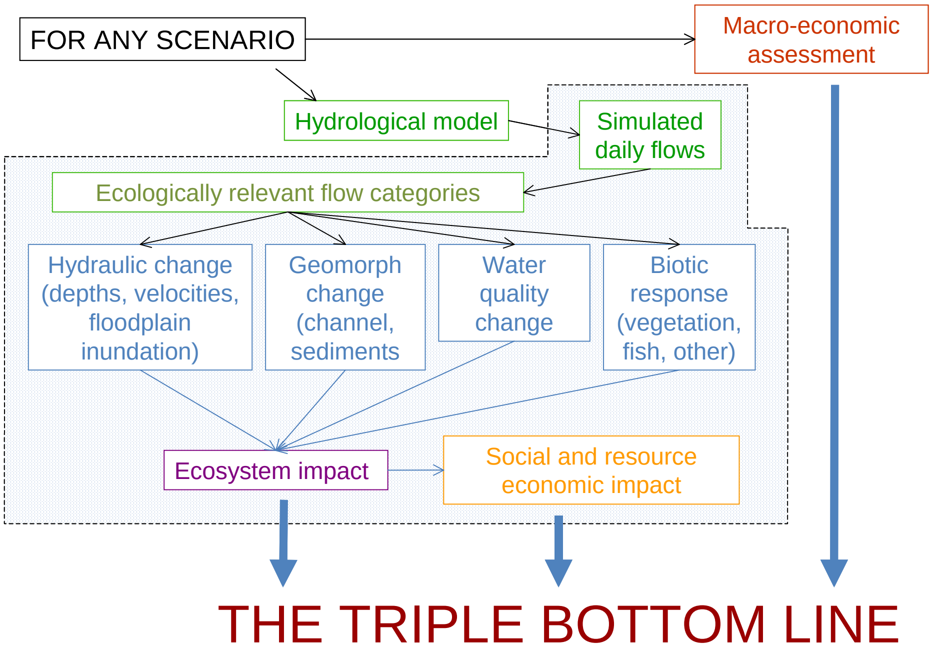


Figure 2.8 Process for assessing responses to flow changes for any scenario. The dotted line represents procedures within the DSS.

Thus, the output of the DSS comprises the following:

- Time series of abundance/concentration/area/cover of each indicator for each scenario flow regime at each site.
- Time series of household income, well-being and other social indicators for each scenario flow regime at each site.
- Mean values of each of the above for each time series (end point for a scenario after 42 years).
- Discipline integrity for each site/scenario after 42 years.
- Ecosystem integrity for each site/scenario after 42 years.
- Social integrity for each socio-economic zone /scenarios after 42 years.

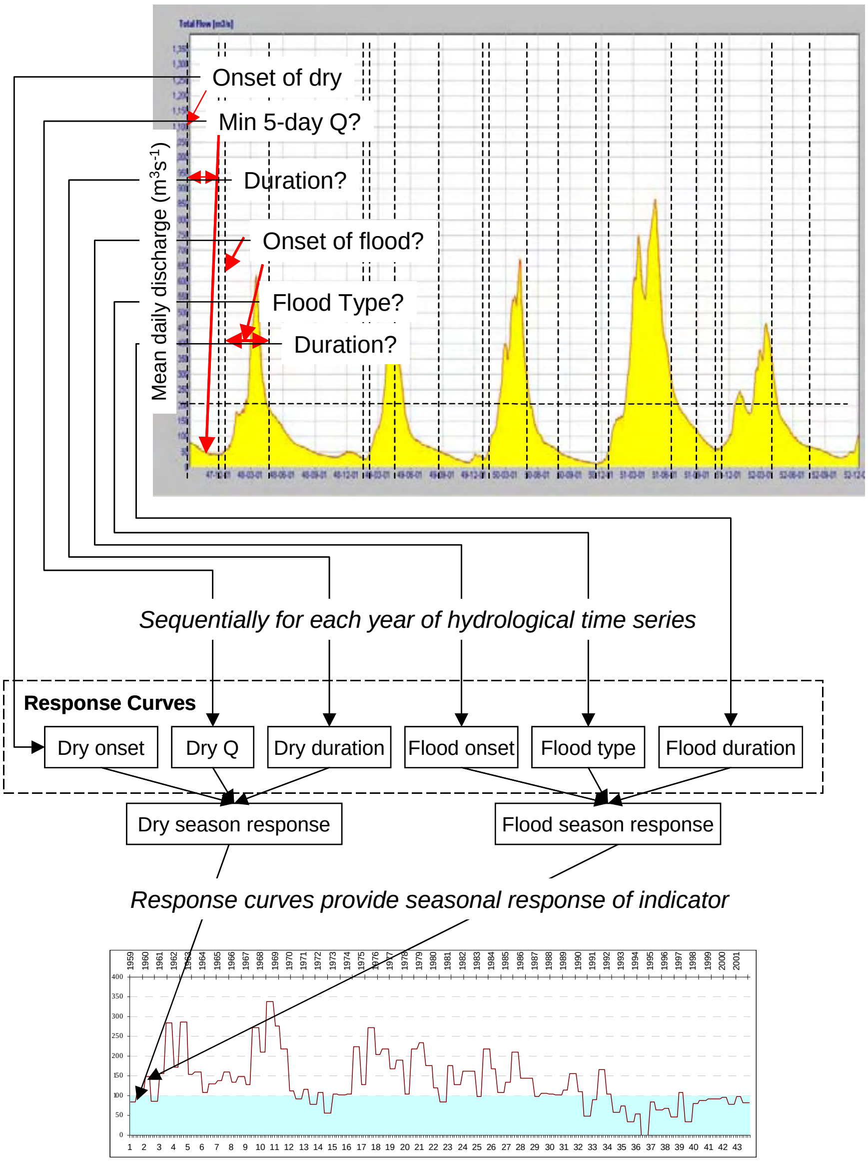


Figure 2.9 **Summary of process in DSS for assessing time-series changes in one bio-physical indicator in response to a scenario's simulated hydrological time series**

Discipline and ecosystem integrity are used to summarise the overall change in terms of the relevant biophysical indicators. This is done using categories from A-F that describe and classify the condition for individual discipline and/or the ecological condition of a whole rivers (Table 2.6).

Table 2.6 Descriptions of the categories that are used to describe and classify the ecological condition of rivers with their associated score in terms of Present Ecological State (PES) (adapted from Kleynhans 1996)

Ecological Category	PES % Score	Description
A	90-100%	Natural. Undisturbed. Also known as the Reference Condition.
B	80-90%	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C	60-80%	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	40-60%	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	20-40%	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-20%	Critically/Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

An approach to determining ecological integrity is explained in detail in Report 03/2009: Guidelines for data collection, analysis and scenario creation.

3. The team

The EF team consisted of a national team from each of the three riparian countries plus an EF process management team. To the extent possible, each national team was represented by one or more specialists from the following disciplines: hydrology, hydraulics, fluvial geomorphology, water chemistry, vegetation, aquatic invertebrates, fish, birds, other wildlife, social and resource economics. The process team consisted of the EF process team leader, a water-resource hydrologist, two specialists responsible for DSS design, technical coordination and data management, and a resource economist. Overall project management was provided by EPSMO and BIOKAVANGO project managers and by government representatives via the Okavango Basin Steering Committee.

The full team is listed at the front of each report in this report series.

4. Team meetings and workshops

The team meetings and workshop were organized according to a fairly standard pattern. For the most part, outside of the plenary sessions when the whole team came together, much of the work was done in three breakaway groups, *viz*.: hydrologists; biophysical specialists (excluding hydrologists); and sociologists. Within each of these groups, further sub-groups based on country or discipline were formed from time to time to undertake specific tasks. In the biophysical group, much of the detailed work pertaining to indicator selection and development of the response curves was done in discipline groups. In these instances, the minimum complement for a group was one specialist from each country. Often, however, these groups comprised three to five individuals.

4.1. Preparation Meeting

Dates: 22nd - 26th September 2008.
Venue: Maun Lodge, Maun, Botswana.

4.1.1 Purpose

The objective of the Preparation Meeting was to set the scene for the EF Assessment. To this end, the basin was delineated into homogeneous units and representative zones and sites were selected. Indicators were selected for social and ecological issues of concern, and the flow regime partitioned into ecologically-relevant flow categories. Initial discussions on the possible make up to the three scenarios to be analysed also took place. These scenarios were then passed to decision makers and stakeholders for further discussion and finalisation.

4.1.2 Attendees

Attendees are listed in Table 4.1.

4.1.3 Activities

Plenary Sessions:

- Concept of environmental flows
- Overview of the TDA: EF Process
- Guidelines for data collection, analysis and scenario creation
- Identification of Integrated Units of Analysis (IUAs)
- Scenario development
- Next steps in the TDA: EF process.

Discipline Group Sessions:

- Discipline-specific delineation of the Okavango Basin
- Selection of indicators
- Identification of linked indicators.

Table 4.1 Attendees at the Preparation Meeting, Maun, Botswana

Discipline	Angola	Namibia	Botswana	Other
Project Management	Manual Quintino	Shirley Bethune	Dominic Mazvimavi Nkobi Moleele Geoffrey Khwarae	Chaminda Rajapakse (EPSMO)
Process Team				Jackie King
				Cate Brown
				Hans Beuster
				Jon Barnes
Hydrology & hydraulics	Manuel Quintino	Andre Mostert	Kobamelo Dikgola	
	Gabriel Miguel	Aune-Lea Hatutale	France Tibe	
	Paulo Emilio Mendes	Matthews Katjimune	Chandrasekar Kurugundla	
	Tiago de Carvalho	Penehafo Shidute	Dominic Mazvimavi	
			Piotr Wolski	
Geomorphology	Helder André de Andrade e Sousa		Piotr Wolski	
Water Quality	Carlos Andrade	Cynthia Ortmann	Wellington Masamba	
Vegetation		Barbara Curtis	Casper Bonyongo	
Macroinvertebrates	-	Shishani Nakanwe	Belda Mosepele	
Fish	Miguel Morais	Christopher Munwela	Keta Mosepele	
Wildlife	Carmen Santos	Kevin Roberts	Casper Bonyongo	
Birds	Carmen Santos	-	-	
Sociology		Dorothy Wamunyima		
OBSC		Laura Namene		Ebenizario Chonguica (CEO OKACOM)

Country Group Sessions:
- Site selection.

Training Sessions:
- (Biophysical and Social Specialists)
    - o DRIFT, including flow categories
    - o Indicators
    - o Severity Ratings
    - o Response Curves.

4.1.4 Outcomes and deliverables

The Preparation Meeting had the following deliverables:
Report No. 03/2009: Guidelines for data collection, analysis and scenario creation
Report No. 04/2009: Delineation Report.

4.2. Knowledge Capture Workshop

Dates: 30th March – 4th April 2009.
Venue: Safari Hotel, Windhoek, Namibia.

4.2.1 Purpose

The main objectives of the Knowledge Capture Workshop were:
Hydrological: To further develop the hydrological models
Biophysical and social: To develop the response curves for each flow category, for each indicator at each EF site, and to calibrate the present-day

time-series of variations for each indicator over the last 40 years.

4.2.2 Attendees

Attendees are listed in Table 4.2.

Table 4.2 Attendees at the Knowledge Capture Workshop, Windhoek, Namibia

Discipline	Angola	Namibia	Botswana	Other
Project Management	Manual Quintino	Shirley Bethune	Dominic Masivimbi Casper Bonyongo	Chaminda Rajapakse Geoffrey Khwarae
Process Team				Jackie King
				Cate Brown
				Hans Beuster
				Jon Barnes
				Alison Joubert
				Mark Rountree
Hydrology	Manuel Quintino	Andre Mostert	Kobamelo Dikgola	
	Gabriel Miguel	Aune-Lea Hatutale	France Tibe	
	Paulo Emilio Mendes	Matthews Katjimune		
Geomorphology	Helder André de Andrade e Sousa	Colin Christian	Dominic Mazvimavi Piotr Wolski	
Water Quality	Maria João Pereira Carlos Andrade	Cynthia Ortmann Laura Namene	Wellington Masamba	
Vegetation	Amândio Gomes	Barbara Curtis	Casper Bonyongo	
Macroinvertebrates	Filomena Livramento	Shishani Nakanwe	Belda Mosepele H. Masundire	
Fish	Miguel Morais	Ben van de Waal	Keta Mosepele	
Wildlife	Carmen Santos	Kevin Roberts	Casper Bonyongo	
Birds	Carmen Santos	Mark Paxton	Pete Hancock	
Sociology	Rute Saraiva	Dorothy Wamunyima		

4.2.3 Activities

Plenary Sessions:

- Concept of environmental flows
- Technical aspects of Knowledge Capture
- Analysis of flow regimes and production of summary statistics
- Layout and use of DSS data entry sheets
- Demonstrations of the development of Response Curves
- Uploading DSS data entry sheets onto specialists' computers.

Discipline Group Sessions (Hydrology):

- Model calibrations of hydrological/hydraulic consequences of scenarios.

Discipline Group Sessions (Biophysical and Social):

- Detailed explanation of data-entry sheets
- Finalisation of indicator lists
- Development of response curves for each flow category, for each indicator at each EF site
- Calibration of present-day time-series for each indicator at each EF site.

4.2.4 Outcomes and deliverables

The Knowledge Capture Workshop had the following deliverables:

Data:	Finalised indicator lists
Data:	Response Curves for each biophysical and social indicator.
Report No. 05/2009:	Hydrology Report: Data and Models.

4.3. Hydrology Workshops

A hydrological working group consisting of hydrologists from the three co-basin states was established to develop and populate the hydrological and hydraulic models for the river basin and the delta and to develop flow scenarios. The activities of the group were as follows:

a) Planning meeting, Pretoria July 2008.
- Preliminary identification of hydrological working group members
- Draft schedule of activities

b) Delineation Workshop, Maun September 2008.
- Hydrological inputs to the delineation of approximately homogeneous lengths of river and linked social areas and selection of representative sites in the most important ones.
- Selection of modeling tools that will be used for providing hydrological input to the EF scenario assessments.
- Identification of data requirements and assignment of responsibilities for collection of the data
- Development of a work plan and programme for the hydrological component of the EFA

Main Outputs :
- *A set of hydrological and hydraulic models and tools to undertake the EFA*
- *Inputs to Report 3: Basin Delineation Report*

c) Dry Season Field trip, Basin, October 2008
- Assessment of flow measurement stations
- Cross-section surveys at selected sites

Main Outputs :
- *capacity building, field training*

d) Model Familiarisation and Training, 1-5 December 2008, Maun, Botswana
- Review of Pitman based basin hydrology (Hughes, Wilks et al)
- WEAP systems model training
- DWA Botswana MIKE-SHE Delta model familiarization
- HOORC Conceptual Delta Model familiarization
- River site hydraulics training

Main Outputs :
- *All team members familiarised with modeling tools*

e) Basin Hydrological Modelling, 19-23 January 2009, Maun, Botswana
- WEAP Reference Scenario Configuration
- Identification of existing, proposed and planned water resource developments
- Construction of draft low, medium and high development scenarios

Main Outputs :

- *Draft Scenario Description Document for review by country teams and OKACOM*
- *Configured basin reference scenario*

f) Knowledge Capture Workshop: 30 March – 4 April 2009, Windhoek, Namibia
- Configuration and testing of Low, Medium and High Development scenarios
- Use of custom software to delineate flow seasons
- Calculation of hydrological indicators

Main Outputs :
- *Configured basin low, medium and high development scenarios*

g) Okavango Delta Modelling Workshop: 20 – 25 April 2009, Gaborone, Botswana
- Review and refinement of the WEAP basin scenario configurations
- Configuration and testing of Low, Medium and High Development scenarios using the DWA MIKE-SHE model of the Delta

Main Outputs :
- *Draft final basin scenario configurations (subject to OKACOM approval)*
- *Calculated hydrological indicators for all scenarios and all sites*

h) Other Activities
- November 2008 – April 2009. Country hydrologists consult with water resource planners and managers to obtain development plans and hydrological data.
- December – January 2009. Development of custom software for flow season identification and calculation of hydrological indicators
- January 2009. Wet season site visits and data collection by country hydrologists
- April – May 2009. Scenario modeling of inundation and vegetation changes using the HOORC Delta model (P Wolski) and Boteti state changes (D Mazvimavi and P Wolski)

4.4. Scenario Workshop

Date: 8th – 12th June, 2009.
Venue: Monkey Valley, Cape Town, South Africa.

4.4.1 Purpose

The main objectives of the Scenario Workshop were:

Hydrological:	To finalise the hydrological team work
Biophysical and social:	To review the response curves in the light of the predicted time-series of variations for each indicator for each of the three scenarios at each site. To summarise the predictions for the biophysical and socioeconomic indicators for the three scenarios.
All:	To sign-off on the scenarios. To discuss and summarise key findings and messages. To identify major knowledge gaps To obtain feedback on the process.

4.4.2 Attendees

Attendees are listed in Table 4.3.

Table 4.3 Attendees at the Scenario Workshop, Cape Town, South Africa Team Leaders

Discipline	Angola	Namibia	Botswana	Other
Project Management	Manual Quintino	Shirley Bethune	Dominic Masivimbi Casper	Chaminda Rajapakse Geoffrey Khwarae
Process Team				Jackie King
				Cate Brown
				Hans Beuster
				Jon Barnes
				Alison Joubert
Hydrology	Gabriel Miguel	Mathews Katjimune	Piotr Wolski	
		Aune Hatutale	Dominic Mazvimavi	
		Andre Mostert		
		Penny Shidute		
Geomorphology	Helder André de Andrade e Sousa	Colin Christian		
Water Quality	Maria João Pereira Carlos Andrade	Cynthia Ortmann Laura Namene	Wellington Masamba	
Vegetation	Amândio Gomes	Barbara Curtis	Casper Bonyongo	
Macroinvertebrates	-	Shishani Nakanwe	Belda Mosepele H. Masundire	
Fish	Miguel Morais	Ben van de Waal	Keta Mosepele	
Wildlife	Carmen Santos	Kevin Roberts	Casper Bonyongo	
Birds	Carmen Santos	Mark Paxton	Pete Hancock	
Sociology	Rute Saraiva	Ndina Nashipili		
Irrigation		Piet Liebenberg		
GIS		Celeste Espach		
OBSC			Tracy Molefi	Ebenizario Chonguica (CEO OKACOM)

4.4.3 Activities

Plenary Sessions:

- Concept of environmental flows
- Overview of the EPSMO/BIOKAVANGO EF Process
- Water-resource developments included in each water-use scenario
- Ecological interpretation of hydrological data: River Sites
- Ecological interpretation of hydrological data: Delta and Boteti
- Biophysical outcome of scenarios
- Social outcome of scenarios
- Overview of the summary outcomes for scenarios and key messages.
- Sign-off on the scenarios.
- Data gaps.

Discipline Group Sessions (Hydrology):

- Finalisation of hydrological reports

Discipline Group Sessions (Biophysical and Social):
- Final review of Response Curves and individual indicator outputs for the three water-use scenarios.
- Explanations for individual indicator responses to the three water-use scenarios.

4.4.4 Outcomes and deliverables

The Scenario Workshop had the following deliverables:
Report 02/2009: Process Report
Report 06/2009: Scenario Report: Hydrology
Report 07/2009: Scenario Report: Ecological and social predictions
Report 08/2009: Final Report.

DSS Software: Full, calibrated DSS.
Powerpoint presentations

4.5. Capacity-building and liaison sessions

The process management team leader, Dr King, visited the Botswana team in Maun on 13-14 November 2008 prior to a scheduled OBSC meeting. She held one-on-one meetings with the following team members to discuss organisational matters involved in the EF assessment and individual Terms of Reference:
- Piotr Wolski
- Dominic Mazvimavi
- Wellington Masamba
- Casper Bonyongo
- Keta Mosepele
- Pete Hancock
- Belda Mosepele

Dr King also visited Luanda from 2-7 February 2009 for further training of and liaison with the Angolan team. One-on-one meetings were held with the following team members on 3 February:
- Gabriel Miguel
- Michel Morais
- Maria João Pereira
- Carmen Santos
- Filomena Livramento
- Helder André de Andrade e Sousa

This was followed by a meeting on the EF social module between Dr King, the project manager and process team resource economist on 4 February. A further two-day team meeting at Mussolo Island revisited the concept and practicalities of EF assessments, and addressed the activities to be completed in the wider TDA study.

4.6. Okavango Basin Steering Committee and TDA Meetings

A joint EPSMO-OBSC meeting took place in Maun 17-21 November 2008. The main objectives relevant to this project were the Okavango Transboundary Diagnostic Analysis (TDA) and Strategic Action Programme. This was preceded by a two-day TDA Integration preparation meeting on 15-16 November attended by:

- Chaminda Rajapakse Project Manager

• Manuel Quintino	Angola National Project Coordinator
• Tracy Molefi	Botswana National Project Coordinator
• Laura Namene	Namibia National Project Coordinato
• Peter-John Meynell	TDA Integration/Natural Sciences Integration
• Jon Barnes	Socio-economics Integration
• Vladimir Russo	Basin-wide Governance and Policy Analysis
• Luis Verissimo	GIS and maps
• Hans Beuster/Dominic Mazvimavi	Basin-wide Hydrology
• Jackie King	Environmental Flows Assessment
• Dominic Mazvimavi	Botswana TDA Coordinator for HOORC
• Mawzi Mawzi	Namibia TDA Coordinator for NNF
• Daniel Malzenbender	NAP/SAP Consultant

The objectives of the OBSC meeting were to:

- revisit the priority focus areas for the TDA.
- formulate development scenarios for the EFA
- brainstorm the first list of initiatives for the Strategic Action Program (SAP), which is the main output of the project.

At the meeting, the final decision on the nature of the scenarios was agreed, in a session facilitated by Gary Forbes (Section 2.6).

The second TDA integration meeting took place at Government Park, Windhoek, Namibia on 6 April 2009 following the Knowledge Capture Workshop. Its purpose was to report back on progress with the hydrological modelling and EF assessment; evaluate the draft reports submitted by the discipline specialists; identify emerging issues; and outline specific chapters of the TDA Report. Those present were:

• Peter-John Meynell	TDA Integration /Natural Sciences Integration
• Jon Barnes	Socio-economics Integration
• Vladimir Russo	Basin-wide Governance and Policy Analysis
• Luis Verissimo	GIS and maps
• Hans Beuster	Basin-wide Hydrology
• Jackie King	Environmental Flows Assessment
• Chaminda Rajapakse	Project Manager
• Manuel Quintino	Angola National Project Coordinator
• Tracy Molefi	Botswana National Project Coordinator
• Laura Namene	Namibia National Project Coordinator
• Lapologang Magole	Botswana TDA Coordinator for HOORC
• Chris Brown	Namibia TDA Coordinators for NNF

The third TDA integration meeting took place in Namibia in August 2009.

5. Specialist activities and reports

After the field trip in October 2008, specialist Terms of Reference were finalised and the three country teams began individual programmes of site visits, research, literature reviews and data analysis. During this process, potential indicators were discussed by email, and final discipline lists agreed on. Each specialist then wrote a report, to a set Table of Contents:

Chapter 1	Introduction and background
Chapter 2	Study area
Chapter 3	Identification of indicators and flow categories
Chapter 4	Literature review
Chapter 5	Data collection and analysis
Chapter 6	Flow-response relationships for all indicators
Chapter 7	References

Most draft reports were submitted in February or March 2009 and were reviewed as follows:

- The biophysical reports for Namibia and Botswana were reviewed by Dr King
- The biophysical reports for Angola were reviewed by a bilingual river scientist Dr Sharon Pollard
- The socioeconomic reports were reviewed by Dr Barnes.

Feedback was provided by the Knowledge Capture Workshop in April. After the Knowledge Capture and Scenario Workshops, the reports were revised and final versions were submitted in June 2009. There was no review of the final versions.

6. The Decision Support System

The Decision Support System (DSS) for the EPSMO/BIOKAVANGO EF process was created in Microsoft ® Excel 2003 (SP3) using standard spreadsheet functions augmented with macros written in Visual Basic for Applications V6.5 (VBA). The DSS was designed to store the specialist-created Response Curves of flow-indicator relationships, and to use these to predict the ecological and social outcomes of any development driven change in the Okavango River's flow regime. Although only four were scenarios assessed during this project (Present Day plus three levels of water-use development), the DSS as designed and populated with data can be queried for any number of scenarios that affect river flow. In this section, the structure and functioning of the DSS is described.

6.1. Structure of the DSS

The files and folders making up the DSS are arranged hierarchically. At the top of the hierarchy is the file *Okavango Scenario Interface.xls*. This is the only file in the top-level folder 1 OKAVANGO DSS. Once all the information has been entered in the data entry sheets, the scenarios can be 'run' from this file, and summary information and results obtained. The folder 1 OKAVANGO DSS contains a subfolder DATA ENTRY SHEETS, which in turn contains nine subfolders: one folder for each site and one for the hydrology. See Figure 6.1.

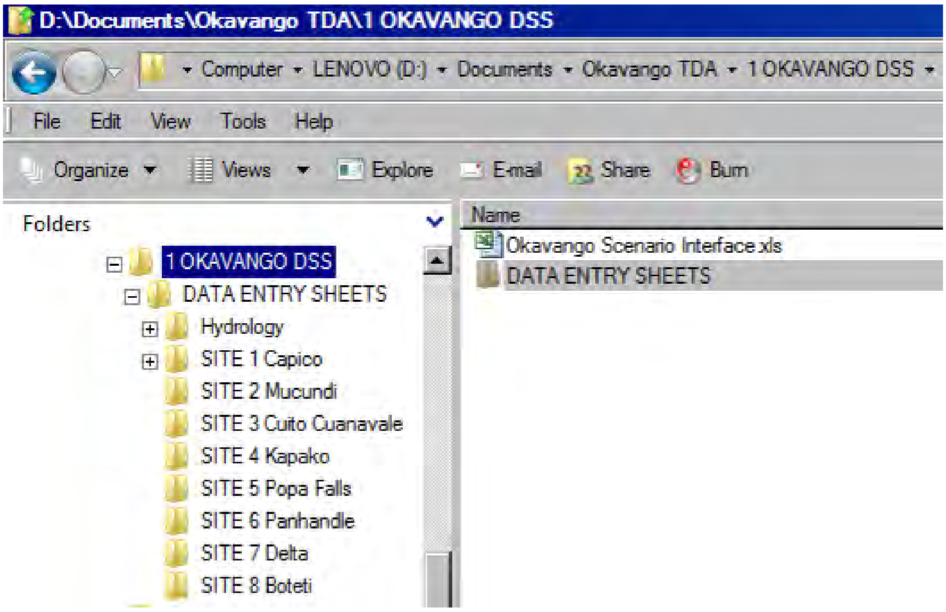


Figure 6.1 Top level of the hierarchy of folders for the Okavango DSS showing the subfolders for hydrology and for data entry for each site.

At the data entry level, therefore, there is a hydrology folder (Hydrology) and a folder for each site (e.g. SITE 2 Mucundi).

In the Hydrology folder there is an Excel file for each site containing the time series data for present day and each scenario and summary hydrological information (e.g. *Site 2 Mucundi hydro.xls*). There is also an Excel file containing summary information for all sites (i.e. *Input hydrology.xls*). See Figure 6.2.

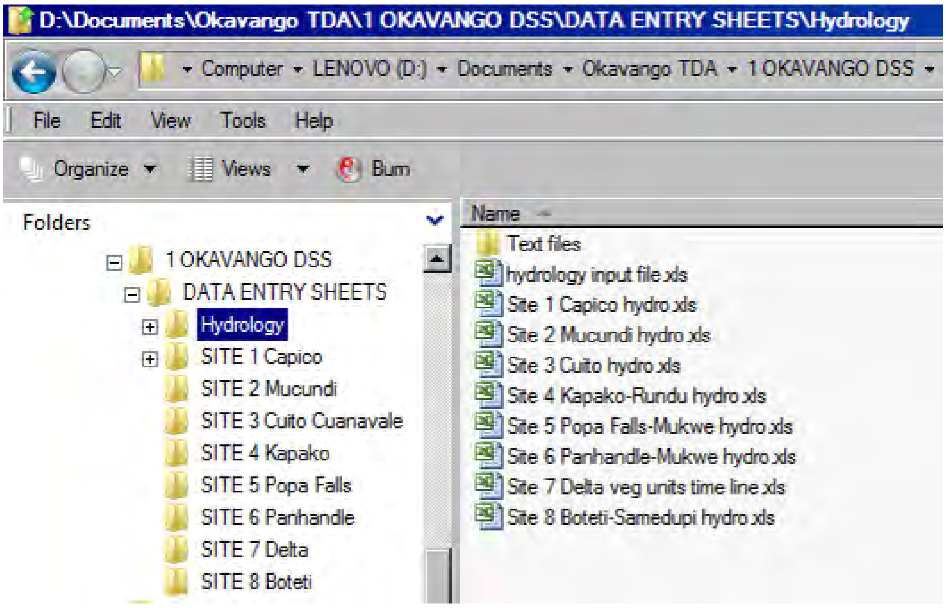


Figure 6.2 Hydrology folder for the Okavango DSS.

Each site's folder (e.g. SITE 2 Mucundi) contains an Excel file for each discipline (geomorphology, water quality, vegetation, aquatic macroinvertebrates, fish, wildlife, birds, socio-economics) and a summary file (e.g. *SITE 2 Mucundi summary.xls*). The discipline files are named by discipline, site number and site name, followed by 'FINAL' (e.g. *Wildlife_Site 2_Mucundi_FINAL.xls*). See Figure 6.3.

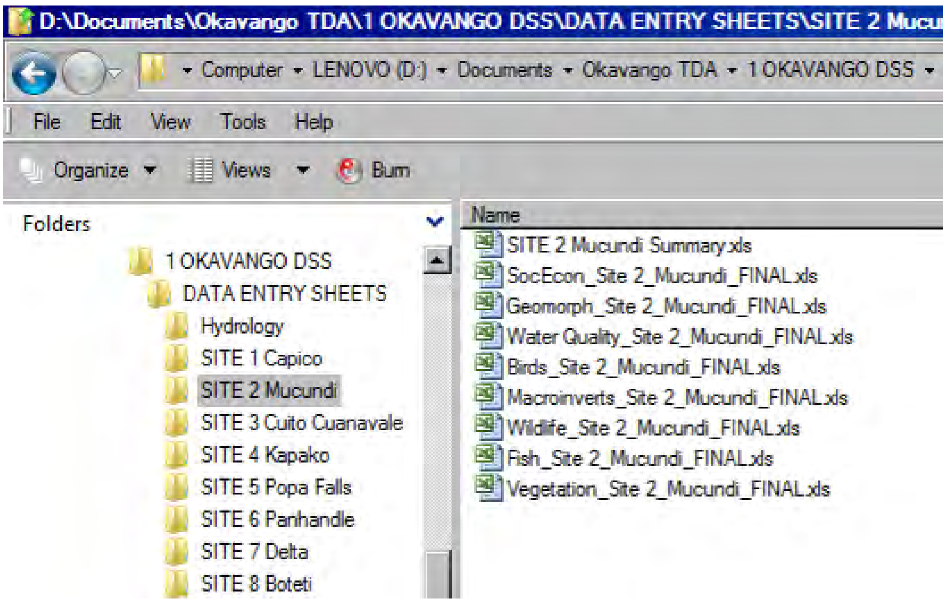


Figure 6.3 Contents of the Mucundi Site folder.

Hydrology and response curve files and folders are grouped in the folder DATA ENTRY SHEETS.

6.2. Flow of information

The basic flow of information is illustrated in Figure 6.4. The site and summary hydrology files pass information to the biophysical response curve files for each site. The individual file outputs are summarised in the site summary file, and this plus some hydrological information feeds into the socioeconomic response curve files. The socio-economic summary information passes back to the site summary file, and the summary from all eight sites then passes to the *Okavango Scenario Interface.xls*.

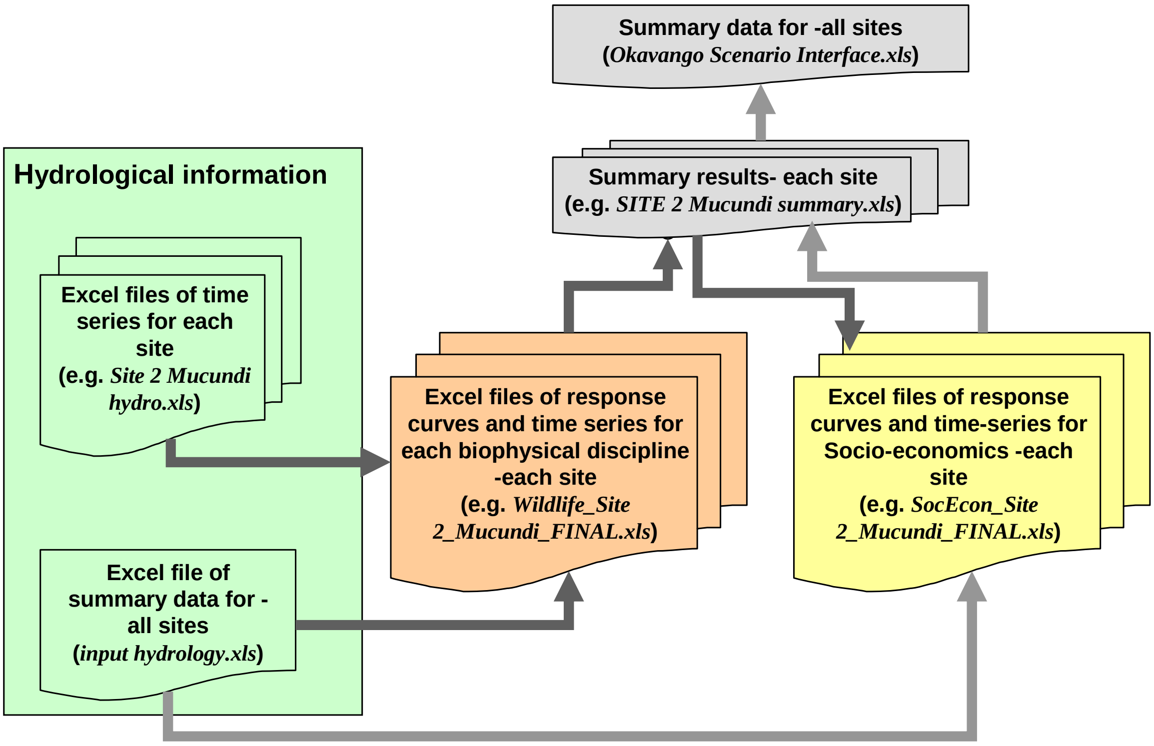


Figure 6.4 **Flow of information through the DSS.**

6.3. Information processing

6.3.1 Hydrology

The primary input into the DSS is the hydrological information produced by the various hydrological models used in this study. The hydrological modelling and indicators are described elsewhere in this report and report series. This section describes the subsequent processing of the hydrological data that prepares the information for the DSS.

A text file containing a time series of annual hydrological values was provided by the hydrological team for each site and for each scenario. This was parsed into Excel and the information pasted into the relevant part of the hydrology site file (Figure 6.5). For example, in the file *Site 2 Mucundi hydro.xls* the simulated hydrological information for the Present Day scenario was pasted to the worksheet *MucundiPD* and the high development scenario information was pasted to the worksheet *MucundiHigh* (Figure 6.6). The time series information was linked to a new worksheet for each scenario (e.g. *PD* and *HighDev*) (Figure 6.6).

Summary statistics (minimum, maximum, average, median, and standard deviations) were determined for each flow category. The summary information was linked to a summary hydrology file (*Input hydrology.xls*) (Figure 6.6), which contained this information for all sites.

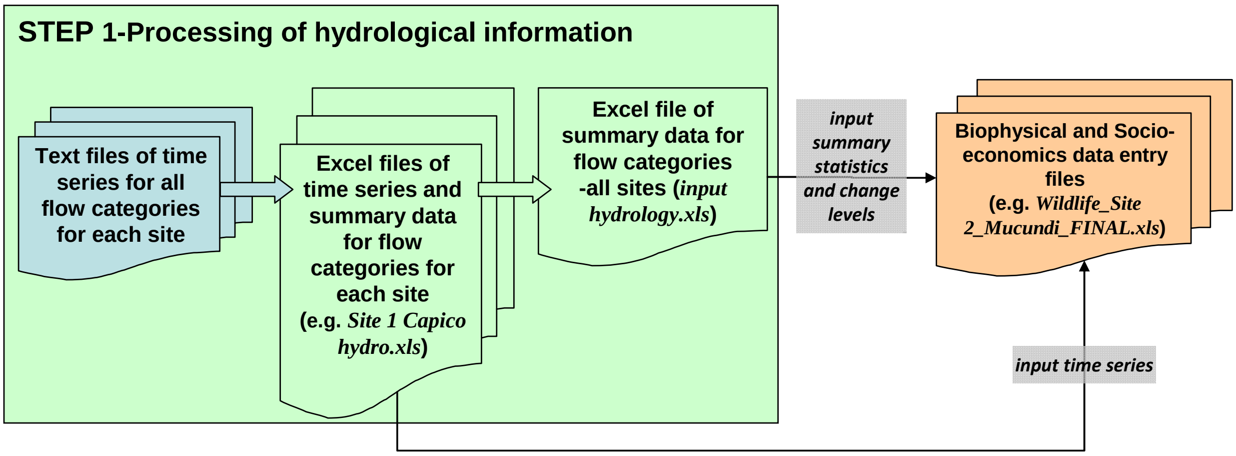


Figure 6.5 **Summary of the hydrological processing.**

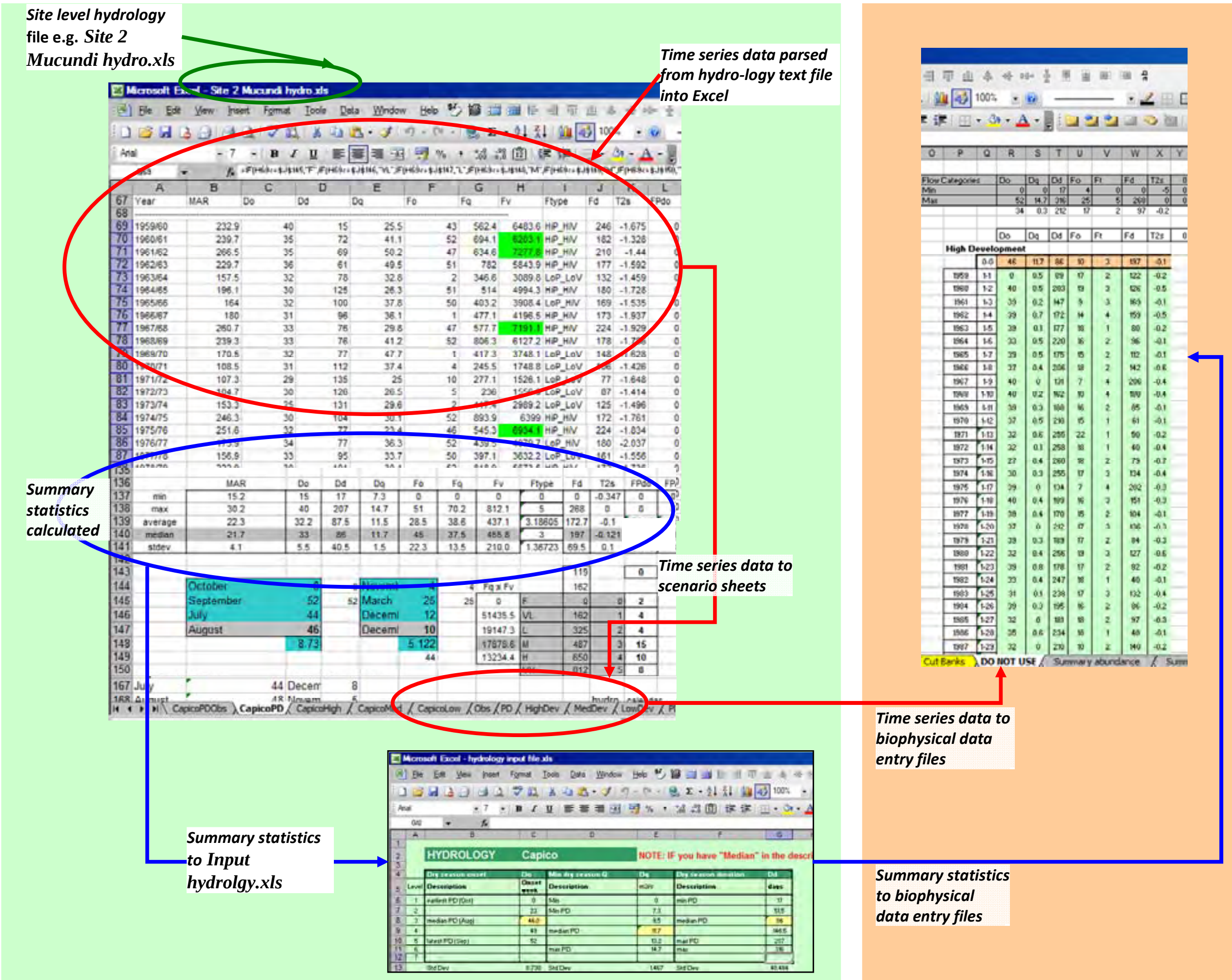
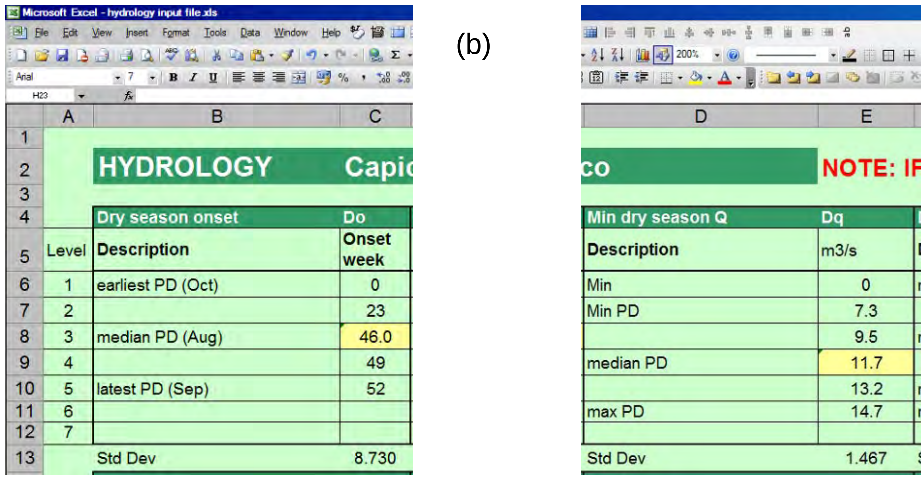


Figure 6.6 **Summary of the hydrological processing showing the relevant sections of the Excel files.**

The hydrological time series information for each scenario (e.g. from the worksheet <u>*HighDev*</u>) was linked to each discipline response curve file via a worksheet labelled <u>*Do Not Use*</u> (Figure 6.6). The summary statistics contained in the file *Input hydrology.xls* were also linked to each discipline response curve file via the worksheet <u>*Eco-hydrology ranges*</u>. The summary statistics provided the input value for each level of the response curve, such as the minimum level experienced under present day conditions, the median level and the maximum level. Intermediate values were determined between these levels, so that at least five levels were provided for response curves (Figure 6.7 a). Where levels lower than or higher than PD were expected under any of the scenarios, these were included as additional levels in the range (Figure 6.7 b).

(a) (b)



Microsoft Excel - hydrology input file.xls

HYDROLOGY Capic

Level	Dry season onset Description	Do Onset week
1	earliest PD (Oct)	0
2		23
3	median PD (Aug)	46.0
4		49
5	latest PD (Sep)	52
6		
7		
	Std Dev	8.730

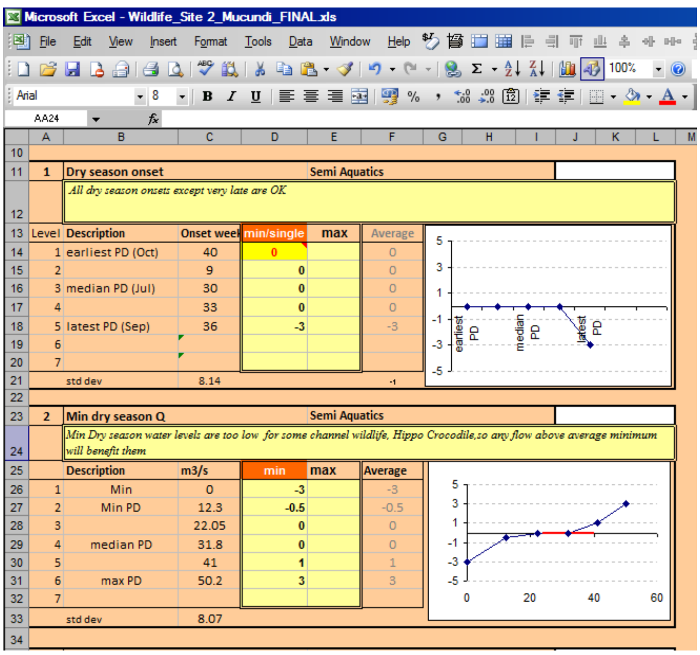
co NOTE: IF

Min dry season Q Description	Dq m3/s
Min	0
Min PD	7.3
	9.5
median PD	11.7
	13.2
max PD	14.7
Std Dev	1.467

Figure 6.7 **(a) The (minimum) five levels provided for the all response curves. (b) An example showing an additional minimum level provided where scenarios were expected to fall outside of the present day range.**

6.3.2 Biophysical data entry files

In each site folder a file was provided for each discipline (e.g. *Wildlife_Site 2_Mucundi_FINAL .xls*). This file contained a worksheet for each indicator (e.g. *Semi-aquatics*, *Frogs, river snakes*, etc.). Each of the indicator worksheets contained a response curve for each flow category (i.e. there would be seven response curves per biophysical indicator) (Figure 6.8). Specialists could choose to leave some of these responses at zero, meaning that the flow category was not relevant or important for that biophysical indicator.



Microsoft Excel - Wildlife_Site 2_Mucundi_FINAL.xls

1	Dry season onset			Semi Aquatics	
	All dry season onsets except very late are OK				
Level	Description	Onset week	min/single	max	Average
1	earliest PD (Oct)	40	0		0
2		9	0		0
3	median PD (Jul)	30	0		0
4		33	0		0
5	latest PD (Sep)	36	-3		-3
6					
7					
	std dev	8.14			-1

2	Min dry season Q			Semi Aquatics	
	Min Dry season water levels are too low for some channel wildlife, Hippo Crocodile,so any flow above average minimum will benefit them				
	Description	m3/s	min	max	Average
1	Min	0	-3		-3
2	Min PD	12.3	-0.5		-0.5
3		22.05	0		0
4	median PD	31.8	0		0
5		41	1		1
6	max PD	50.2	3		3
7					
	std dev	8.07			

Figure 6.8 The data entry file for Wildlife at Site 2 (Mucundi), showing the worksheet for Semi aquatics. Two response curves are visible: for Dry season onset and for Min dry season Q.

Calculations happened in two season groupings: the Dry season and the Flood season. In calculating the overall *season's* response of the indicator, the average of the responses to each of the flow categories within that season was taken. As an example, consider the case where only two flow categories were relevant (e.g. dry season onset and dry season minimum 5-day discharge). If the dry onset for year one was calendar week 35 (hydrological week 48) (left part of Figure 6.9). The specialist gave this a response rating of -2 (middle part of Figure 6.9, top response curve). This would translate to a % loss in abundance of 38% (top, right part of Figure 6.9). If the dry season minimum Q was 41 then a response rating of 1 is given (second response curve on Figure 6.9). This would translate to a % increase in abundance of 11%) (see Table 2.5 for the relationship between rating and % change).

Thus the overall dry season response would be a loss in abundance of 13.5% (average of -38% and +11%). Given that the flood season was considered not to be relevant, the overall response for the year would be a loss in abundance of 13.5% (bottom right of Figure 6.9). Thus, the value appearing on the biophysical time series for Year 1 is 86.5% of PD (bottom of Figure 6.9-time series).

If the Flood season were relevant, then the calculations would take the Dry season abundance / concentration just determined as the input into the Flood season calculations.

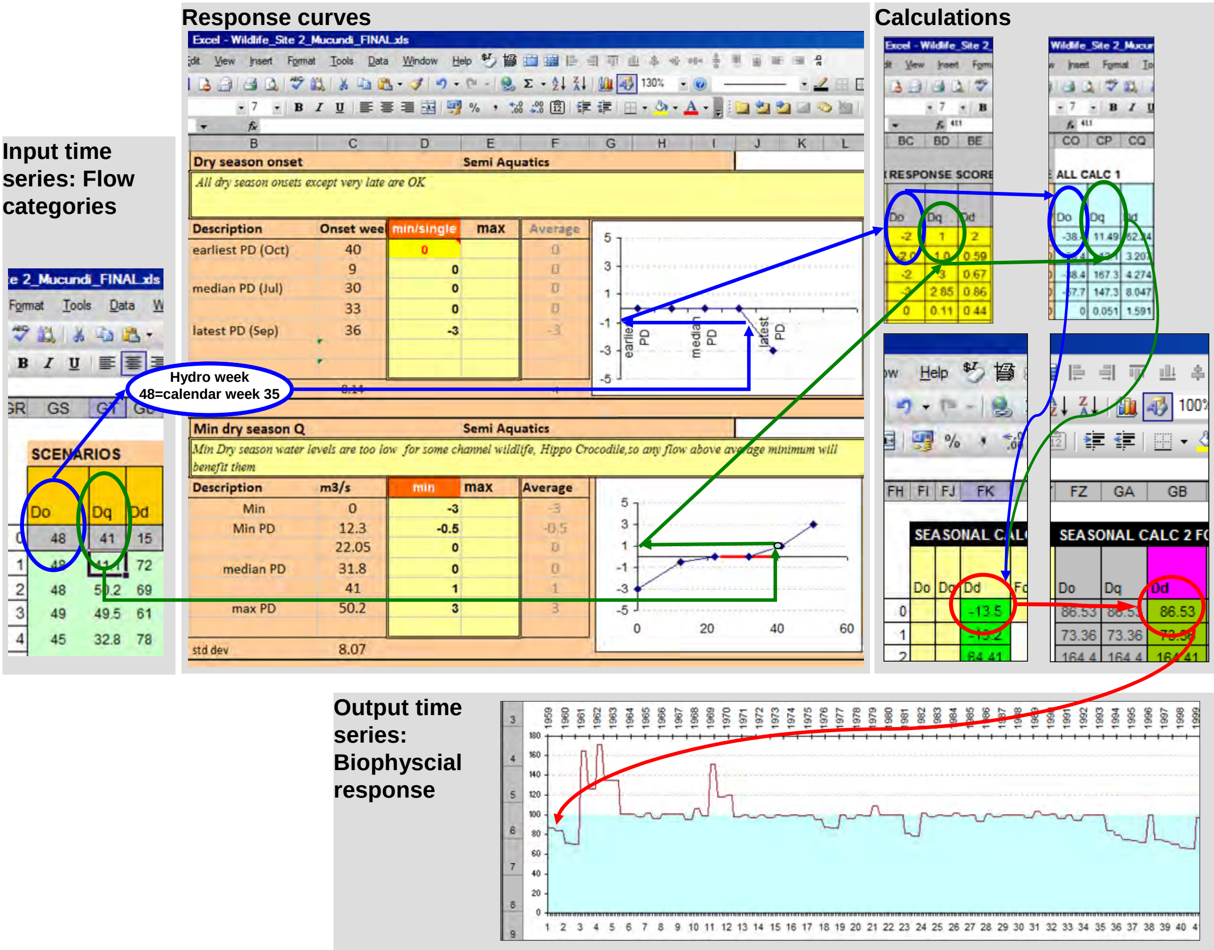


Figure 6.9 **The input, series of calculations and time series output for one indicator (**in this example, Semi Aquatics for Wildlife**) showing its response to Dry season onset (Dq) and Dry season min Q (Dq).**

In addition to the seven response curves for each indicator, there were various "modifiers" which could be applied to each indicator (Figure 6.10). These modified if or how quickly the indicator would return to median values after an increase or decrease, whether the indicator was dependent on the previous year's value, whether there was a lag in the response, whether there was a minimum or maximum that the indicator would reach, and whether density-dependent modification was necessary.

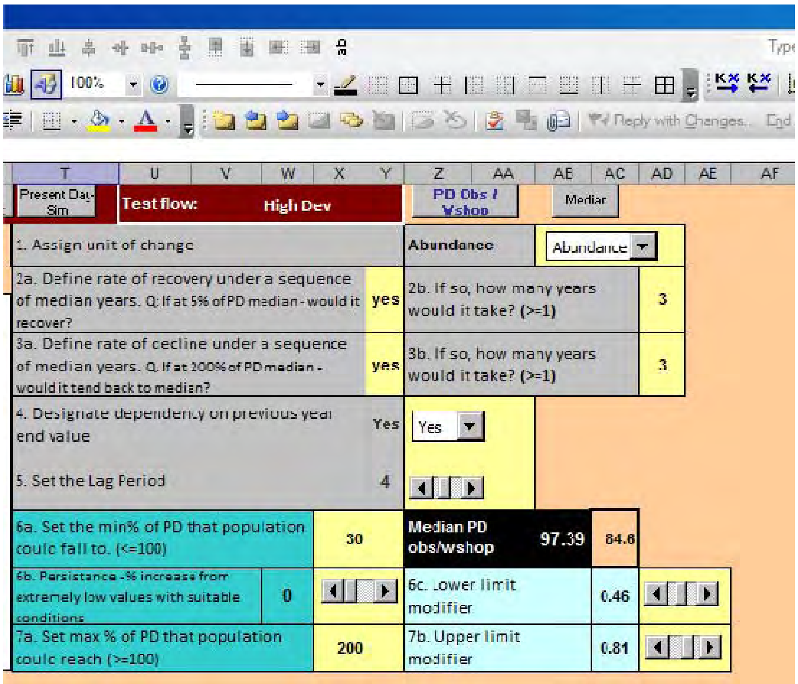


Figure 6.10 **Modifiers available which could be applied to each indicator.**

The response curve and modifier information was linked to calculations which determined the seasonal response based on the time series of input flow categories. From this, a time series of the biophysical response was created for each indicator and displayed at the top of the worksheet (Figure 6.11). The time series response for different scenarios could be displayed by clicking on one of the scenario buttons at the top of the screen (Figure 6.11). The scenarios included were the Present Day and the Low, Moderate and High Development scenarios (see Report 6 of this report series: "Scenario Report: Hydrology" for a description of these).

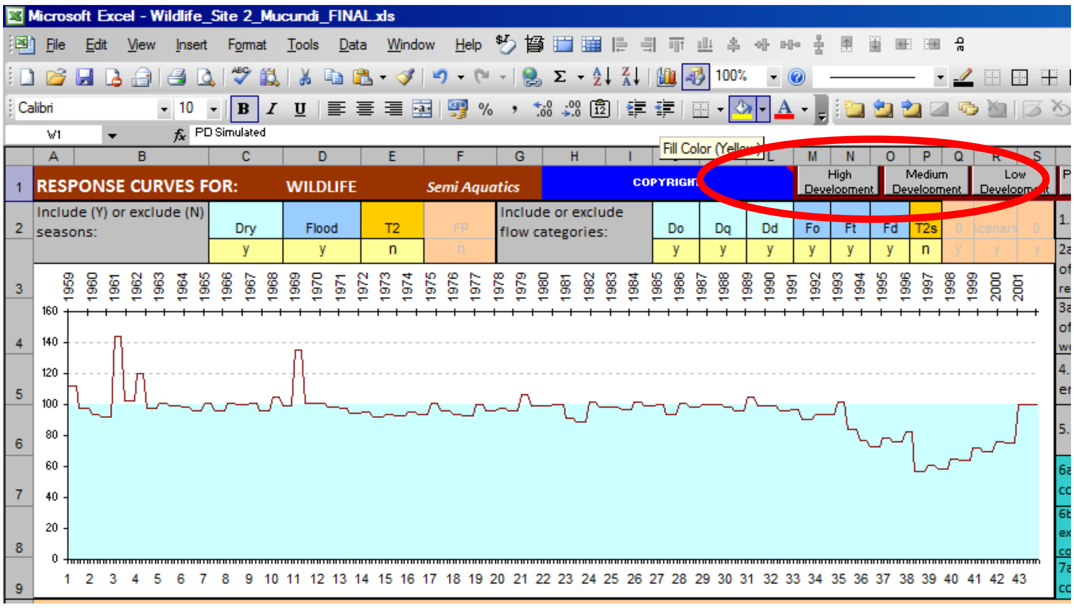


Figure 6.11 **Time-series of the Present Day biophysical response of Semi Aquatic wildlife. The screenshot also shows the buttons to click to see different scenarios (red circle).**

The time series of abundance responses for all scenarios were summarised in the worksheet Summary abundance. In addition, the Ecological Integrity rating for each scenario was determined for each indicator and for the discipline as a whole (see Section 2.10 and Table 2.6). Summary integrity results were displayed on the worksheet Summary integrity.

6.3.3 Socio-economic data entry files

Only after the relevant biophysical responses had been determined could the socio-economic time-series responses be determined. Inputs into the socio-economic response curve files came from the site summary files (e.g. *SITE 2 Mucundi summary.xls*) and relevant hydrology files (i.e. *Input hydrology.xls* and, for example, *Site 2 Mucundi hydro.xls*).

The basic layout of the socio-economic response curve files was similar to the biophysical response curve files. However, most of the response curves were responding to biophysical indicators, such as fish abundance, grass abundance and wildlife abundance (obtained from *SITE 2 Mucundi summary.xls*) rather than to the flow categories. In addition to the basic response (e.g. fish catch), the impacts on household income and contribution to national income were also determined for each indicator, if relevant (Figure 6.12).

Thus, for all of the socio-economic indicators a score was available which indicated, for example, the size of the fish catch (in response to changes in fish abundance), the size of the grass harvest (in response to grass abundance), or the degree of impact on health and well-being (in response to the turbidity of the water). In addition, for most of the socio-economic indicators, the contribution to household income and national income was determined. Contribution to household and national income was not determined for water-quality changes, or for intangible, indirect or non-use values.

Further processing of the socio-economic information took place outside of the DSS.

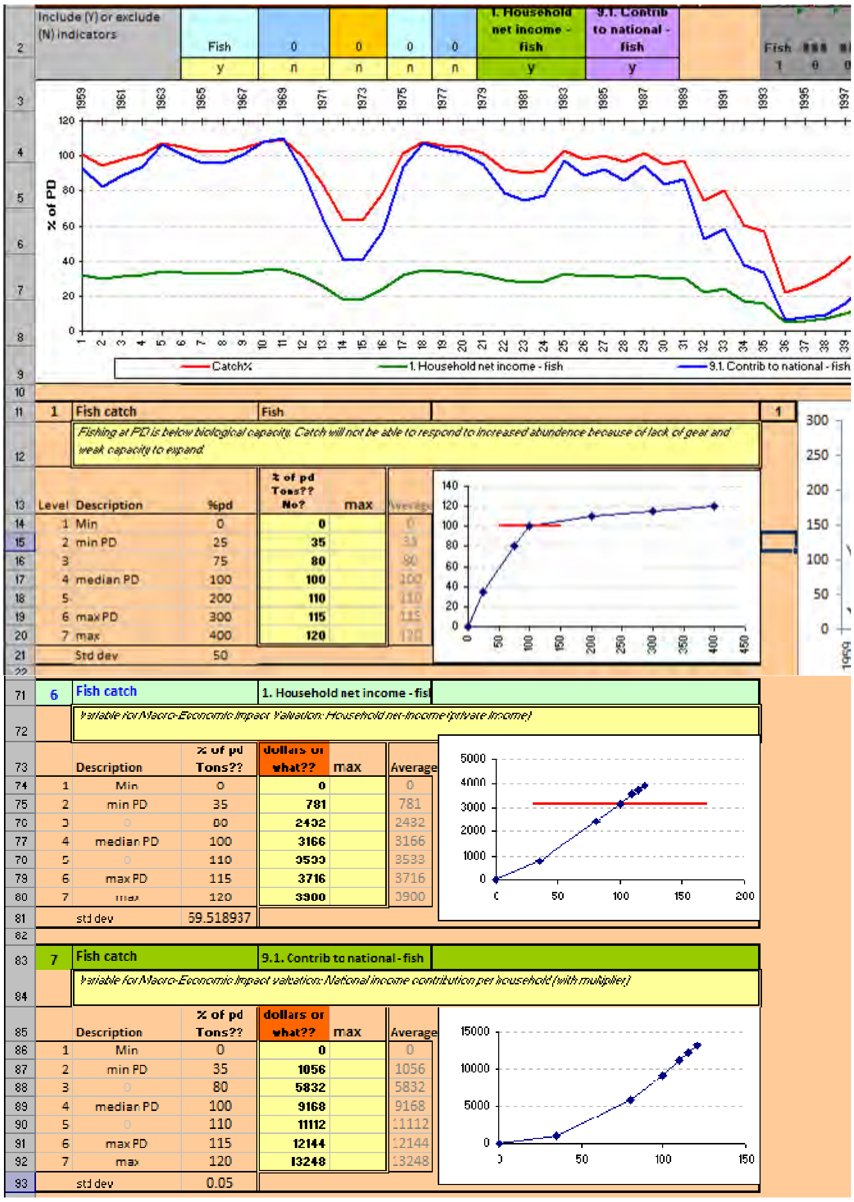


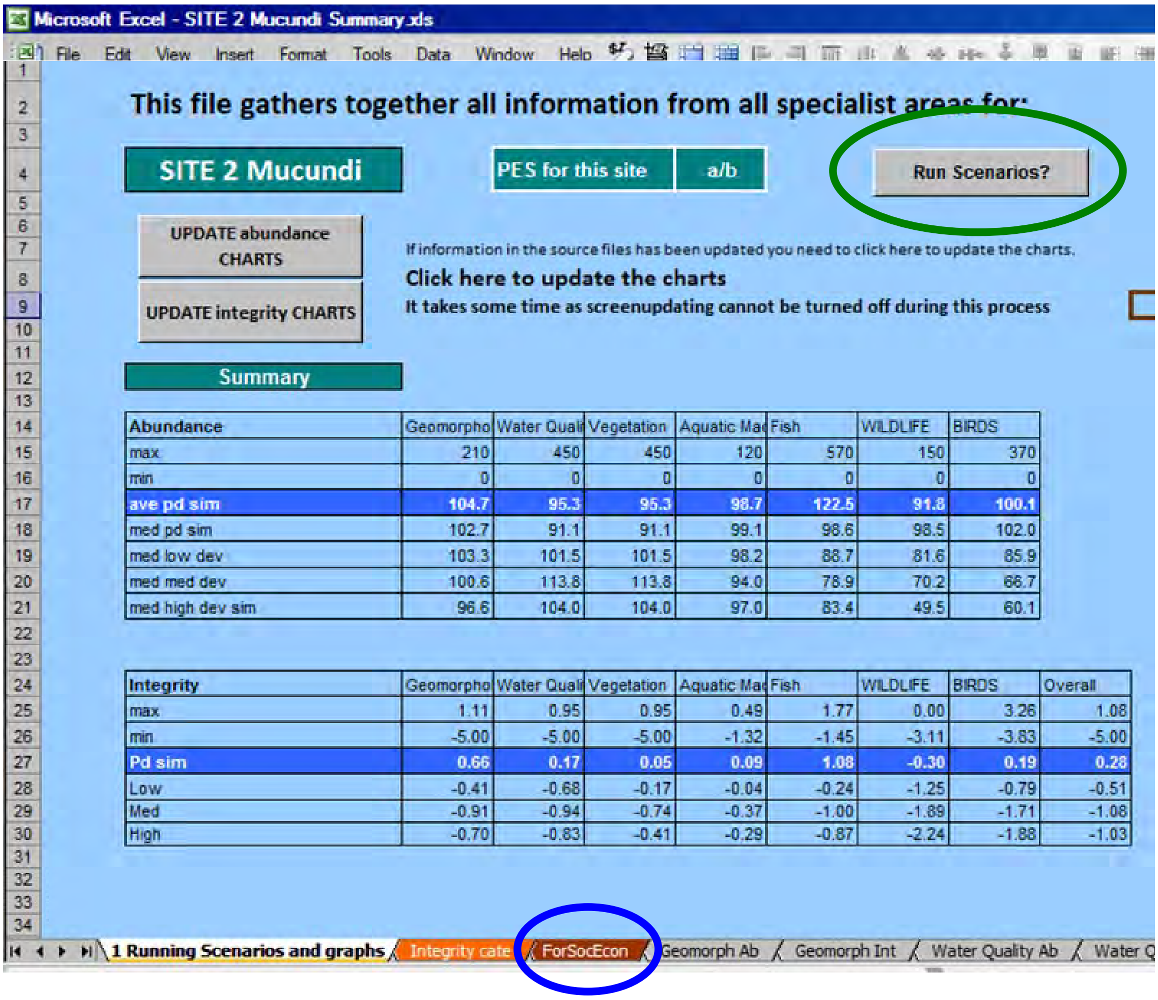
Figure 6.12 **Socio-economic response curves for Fish catch and its contribution to household and national income, together with the resulting time-series.**

6.3.4 Site summary files

For convenience, the scenario abundance time-series and integrity results for all indicators from all disciplines (including socio-economics) were gathered together in the Site summary files (e.g. *SITE 2 Mucundi summary.xls*). All of the information in the Site summary files is linked to *Okavango Scenario Interface.xls*. The relevant biophysical results for the Site are collected in a worksheet *ForSocEcon* (Figure 6.13 – the blue circle indicates the tab) which is linked to the site's socio-economics file to provide the time series of inputs for the socio-economics response.

All scenarios for all indicators and all disciplines can be run from this Site summary file by clicking the button "Run Scenarios" (Figure 6.13 – green circle).

The Site summary files thus provide a vital link between the biophyscial information and the socio-economic information at a site and between the response curve files and the main file, i.e. *Okavango Scenario Interface.xls*.



Abundance	Geomorpho	Water Quali	Vegetation	Aquatic Mac	Fish	WILDLIFE	BIRDS
max	210	450	450	120	570	150	370
min	0	0	0	0	0	0	0
ave pd sim	104.7	95.3	95.3	98.7	122.5	91.8	100.1
med pd sim	102.7	91.1	91.1	99.1	98.6	98.5	102.0
med low dev	103.3	101.5	101.5	98.2	88.7	81.6	85.9
med med dev	100.6	113.8	113.8	94.0	78.9	70.2	66.7
med high dev sim	96.6	104.0	104.0	97.0	83.4	49.5	60.1

Integrity	Geomorpho	Water Quali	Vegetation	Aquatic Mac	Fish	WILDLIFE	BIRDS	Overall
max	1.11	0.95	0.95	0.49	1.77	0.00	3.26	1.08
min	-5.00	-5.00	-5.00	-1.32	-1.45	-3.11	-3.83	-5.00
Pd sim	0.66	0.17	0.05	0.09	1.08	-0.30	0.19	0.28
Low	-0.41	-0.68	-0.17	-0.04	-0.24	-1.25	-0.79	-0.51
Med	-0.91	-0.94	-0.74	-0.37	-1.00	-1.89	-1.71	-1.08
High	-0.70	-0.83	-0.41	-0.29	-0.87	-2.24	-1.88	-1.03

Figure 6.13 The front page of the site summary file for Mucundi (*SITE 2 Mucundi summary.xls*).

6.3.5 Okavango Scenario Interface

The biophysical abundance and integrity information and the socio-economics scores and contributions to household and national incomes from all disciplines and all sites are gathered together in *Okavango Scenario Interface.xls*. Time series information and graphs for all indicators and all sites are gathered together per discipline. Summaries per discipline are also provided and biophysical discipline level and overall integrity scores are calculated (Figure 6.14).

Scenarios for all sites can be run from this file by clicking on the button “1. RUN SCENARIOS”. Graphs need to be updated by clicking on the relevant button (Figure 6.14).

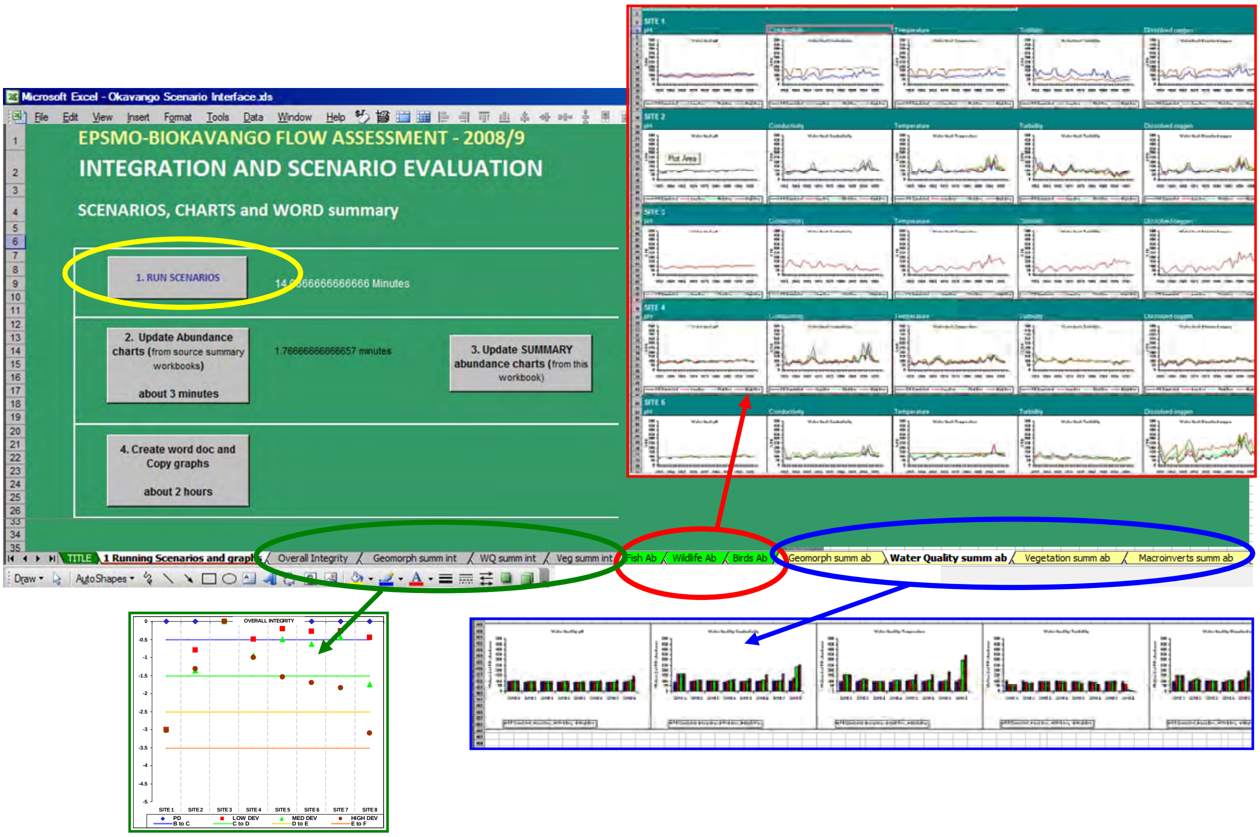


Figure 6.14 **The front page of the site summary file for Mucundi (*SITE 2 Mucundi summary.xls*). the circles ring the tabs which produce various of the outputs such as Abundance time series graphs for all indicators all sites (red), summary abundance graphs (blue) and integrity graphs (green).**

7. Conclusion

This report outlines the process and the DSS used in the EPSMO/Biokavango EFlows Assessment. The process is complex, represent a new branch of management-orientated science, and challenges all team members to approach their data and understanding of the river ecosystem and its users in new ways. Three main advances should emerge from its application. First, a body of knowledge has been captured in a DSS that will reside with OKACOM and will be available to the three countries for exploring the potential advantages and disadvantages of possible future water-use developments. The DSS is transparent regarding the basis for its predictions of ecological and social change, and can be updated as understanding of the ecosystem and its users improves. Second, three scenarios of possible water-use development have already been created that identify areas of concern in terms of potential ecological and social impacts. These can inform discussion and negotiation within and between the countries on the level of acceptable basin development. Third, a body of professionals in each of the three countries has worked together at the country and basin level in what has been an ambitious capacity-building exercise. These professionals can form a core of expertise for further work in this field at the country and basin level.

8. References

Adamson, P. 2006. Hydrological Background and the Generation of Exploratory Flow Regimes for the Development of the Impact Analysis Tools. Integrated Basin Flow Management. Internal Report of the Mekong River Commission, Laos PDR. 45 pp.

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

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

The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

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

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

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

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

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